PREFACE

Physical planning and engineering design are fundamental processes in development and operation of a port. Many of the important decisions made by governments regarding the ports for which they are responsible are decisions about the strategic development or operating performance of their ports. At the workaday level, whether a port is in public or private ownership, the entity directly responsible for managing it is frequently faced with making investment and maintenance decisions based on port planning and design deliberations.

It is important to recognise that this publication does not treat port planning and design as the exclusive province of technical specialists.

Port planning can be an issue which challenges a broad range of responsible or interested parties. A nation's or community's leading decision makers, individuals who sit on port authority boards, managers who operate a port, specialists who provide expert technical advice and many others may all find themselves jointly contributing to a port development decision.

Therefore, the guidelines in this publication have been produced with a broadly-based readership in mind. At its most basic level the publication will be of value as a source of guidance for technical specialists. However, several sections have been included for the benefit of decision makers who have to deal with the financing of port development, the politics of port-city relations, environment protection and other areas of similar complexity.

In fact, the aim in producing these guidelines in a form suitable for electronic transmission is to see them made available as an educational tool to anyone seeking information about the development of ports.

Given the breadth of topics it addresses, the publication is potentially a useful reference document for government ministers and officials who deal with port matters, for members of port authority boards and for all managers within a port, not just those with technical roles.

Placement of the publication in public and institutional libraries, with universities and industry associations, etc., deserves consideration, as this may help in spreading an understanding of the many considerations involved in decisions on port development and operation.

IAPH members are encouraged to distribute the guidelines electronically, on CD-rom or in print to all organisations, interest groups or individuals who they believe can benefit from having access to the information which the guidelines provide.

CHAIRMAN'S MESSAGE

The *IAPH Guidelines for Port Planning and Design* ("the Guidelines") - in the form represented by this current publication - have evolved over many years from the work of successive Technical Committees of IAPH concerned with the planning, development and maintenance of port infrastructure and equipment.

Distinct IAPH guidelines for port planning and design were initially published in April 1985 as a chapter in the IAPH Guidelines on Port Safety and Environmental Protection. An update in 1991 was followed in May 1993 by the introduction of the first stand-alone version of the Guidelines.

The IAPH Port Planning and Construction Committee was established in 1993 as the result of a general restructuring of IAPH Technical Committees. As one of its Terms of Reference, the new Committee inherited responsibility for reviewing and updating the "existing IAPH technical guidelines on port planning and design".

As Chairman of the Port Planning and Construction Committee since 1999, I must acknowledge the quality of the 1993 edition of the Guidelines. In the review phase of its work, the present Committee found no need to radically amend any of the previous content of the Guidelines. This latest version essentially adds further material to the excellent content of the 1993 edition.

For the Guidelines to retain the necessary credibility it is vital that they reflect a high degree of relevant knowledge and experience within the membership of the Committee responsible for producing them. The current membership of the IAPH Port Planning and Construction Committee maintains the high standard of technical and professional expertise which led the 1993 edition of the Guidelines to become one of the most authoritative and sought-after products of IAPH technical committee work.

The review and revision process leading to this new edition was initiated by Mr Philip Ng, who chaired the Port Planning and Construction Committee from 1993 to 1998. Other important contributions during the early stages of the review were made by Messrs. J Barraclough, B Berwick, R Buchanan, L Montero and P Wiedemeyer. The current members of the Committee, many of whom have also been involved in the process since its inception, wish to acknowledge the interest and attention given by these skilled individuals who are no longer associated with the Committee but whose suggestions have been incorporated in this edition.

Drafts of the revised version were peer-reviewed by The International Association of Dredging Companies (Mr P Hamburger, Secretary General) and The International Association of Cities and Ports (Mr O Lemaire, General Manager). Comments and material offered by these bodies have been included in relevant sections of the text. The Committee is grateful for these contributions.

Ms P Sen of Sydney Ports Corporation provided valuable assistance with formatting of the revision.

The Port Planning and Construction Committee aims to continually review the Guidelines and, as new material emerges, to issue supplementary papers while endeavouring to limit the cycle for fresh reprints to once every four years.

John Hayes
Chairman, IAPH Port Planning and Construction Committee

September 2001

COMMITTEE MEMBERSHIP
(as at May 2001)

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Mr S Naruse, Ministry of Transport, Japan (Vice-Chairman)

Mr V Balakrishnan, Port Klang Authority, Malaysia

Mr W Bauleka, Maritime and Ports Authority of Fiji

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Mr J Lapolla, Canaveral Port Authority, USA

Mr T Navaratne, Sydney Ports Corporation, Australia

Mr P Ochota, representing Association of Australian Ports and Marine Authorities

Mr M Ohno, Japan Port Consultants

Ms J Qian, Ministry of Communications, China

Dr A Sachish, Ports and Railways Authority, Israel

Mr P Scherrer, Port of Le Havre, France

Mr Sumardi, Indonesia Port Corporation III

Mr A van der Boon, DHV Consultants, The Netherlands

Ing P van der Kluit, IAPH Representative in Europe

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PORT PLANNING AND DESIGN

1. PORT PLANNING

1.1. INTRODUCTION

1.1.1. Port Development Plans

Ports form an important element in the economic and social development of virtually all countries. Accordingly, port planning should not only concern the port itself but also consider wider economic, social and physical factors in determining the role of the port in the overall regional and national development plans.

Factors that may be involved are, for example:

- space and land requirements;
- economic development of the hinterland of the port;
- port related industrial development;
- existing and expected cargo flows and composition per trade;
- type and size of vessels per trade;
- land and water transport links with the hinterland;
- access to and from the sea;
- physical development potential;
- nautical and hydraulic aspects;
- adjacent land uses and extent of urbanisation;
- safety and environmental impact;
- economic and financial analyses;
- existing structures and facilities;
- social impact, eg., community feelings about port activities;
- impact on habitats, including habitats of transient population.

Some of the above are discussed in more detail in Sections 1.2. to 1.13.

1.1.2. Interaction of Disciplines

The above list of typical aspects serves to illustrate that port planning is a complex and multidisciplinary activity. The different aspects or disciplines are very much interrelated and no conclusion in one field can be drawn and maintained without taking cognisance of the findings in other fields.

Therefore, port planning is often an iterative process, as illustrated schematically in Figures 1, 2 and 3.

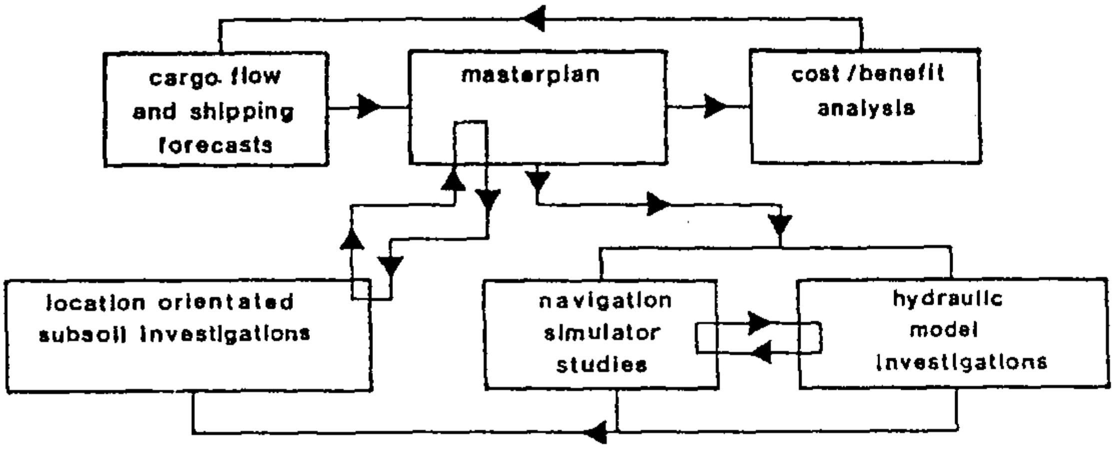


Fig. 1 Interrelation and interaction of activities and disciplines in port planning.

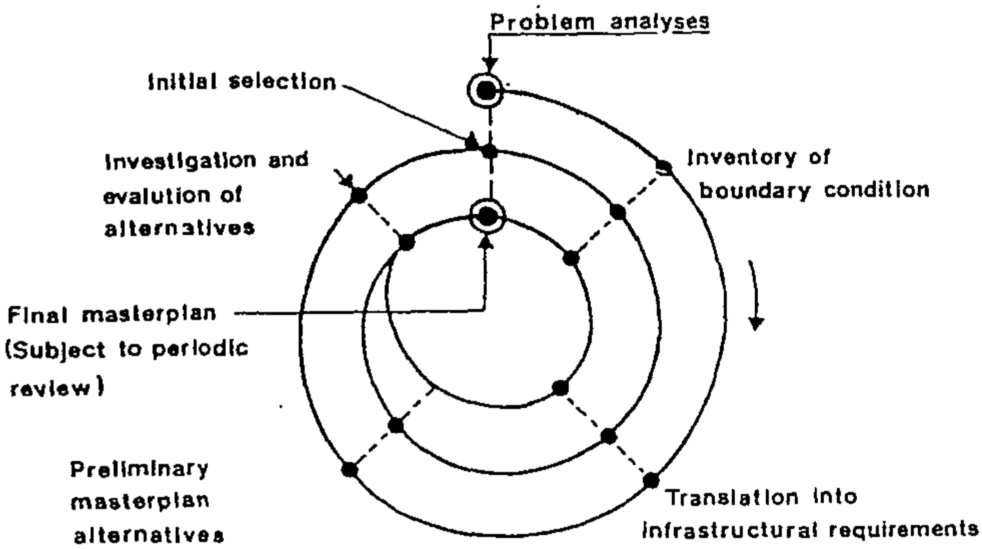


Fig. 2 Schematic presentation of the iterative process of port planning

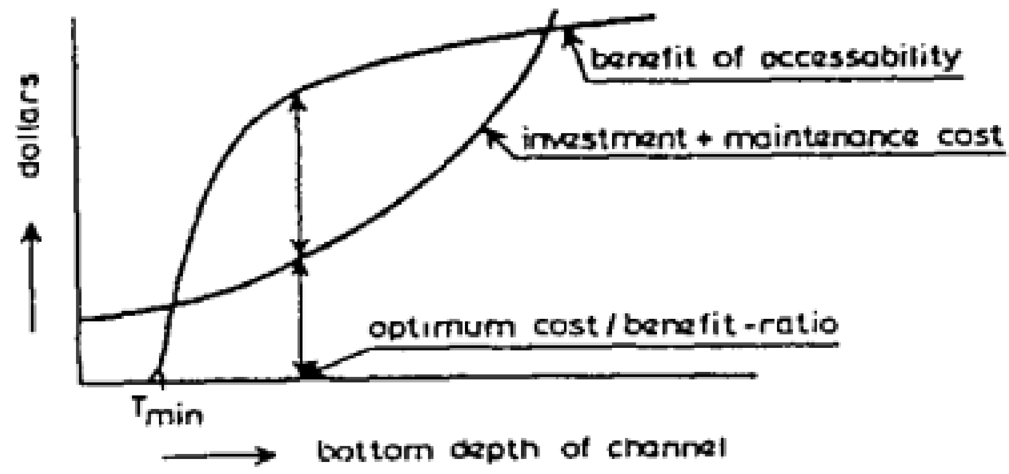


Fig. 3 Optimisation of bottom depth

1.1.3. Through Transport System

A port cannot be planned or designed as an arbitrary arrangement of independent terminals, etc. It cannot even be planned as an independent whole, because the arteries connecting the port to the sea and to the hinterland are as important as the port itself and may indeed, unless upgraded, be the controlling capacity restraints.

In other words, a port should always be studied and planned in its true function, that is a node or transit point in a generally rather complex system.

Some studies involve many complicated and interrelated problems, whilst others are relatively simple. It is preferable to consider all relevant factors initially. Simplification when the correct strategy emerges is easier than the introduction of additional factors at a later stage.

1.1.4. Port Types and Functions

There is a great diversity in sizes, types and functions of ports. One may distinguish, for example, coastal ports and river ports, natural tidal harbours and enclosed docks.

In terms of function there are multi-purpose ports (e.g., general cargo, container, ferry, bulk ports), dedicated ports (handling one specific cargo e.g., ore, oil or ro-ro), leisure ports, fishing ports and naval ports, etc.

1.1.5. Port Improvements

Many port planning studies seek to increase the capacity and/or efficiency of existing facilities, rather than to design new ones. Consideration should always be given to optimisation of existing facilities by improved operational control of both port and through transport systems, or by relatively minor improvements/modernisation of those facilities. Worldwide experience has often shown that substantial increases in throughput can thus be achieved economically and that major infrastructure improvements can be avoided or postponed.

If the demands cannot be met by improvement of existing facilities then it is necessary to consider plans for expansion or development of facilities within or adjacent to the port or sometimes for a new port.

1.2. ECONOMIC CONSIDERATIONS

1.2.1. Cargo Flow Forecasts

Port planning will generally start with an economic assessment to establish cargo flow forecasts by commodity and origin/destination. Regional and national development studies and, possibly, marketing studies for particular commodities will be required as a basis for the forecasts. Statistics on cargo and ship movements at existing ports are also required.

Indicative forecasts are appropriate for master planning, with detailed projections for about 5 years for the economic analyses of future developments. Forecasts should reflect the estimated volumes of any new cargoes as well as anticipated changes in flows of existing cargoes.

1.2.2. Transport Costs

Port planning will generally aim to minimise total transport costs for the different commodities handled. But ports are only a link in the total transport chain and minimisation of the cost of one link does not necessarily lead to the reduction of the total cost. Consideration should be given to the costs of all relevant transport elements: cargo handling, transport at sea and on land and storage at various stages in the chain. For large quantities of bulk commodities, marine transport cost will be minimised by the introduction of large bulk carriers, but port costs may increase steeply due to the investments necessary to receive these large ships, as indicated in Figure 4.

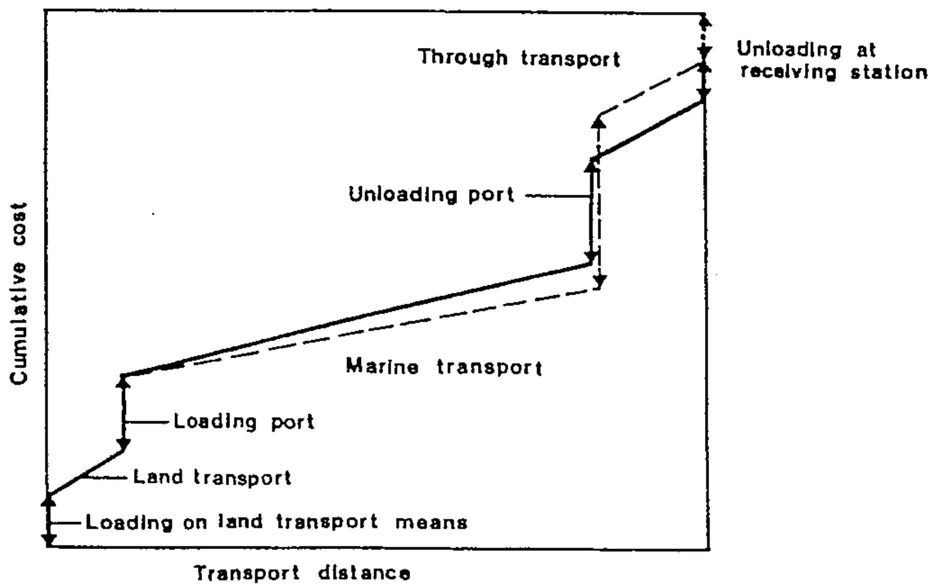


Fig. 4 Cumulative cost in a transport chain

1.2.3. Economic Feasibility

The economic feasibility of a port development will be based on consideration of costs and benefits on a national or regional scale, including any secondary effects. The economic costs and benefits from a national or regional perspective should not be confused with the financial costs and benefits to the actual investor.

In calculating the actual value of the chosen economic feasibility criteria one can follow either a deterministic or a probabilistic approach. For the former, the different parameters - cargo flow forecast, construction and maintenance costs, future productivity and costs of labour, etc. are given "best guess" values resulting in a single value for the feasibility criteria. For the latter, the more important parameters are assigned a probability, resulting in a probability distribution of the criteria. The probabilistic approach, sometimes mistakenly called "risk analysis", is more complicated, but it can give the investor a better overall insight into the type of outcome to be expected.

The use of a macro-economic study to decide on the economic feasibility of a project does not exclude the use of micro-economic studies for other purposes. A typical micro-economic study in which only the costs and benefits of the port itself are considered - may, for example, serve to determine the level of port tariffs needed to cover costs. Financial viability must also be addressed.

One of the vexing questions for investors in ports is that of whether to gain a guarantee of usage before making the investment or, alternatively, whether to undertake the investment believing that the resulting facility will attract usage. A project which relies on a pre-agreed guarantee of usage is often referred to as 'demand driven'. A speculative project, the type which tends to be undertaken in an attempt to boost economic activity, is referred to as 'supply driven'.

Major port development tends to occur in large chunks, with each chunk requiring heavy capital expenditure. The cargo throughput at a newly completed facility may be low initially, as the facility may have been constructed as a means of accommodating marginal volume growth, ie., growth beyond the capacity of the pre-existing facilities in the port. Hence, if revenue is linked to cargo throughput and the facility is only accommodating volume at the margin, the investor may not be able to enjoy a positive cashflow from the facility for a number of years.

Governments lacking the funds required to finance port development (or preferring to put their scarce funds into projects which generate quicker returns) are turning increasingly to the private sector to make major investments in ports. Chapter 5 of these guidelines addresses private participation in port facility development.

1.3. SHIPPING ASPECTS

The selection of a design vessel - or vessels - has a very great influence on virtually all port projects. The vessel's dimensions and the manoeuvring characteristics are controlling factors in determining the depth and width of approach channels, port entrances, manoeuvring areas and basins, as well as in the design of jetties and quay walls, as discussed more in detail in Section 1.9. Shipping economic considerations determine the type and optimum size of vessel for the nature and the volume of the cargo together with the transport distances involved (having due regard to anticipated developments in ship design). Where possible, designs should cater for future increase in vessel size. There will, though, be cases where natural limitations will preclude the port from responding to increases in vessel size or methods of shipping.

The optimum vessel for marine transport does not necessarily constitute the cheapest solution for the overall transport cost. The infrastructural provisions required for receiving large or very large bulk carriers at the loading and/or unloading port may be so costly that the use of smaller ships would be more economical in the total picture. Or there may be physical restrictions that all but prohibit the accommodation of ships above a certain size. If it is not economical to deepen the approach channel at the existing port (or to develop a new site), there may be advantages in handling partly laden ships which are lightened/loaded to full capacity by lighterage or in neighbouring ports. This must be considered when deciding the characteristics of the design vessel.

Therefore, the selection of a design vessel is a matter of economic optimisation, taking into account all the different parameters involved.

1.4. PORT ZONING

1.4.1. General

Zoning may mean different things to different readers. There will be cases where the full spectrum of land uses in an urbanised area is regulated by way of a zoning scheme administered by a government agency with the power to control development of all kinds, not just port development. In these cases, zoning affecting the port is determined by the other agency and the port authority must fit its infrastructure plans into the overall framework. Competition for use of waterfront land may place a limitation on the amount of land a government planning agency may be prepared to zone for port purposes. The port authority may find it necessary to argue strongly to ensure that short term expedient views on how a waterfront area might be put to 'better' use do not prevent the area from being reserved for future port purposes.

Some governments, recognising the vital economic significance of ports and the fundamental need to reserve waterfront sites for port purposes, may in future need to adopt 'port protection' policies and associated legislation. Such instruments would signal a determination to treat port uses as the highest and best use of relevant waterfront areas, irrespective of any views to the contrary - such as views typically put by communities seeking use of the waterfront for recreational activities.

However, for the purposes of these guidelines, the term 'port zoning' has a narrower meaning - namely, zoning for the use of land within the defined port area.

Port zoning principles are a guiding tool for port development plans. The objective is to balance the requirements for each zone in the total setting, allowing for future developments as well as immediate needs.

A zoning schedule should be prepared taking into account the following elements:

- water depth requirement for each terminal
- land area requirement for each terminal
- storage and handling criteria for each class of cargo
- the influence of prevailing winds
- safety considerations

- traffic flow system
- inland transport access: road, rail, inland water transport
- services corridor requirements for pipelines, cables, conveyors, etc.
- navigational considerations
- subsoil conditions
- topography
- social aspects and urban development
- environmental considerations
- national and international conventions, laws and regulations
- buffer zones.

The port zoning plan is the result of an evaluation of all the above elements. It will show the different port areas divided into categories, superimposed on the port infrastructure masterplan.

It is desirable that statutory force should be given to the port zoning document drawn up by the port authority. Discussions with the organisations and administrations in charge of national development will then be easier; especially insofar as the functional characteristics of port components will have been fixed before the birth of external projects likely to interfere with them (example: a bridge spanning a canal).

1.4.2. <u>Dangerous Goods</u>

The term 'dangerous goods' is used to describe substances which give off noxious gases in the event of fire or accidental release, or which pose a special risk of fire or explosion. The storage and handling of dangerous goods should be zoned so as to minimise the risk of accident or fire, to allow containment, and to reduce to acceptable levels the risk of harm to life and property in the event of such fire or accident. Buffer zones may have to be provided as a means of separating storage areas for dangerous goods from neighbouring areas, whether within the port or adjacent to the port. Every effort should be made to ensure that buffer zones remain as such, ie., no relaxation of the zoning should be permitted. Other uses should not be allowed to 'creep into' buffer zones over the course of time.

For dangerous goods zoning purposes, the potential effects of accidents and fires should be evaluated in terms of the level of danger and the distances over which danger exists. Acceptable levels of danger should be formulated for zones liable to be affected. In particular, hazard to life in residential areas near the port should be considered. The risk assessment methodology should include the following steps:

1. Make an inventory of "unavoidable" accidents
2. Determine which dangerous substances are involved
3. Determine lethal limit values (e.g. LClo for toxic products and 0.03 bar for flammable products)
4. Choose calculation model
5. Use outcome of calculations for zoning dangerous goods storage and handling areas relative to residential and other areas.

Consideration should be given to compliance with national and/or international standards and criteria for individual risk and societal risk.

Risk assessment should also address the availability and reliability of existing fire fighting services (municipal or industrial) within a radius of 25/50km and the minimum supplementary fire fighting service that will need to be set up in the port as a consequence.

1.5. PHYSICAL CONDITIONS/SITE INVESTIGATIONS

1.5.1. Physical Data Necessary

A thorough understanding of site physical conditions at the location of potential ports is of extreme importance. Established ports will have accumulated valuable records of the overall environment. Previous site investigation data and construction records together with historic charts of sea bed topography, geological maps and exposed geological features will all contribute to this understanding. For the development of new ports and at existing ports where there is insufficient data, site investigations will be required for the planning stage. More localised and detailed investigations will be required for the final design.

There are still frequent occurrences of skimping on the cost and/or time allowed for adequate investigations. If these data are insufficient, incorrect conclusions may be drawn resulting in under or over design. An incorrect assumption can lead to potentially disastrous consequences, while over design is inherently expensive.

Data of a continually varying nature, particularly waves and wind, require a measurement period over a number of years before a statistically meaningful picture is obtained. In many countries these meteorologic and oceanographic data are collected at different locations along the coast continuously as a matter of routine. It is strongly recommended that all exposed ports should do so for the benefit of future extension projects unless the deep sea wave climate is already monitored.

1.5.2. Geotechnical Studies

1.5.2.1. Soil Investigations

Soil investigations are necessary for the design of foundations for all port structures including breakwaters, quay walls and buildings. They are also necessary for planning and design of dredging and reclamation including evaluation of settlement and, sometimes, to study the availability and quality of local construction materials, e.g., reclamation material, concrete aggregates, rock armouring or cement. These investigations will be of limited value unless controlled by experienced professional specialists. The most common methods of investigation on shore are:

- percussion (soft soil) or rotary (hard soil) borings with in-situ testing, ground water measurements and sampling
- laboratory testing of soil and water samples to allow classification and to measure engineering properties
- cone penetration tests (cpt), to provide rapidly information on subsoil bearing capacity in soft soils
- seismic surveys, to obtain a more continuous indication of the depth of the different strata than that from borings or cpt's alone
- geochemical surveys.

Similar techniques apply offshore but both borings and cpt's will be more expensive as they require a stable platform and are dependent on favourable weather and sea conditions. Cpt equipment is very sensitive in this respect. In quiet waters, barges or medium sized fishing vessels may be used, equipped with adequate lifting gear and anchors. If conditions are less favourable, a scaffold tower or self-elevating platform is required. In deep water one may have to resort to drop type, remote control or diver operated boring and/or cpt equipment, e.g., Vibrocorer or Senkovitch. They are relatively fast, easy to operate and economical, but penetration is limited.

Seismic sub-bottom profiling is particularly suitable for offshore investigations to supplement borings and cpt's and is often run simultaneously with a bathymetric survey. With suitable soil conditions a limited number of borings may be used to calibrate a full scale seismic survey with considerable savings in time and costs.

If the soil or sediments to be investigated are likely to be contaminated then special caution may be necessary in choosing the methods for boring and laboratory testing.

1.5.2.2. Earthquakes

In earthquake-prone areas, special attention should be paid to the earthquake related risks and investigations may be required to ascertain risks of foundation failure due to liquefaction in loose granular soils. In such areas the seismicity of the site will have to be evaluated and suitable design criteria established. Considerable care must be taken in determining the type of earthquake damage that could occur and to design structures so that catastrophic damage is avoided. Attempts to reduce to negligible proportions the risk of damage from seismic action in some areas may be prohibitively expensive and it may be necessary to accept the possibility of some damage if the design earthquake occurs. However, where essential services are involved (to allow evacuation of victims, or to supply relief goods), higher factors of safety are appropriate.

1.5.3. Hvdro-meteo Investigations

Hydro-meteo data are required for both planning and design and in considerable detail if hydraulic modelling is required. The area of the proposed development and adjacent areas of influence, including potential spoil grounds for winning reclamation material and dump grounds, should be covered. Basic investigations and measurements include some or all of the following, depending on available information, site conditions, nature of the project, etc:

1.5.3.1. Wave Data

Waves are of primary importance for the prediction of conditions within the harbour area for different layouts and for the design of breakwaters.

The great variety of wave recorders on the market includes accelerometer-buoys, sea-bottom pressure recorders, fixed resistance type, laser type, supersonic type or radar surface level recorders, etc. Expert advice is necessary to select the most suitable equipment for specific circumstances. Some instruments though cheap and reliable do not react to long period wave components; a novel instrument records both wave height and direction - which in certain cases can be very important - but it is expensive.

As wave heights and wind forces have a stochastic character, the establishment of a statistically reliable picture requires several years of observation. Waves should be measured in deep water, where they are not distorted to a significant extent by shoaling or refraction. Some instruments can be equipped with automatic shore receiving, data processing and filing systems. This is most valuable because it makes the results immediately accessible and avoids storage of non-interesting data, e.g., records over long periods with low wave heights.

In certain areas, due consideration should be given to the possible occurrence of tsunamis, i.e., long period waves of seismic origin.

1.5.3.2. Current Velocities and Directions

Currents are usually measured by propeller-type or electromagnetic current meters in fixed locations at a number of water depths and by tracking floats with measurements over one or more spring and neap tide periods, repeated as necessary if seasonal variations occur.

It is important that a clear insight is obtained in the different current components, i.e., permanent sea currents, tidal currents, wave-generated long shore currents, wind-generated surface currents and sometimes also density currents.

1.5.3.3. Tidal Heights

Tides are generally recorded permanently by means of a fixed gauge in the port or sheltered area. One year's observation - possibly less - is adequate to produce a tide prediction, but to predict extremes caused by storm surges associated with hurricanes, etc., extended observations may be required. Maximum wind set up may vary from a few decimetres to a few metres in extreme cases.

1.5.3.4. Sediment Transport

Silt load, salinity and temperature measurements for use in coastal and estuarial studies, bed movements, etc., are generally carried out at the same time as current measurements. The effects of reclamation, dredging and deepening of channels on sediment transport could be significant in that any of these works has the potential to alter flow patterns and current velocities and therefore may affect the volume of silt which would otherwise be deposited.

1.5.3.5. Wind

Wind velocities and directions should be recorded by at least one anemometer, established at an unobstructed high spot, eg., a breakwater head. Wave height is determined by wind velocity in the open sea which may be double that in a sheltered port area.

1.5.3.6. Bathymetric Surveys

Carefully controlled surveys by echo sounder in conjunction with electronic positioning devices, sometimes supplemented by side scan sonar (or interferomic seabed inspection sonar), are needed to define the sea bed topography and as a reference for comparison with historic and future charts. In areas where seabed contours change frequently due to morphological conditions, repeated surveys will be necessary.

1.5.3.7. Floods

Care should be taken to investigate whether a site under consideration for port development is prone to flooding.

1.6. HYDRAULIC CONSIDERATIONS

1.6.1. Waves

In a harbour, adequate protection from wave action is essential. Ships should be protected at berth so that the risk of the vessel breaking moorings is minimised.

The allowable wave heights at berths depend on wave period, the orientation of the ship, wave direction, its size and hydrodynamic characteristics and the elastic behaviour of the mooring system.

A better insight to the actual motions of ships at berth may be obtained through mathematical and/or physical model tests in conjunction with wave penetration studies and models. The validity of such tests is dependent on the correct modelling of the mooring system, which is not normally prescribed by the terminal operator.

Special attention should be paid to the possible occurrence of "seiches", (low amplitude, very long period waves often caused by meteorologic phenomena). Harbour basins may have a resonance response in specific circumstances and ships may seriously be hampered in cargo loading and unloading operations and even, in case of heavy surging, break loose from their moorings.

In the absence of more detailed information, guidelines to acceptable wave heights for various cargo handling operations and mooring conditions are given in publications such as PIANC bulletins and in certain national and international standards.

1.6.2. Morphological Regime

Before starting any port construction, hydraulic studies are required to assess the stability of the existing morphological regime and prevailing sediment transport patterns. Subsequently, the effects of a disturbance of the existing situation have to be investigated, e.g., the local accretion or scour of the coast, shifting of stream channels, changes in current patterns due to the construction of breakwaters or dredged channels and a quantitative estimate made of the maintenance dredging required in the port and its approaches.

The investigations may consist of calculations, mathematical models or physical models, sometimes with movable bed. The latter type models, though rather expensive and time consuming, may be necessary depending on the problem in hand. Even with extensive investigation, precise predictions of sediment movement cannot be expected but it is important to ascertain the dominant effects to allow effective corrective measures to be decided upon.

1.7. NAUTICAL CONSIDERATIONS

1.7.1. Approach Channel

The basic nautical requirement for a port is that ships must be able to enter and leave port safely and efficiently, even in marginal conditions. This basic requirement results in a number of guidelines for the design of the port approaches:

- The approach channel (if any) must be of adequate width and depth so as to ensure an acceptably low risk of grounding and collision. (see Figure 5).

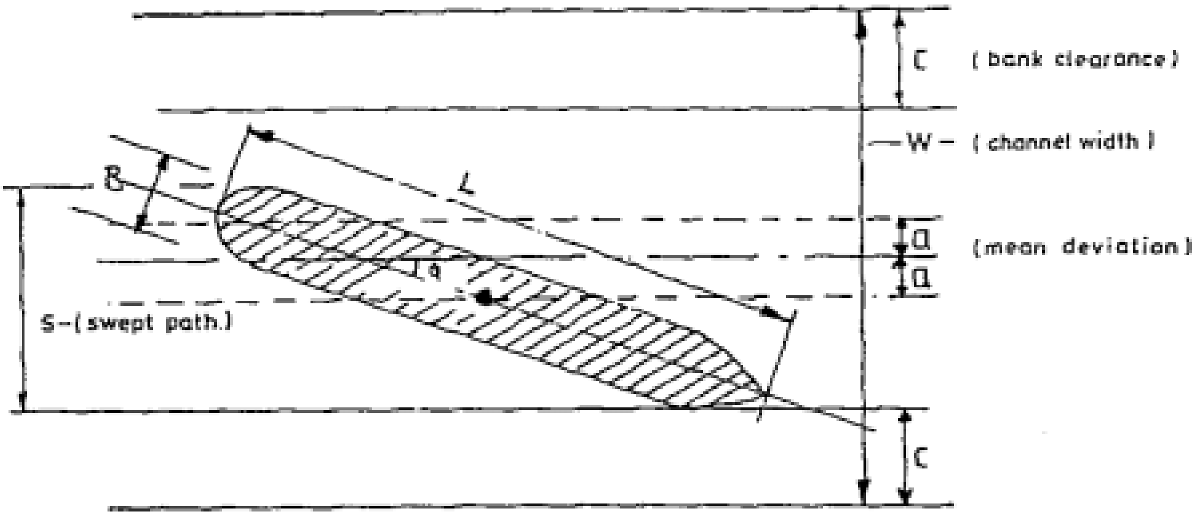


Fig. 5 Approximate Channel Width Requirements

- The approach channel should preferably be straight and the centre line should coincide with the centre line of the port entrance and entrance channel. If curves are unavoidable, they should be located at an ample distance from the harbour entrance because a curve in or near the entrance requires vessels to make course corrections in an already difficult and critical area. One large curve is preferable to several small ones. If more than one curve is unavoidable (in long channels), there must be ample straight sections between subsequent curves.

- For safety reasons, the vessel should be able to interrupt the approach and drop anchor up to a point as close to the harbour entrance as possible. In long channels, anchorages may have to be provided for that purpose.

- The approach channel should be so orientated that ships enter port as far as possible against the predominant current direction.

- Cross-currents should be kept as low as possible but particularly sudden crosscurrent changes should be avoided, as they constitute a nautical hazard.

- The approach channel orientation should avoid beam-on waves (especially long period waves) due to the risks from heavy rolling of the ship and consequential course instability, and of grounding.

- The provision of modern navigational aids and position fixing systems is essential for vessel safety in constrained waterways.

- Bank effects should be considered in the channel design and swing basin design.

Further information can be found in the PIANC/IAPH publication "Approach Channels - A Guide for Design".

1.7.2. Manoeuvring Area

To reduce the risk of collision, special attention should be given to the provision of sufficient space for safe manoeuvring within the port. Equally, as sheltered space within the port is generally at a premium, excess provision should be avoided. The manoeuvring space depends on a number of factors such as:

- the type, size and draft of the vessels
- current and wind conditions
- number of tugs and their power.

Big ships have a much lower displacement ratio than smaller ships and thus require a relatively much greater stopping distance. Due to their restricted manoeuvrability, large ships will normally be required to have tug assistance within congested port areas as will vessels carrying dangerous cargoes. Smaller ships, having shorter stopping distances and better directional control can normally stop under their own power (see Figure 6).

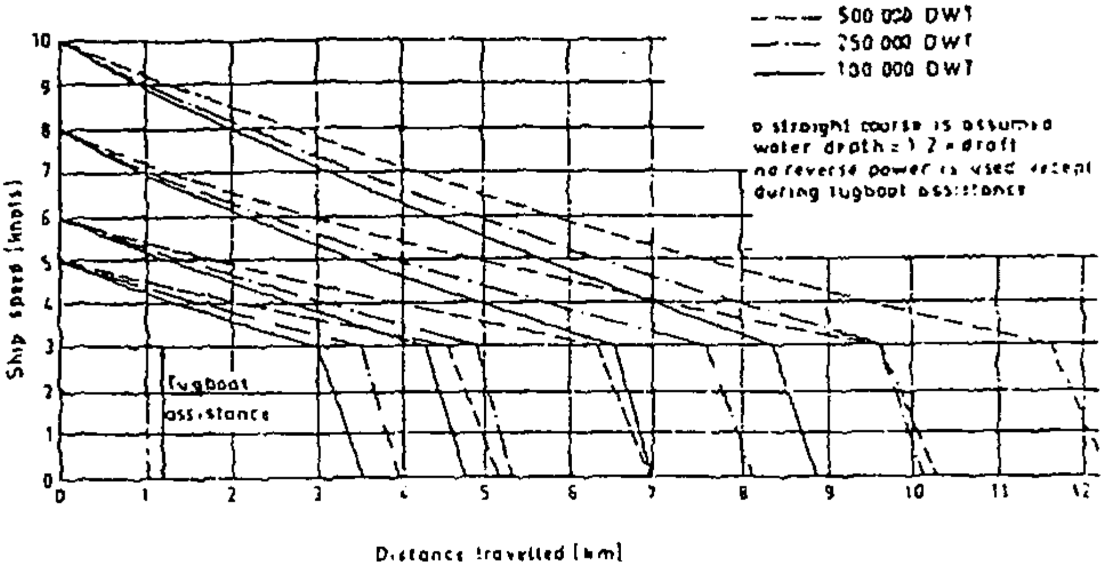


Fig. 6 Stopping Distances for Tankers in Shallow Water

1.7.3. Dynamic Underkeel Clearance Systems

Where tidal variations are extreme and/or the approach to a port necessitates passage through a long channel, the concept of dynamic underkeel clearance can be of value in determining the depth to which the channel needs to be dredged. The availability of accurate satellite-based geographic positioning systems allows the precise location of a ship in a channel to be calculated at any moment. When combined with accurate real time readings of the state of the tide and the draft of the ship, the information on the ship's location in the channel allows the underkeel clearance to be determined continuously as the ship proceeds through the channel. The quality of information obtainable in this manner provides masters and pilots with sufficient confidence to operate vessels with less underkeel clearance than conventionally recommended. Thus, a channel managed under a dynamic underkeel clearance system does not need to be as deep as would otherwise be proposed. Dynamic underkeel clearance systems are operating successfully in ports in Western Australia.

1.7.4. Use of Ship Simulators

Availability of ship (navigation) simulators permits the design of a channel to be tested under laboratory conditions before a commitment is made to undertake actual channel construction. Simulation of alignment and width options is a cost-effective means of ensuring that the safest possible conditions for navigation will be achieved in situ when the channel is in operation. See also Section 1.9.10.

1.8. ENVIRONMENTAL CONSIDERATIONS

1.8.1. General

Ports are nodal points where the various modes of transport come together and industrial activities take place. This means that, in port areas, the environmental components such as water, air and soil are at risk of being contaminated as a result of a large number of activities occurring within a relatively small area.

However, protection of the environment is an essential consideration if a port authority is to be allowed to fulfil continuously its major obligation. This means that, in the decision making process, the environment must be considered alongside economic aspects.

Apart from the fact that intensified care for the environment is the duty of the community as a whole, including the port community, there are other arguments in favour of environmental care.

Today, ports are no longer relatively isolated locations where cargo is transferred from one mode of transport to the other. Where port developments are linked with urban and industrial developments, there are additional environmental requirements and, sometimes, regulations.

Ports are no longer selected on a cost basis alone. Today, ports are vital elements in logistic chains. This brings along new challenges. Besides price, it is the quality of the service which determines which ports will get the business. Quality in logistic terms means reliability.

The role of ports in logistic chains requires reliable service of good quality. Consequently it is in the interest of staying in business to work towards a cleaner port environment.

Furthermore, a clean port is an attractive port - not only attractive to work in or to live nearby, but also attractive for companies who are looking for a place to set up a new business.

There is another very much down to earth argument which pleads in favour of environmental care. Ports make their money with two major assets: the water and the adjacent land. They should not allow these assets to deteriorate in quality since this represents an important depreciation in capital value.

These considerations mean that ports should accept the principle of sustainable development, as introduced by the Brundtland report "Our Common Future" as a guiding principle. Ideally medium size and larger ports should have a full-time environmental staff member or section to handle environmental matters on a continuous basis.

It is also advisable for a port to have in place an Environmental Management Plan along with a program of regular Environmental Audits of Compliance.

For most port planning and development projects, an environmental assessment process is mandatory in most countries. The environmental assessment will be used as a risk assessment process in the planning and feasibility stages of port construction. Assessments are used to evaluate all types of property (i.e. virgin land, recycled land, etc.). Mitigation measures (i.e. wetland restoration, environmental cleanup, etc.) may also need to be taken as a result of the assessment and these measures can increase the construction costs significantly depending on the amount/type of mitigation that is required (see Section 1.9.11.).

The laws and regulations on environmental assessment vary from country to country. Most countries require the submission of an environmental impact statement (EIS). The EIS should contain the explanation of the environmental consequences of the proposed construction, significant beneficial and adverse impacts (as well as cumulative and secondary impacts), proposed mitigation measures, alternatives considered, any unresolved issues, compatibility with land use plans and policies and a listing of the permits that will be required for the proposed construction. Depending upon the laws and regulations, the EIS may have to be prepared by a qualified environmental professional thus adding additional cost to the overall construction. Preparation and review time of the EIS should be incorporated into the overall schedule of the project.

There are many methodologies that have been created to assist in the development of the EIS and, depending upon the type of project being considered, one specific methodology may be more beneficial than another but in general, the various methodologies can be separated into six types:

1. Ad hoc – These methodologies generally provide little guidance for impact assessment and are generally effective for the professional who is exceptionally experienced in the type of project being studied.

2. Overlays – Overlays rely on maps of the project area's environmental characteristics and noting the different environmental characteristics within the project limits identifies the impacts.

3. Checklists – Checklists provide a specific list of environmental parameters to be investigated for potential impacts. Measurement and interpretation of the data to be collected, in some cases, can be difficult with this method.

4. Matrices – Matrix methodologies use a list of project activities and a checklist of potential impacted environmental characteristics. This allows the identification of cause-and effect relationships between specific activities and impacts via the matrix that is developed.

5. Networks – Networks use a list of project activities to form cause-condition-effect relationships. This then allows the impacts to be identified by selecting and mapping out the appropriate project actions.

6. Combination Computer-aided – Uses a combination of matrices, networks, analytical models and a computer aided systematic approach to identifying impacts.

The various methodologies have their strengths and weaknesses as well as varying levels of complexity and the choice of which methodology is to be used is determined by the environmental professional.

1.8.2. Sources of Environmental Degradation

The most common sources of environmental degradation are discussed below:

(i) During the construction process:

a) Elements associated with inadequate planning for the use of space, such as the mixed location of residential areas and storage areas for dangerous cargoes and noxious substances.

b) Elements associated with inadequate planning causing disturbances and hindrance to daily life of citizens.

c) Nuisance generated during the course of construction such as vibration, noise, stench, dust and others.

d) Rainwater runoff controls, stormwater and washdown areas.

(ii) Elements associated with port operations:

a) Ships
- air pollution
- water pollution
- erosion by ship-generated waves
- ship-generated noise (eg. from exhaust fans).

b) Cargo Handling
- noise (in particular equipment warning signals/sirens)
- dust
- waste and exhausts
- lorry traffic
- train traffic - especially in shunting areas
- accidents
- night-time floodlighting (especially effects of 'light-spill')
- odours.

c) Generated by peripheral economic activities
- caused by industrial activities (wastes, exhaust from factories)
- generated from urban activities (such as wastes and garbage from houses and construction works).

1.9. MASTERPLAN DEVELOPMENT

1.9.1. General Philosophy

The port masterplan should cover all the requirements relating to the long term development of the port, having regard to physical boundary conditions, international and national laws, rules and regulations, operational factors and user requirements. It will consider economy of scale, efficiency and trade-off benefits, all within a harmonious yet flexible development of the whole port complex.

All developments outside the port's cargo handling operations but with a direct economic relationship with port activities should be included in the masterplan.

Aspects like the vicinity of residential areas, green zoning between different land uses and separation of port and industrial activities for environmental and safety reasons play an important role in the port masterplan.

1.9.2. Hinterland Connections

As transport in ports provides only a few of the links in the total transport chain, the connections to other links are of major importance. For goods and passengers entering or leaving the port area, these connections are prominent to the port masterplan.

The connection can be multifold:

sea <-> sea
sea <-> river/lake
sea <-> land: rail/road/air

Each connection has its own specific requirement in relation to:

- loading and unloading
- (temporary) storage
- land use at the loading and unloading site
- customs and other administrative means
- passage through the port area.

1.9.3. Infrastructure Requirements

Based on the economic and shipping requirements as discussed in Sections 1.2. and 1.3. and on the site conditions reviewed in Sections 1.4. to 1.8., a variety of preliminary masterplans can be drawn up and compared. To that effect the projected cargo flows and ship types, sizes and number first have to be evaluated in terms of approximate water and land area requirements, quay lengths and/or number of berths.

At this stage, no great amount of detail or refinement is desirable. It is neither necessary nor indeed feasible to develop all possible options.

The ultimately required detailed studies and degree of accuracy will be developed during the evaluation and selection process required for project optimisation.

1.9.4. Water Areas

The general lay-out aspects of approach channels and manoeuvring areas have been discussed in Sections 1.7.1. and 1.7.2.

1.9.4.1. Channel Widths

The required approach channel width depends largely on local conditions, eg., cross currents and cross current gradients, and whether one-way or two-way traffic (or limited two-way traffic) will be allowed.

1.9.4.2. Access Channel Depth

For the approach channel depth the PIANC recommendations (see reference in Section 1.7.1.) mention the maximum draught D of the design vessel plus a gross underkeel clearance varying from 0.20D in open sea areas exposed to strong and long stern or quarter swell to 0.10D for less exposed channels or parts thereof. The gross underkeel clearance constitutes the total effect of ship response to waves and swell, vessel squat and trim, sounding inaccuracy and dredging tolerance and, finally, a nett clearance specified as 0.5 to 1.0m. Allowance should also be made for water salinity effects on ships' draughts and sea level variations during manoeuvres.

The validity, however, of these PIANC guidelines is limited, as they refer particularly to VLCC's or large bulk carriers under specific (North Sea) conditions. Other gross clearances apply for different vessel types and in different maritime environments.

Hence the 0.1D must be regarded as a minimum value but maximum values could be as high as 0.5D for smaller vessels in unfavourable conditions.

The above gross keel clearance need not necessarily be present at all stages of the tide. The fully loaded design vessel does not have to be able to enter at low low water (LLW) with an extreme swell running at the same time. The port operator can decide on specific "tidal windows" (and sometimes also current, wind and wave windows) during which the deeper draught vessels may enter and outside which they must wait at the anchorage. The introduction of such tidal (and other) windows can save considerably on dredging cost but at the same time increases ship waiting costs. The determination of the width of these "windows" is therefore subject to economic optimisation.

Often, in access and entrance channels with muddy bottoms, no clear bottom line can be distinguished, as there is a more or less continuous transition from water to firm soil. In such cases the nautical bottom may be assumed to coincide with the level at which a relative density of 1.2 is reached at the sea bed, but this varies with the ratio of mud to sand.

1.9.4.3. Manoeuvring Area

The sheltered manoeuvring area inside the port largely depends on the required stopping length as discussed in Section 1.7.2. Immediately inside the entrance some widening of the channel on one or both sides is generally required as the diminishing cross current - first at the bow, then over the full length - can lead to course deviations. For preliminary planning purposes the general shape and dimensions of the manoeuvring area is indicated on Figure 7. The construction of berths along manoeuvring area boundaries should be avoided for safety reasons.

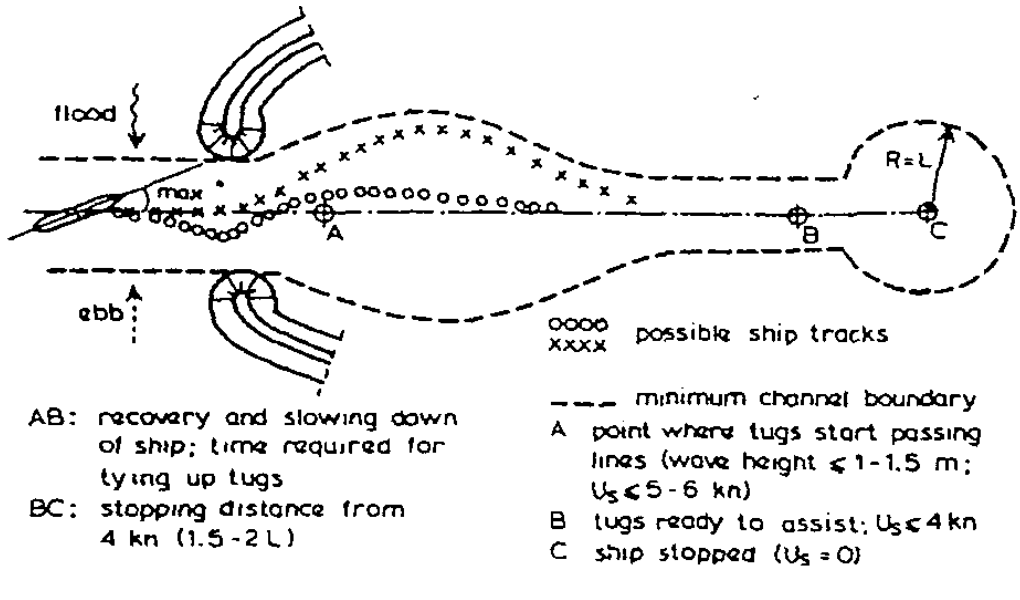


Fig. 7 Stopping procedure and inner channel dimensions

The width of long harbour basins (say 1,000m) should normally allow ships to be turned around in the basin. The minimum width then needed is L + B + 50m (clearance with other vessels and passing space for tugs), or about 8B + 50m. For shorter basins a value of about 6B is a fair minimum. Similar considerations apply for the distance between facing tanker jetty heads.

Provision is also required for anchorages outside the port area.

1.9.5. Number of Berths

The number of berths required for projected cargo flow will depend on:

- the volume and type of cargoes
- the size and frequency of arrival of various types of ships
- the efficiency of cargo handling methods
- an acceptable level of ship waiting time.

Dolphin and anchorage berths either midstream or in the middle of the basin should be considered as part of the total number.

Certain commodities (e.g., oil, liquified gases etc.) as a general principle will be handled at specialised terminals for safety reasons. Containers, roll-on roll-off traffic, bulk cargoes, steel or forest products and foot passengers, when moving in significant quantities or numbers, will also have specialised or dedicated berths, otherwise these trades will be handled at general cargo or multipurpose terminals. A layout comprising a number of berths in one straight line (i.e., marginal wharf) generally offers the most economical arrangement having regard to operational flexibility and the optimal use of cranes and cargo landing space.

1.9.6. Land Area Requirements

The requirements for land in and around the port should be based not only on an economic traffic forecast for say 10 or 20 years, but also on optimal developments which by their nature cannot be quantified in an economic traffic forecast. Industrial development as a spin-off of the presence of the port may be hard to predict, but still it is considered an asset to make (large) landplots available for those industries, whenever the development conditions are right.

For the long-term horizon the land requirements should be assessed with due consideration of:

- All relevant terminals for basic transfer of goods (and passengers) from ship to shore and vice versa

- Facilities for towage, pilotage, fire fighting, bunkering, etc.

- Storage of goods either short term or long term. Especially for bulk cargo, a port is to some extent an ideal location for long-term storage. Partial volumes may be abstracted over time in accordance with the direct needs.

- Industries which ship or receive large volumes of goods by the maritime transport mode, may have to be established at the port's waterfront for economic reasons. Land space for such industries might be reserved and/or options for later allocation might be kept open.

- Industries other than those mentioned above may have a relation of economic significance with the industries at the waterfront. These related industries therefore require a location in the vicinity. Here again, land reservation should be made and/or options for later allocation kept open.

- Landbased infrastructure networks may have to be extended if capacities have to be increased for transportation of larger volumes. Land space should be allocated to road systems (including intersections, parking); rail systems (including marshalling yard, sidings); utility corridors for pipeline transportation, water supply, drainage, sewerage, power distribution, telecommunications, etc.; corridor space for cargo conveyors and pipelines.

- Environmental zoning may be essential for reduction of pollution in all its aspects. Through green zoning and functional separation of port and industrial activities, satisfactory environmental conditions may be achievable.

The normal definition of a port conceives the port as a body of water and a tract (or tracts) of land immediately adjacent to the water. However, some ports include supplementary land areas located well inland from the waterfront. Such 'satellite' areas tend to be used for 'off-dock' storage and handling of cargo in transit. The terms 'inland port', 'inland depot' or 'dry port' are typically used to describe these sites where cargo is held some distance away from actual waterfront.

It is particularly common for inland ports to be linked to the main terminals at the waterfront by high capacity transport corridors, especially rail corridors (eg. Alameda Corridor at Los Angeles/Long Beach, California).

When planning the land area requirements for a port, it may be appropriate to consider whether a benefit can be derived from locating some cargo handling activities well inland from the waterfront. An inland location may be less costly than land at the waterfront and may also be closer to the local origins and destinations of the cargo.

Cargo assembly and distribution hubs in the hinterland, linked to the waterfront by rapid shuttle transport services, have been examined in a report entitled "The Future Role Of Ports In Combined Transport and Distribution Centres", prepared in 1996 by the IAPH Combined Transport and Distribution Committee.

1.9.7. Dock Basins

Some ports are protected, particularly from tidal effects, by shipping locks or entrance gates.

Chamber locks (with two sets of gates) allow the maintenance of a virtually constant water level. As a result, the cost of quay walls and other port structures is minimised, whilst port operations are not hampered by water level fluctuations. In part-tide basins with single entrance gates, as frequently used in smaller ports, water is retained over the lower part of the tidal cycle.

However, locks and gates have the disadvantage of being costly in themselves, requiring careful maintenance and operation and constituting a delaying element in the passage of ships.

The decision whether or not to build dock basins obviously depends on the tidal range and on the nature and volume of the traffic. The handling of general cargo is more sensitive in this respect than bulk cargoes. For a general cargo port or general cargo basins, the construction of locks would normally be considered for mean tidal ranges of 5 to 6m or over.

1.9.8. Environmental Protection and Safety

In port planning, environmental and safety aspects play an increasingly important role, to the extent that they may influence the location, shape and dimensions of the port infrastructure.

For that reason, most projects should have specialists (e.g., marine biologists and safety experts) in the study team. Environmental aspects may, for example, concern:

- Potential damage to the marine or surface flora and fauna due to dredging or reclamation works;
- The treatment and handling of contaminated dredged material;
- Increase of inland salt intrusion due to deepening of rivers or channels;
- Water pollution from port industries, cargo handling operations or adjoining population centres;
- Air pollution from dust generating cargoes (coal, grain) or from escaping gases (chemicals, oil products).
- Change in currents due to the construction of breakwaters/inland basins and which may affect nearby bays or beaches
- Effects of the development of a port on adjacent tourist resorts.

Safety aspects are related particularly to the prevention of accidents during transport or handling of dangerous goods.

No port project can be made environmentally harmless nor operationally totally safe. However, with adequate planning and design and the strict enforcement of codes and procedures, etc. for all parties involved - ship owner, terminal operator and port manager - damage and risk can be reduced to an acceptable level.

For most port development projects an environmental impact analysis will be required and consideration given to alternative sites and design types as well as methods to reduce or eliminate harmful environmental effects both during construction and operation.

Certain precautionary measures should be incorporated during port planning:

- Define responsibility at all levels for dealing with hazardous cargoes, damaged goods and accidents and emergencies.
- Locate terminals handling dust generating materials or obnoxious liquid or gaseous cargoes on the lee of urban areas and busy port areas.
- Locate berths for vessels carrying very sensitive cargoes such as LPG or LNG to avoid risk of collision between a gas tanker at berth and other port traffic.
- Designate different and well segregated port areas for different groups of commodities: oil and oil products; chemicals; ores and coal; grain; conventional general cargo/containers/ro-ro. Special arrangements are necessary for preventing leakage from pipelines, tanks and drums, etc. from entering the sewer system or contaminating the ground.
- Maintain adequate safety distances between dangerous goods terminals and busy port areas or urban areas. Too little is known yet to give generally accepted figures, but appropriate guidelines for some main products are:

LPG	:	3,000 to 4,000m
LNG	:	2,000m
Oil and oil products	:	1,000m

1.9.9. Evaluation

Based on the initial estimates of land and water area requirements, principal dimensions, safety distances, etc., alternative preliminary or conceptual masterplans can be systematically developed. The more promising alternatives are subsequently worked out in more detail and may be checked by a further evaluation process.

A procedure widely used is the "multi criteria analyses" wherein the primary and secondary evaluation criteria are given weighted marks leading to a numerical comparison between the alternatives. Once the conceptual masterplan has been decided upon, the optimisation process can start.

1.9.10. Optimisation

Project optimisation is normally required with respect to such major factors as demands, operation, engineering, economic, financial considerations.

Regarding cost, there is an obvious need to minimise capital outlay without affecting the quality of the port project. This may, for instance, entail a considerable effort in comparative design, eg., to determine the quay structure which provides best value for money, to balance volumes of hydraulic dredging with hydraulic fill, and so on.

Regarding hydraulic aspects, matters like wave penetration, seiches and rate of siltation are of paramount importance. For investigation purposes, mathematical models have now largely replaced physical models due to the ever increasing sophistication and capability of mathematical modelling techniques.

Regarding nautical aspects, the use of navigation simulators has become common practice to investigate the course behaviour of different types of vessels in the prevailing circumstances of channel and port layout, winds and currents. A real time simulator in which the pilots themselves participate will generally be required. A number of such simulators (with or without visual display) are available in different countries.

1.9.11. Environmental Mitigation Measures

The masterplan for long term development of a port may need to make provision for some offsets to mitigate for the impacts of port development on the amenity of the chosen area.

For example, wildlife habitats may need to be preserved - or possibly replicated at another location.

Mitigation is a matter of displaying sensitivity towards any existing item of cultural, natural or heritage significance which would potentially be disturbed or destroyed by the progress of port development. In essence, mitigation involves minimising objections to port development by minimising the sense of loss an affected community may feel if beaches, fishing grounds, historic features, bird habitats, residential amenity or other community 'treasures' are threatened by the port development plans.

Mitigation measures for port development can be extensive depending upon the size, location and purpose served by the project being considered. Below are some of the many possible mitigation measures that may need to be taken. Note that this list is general in nature and is not all-inclusive. Additional measures specific to the project may be necessary.

- Dredge and/or fill operations should be kept to a minimum.
- Site disturbances (i.e. erosion control, minimizing areas of cut and fill, etc.) should be kept to a minimum
- Wetland mitigation – This should be considered only after avoidance and minimization steps have been taken
- Minimize adverse effects on any possible cultural resources
- Consideration of measures to reduce impacts on air quality (during construction and during the project’s operation)
- Consideration of treatment of runoff water
- Avoiding impacts to wildlife, especially threatened, endangered and/or sensitive species that may be present
- Compliance with local zoning permits
- Noise abatement measures
- Take steps to eliminate or minimize any hazardous material release to the environment (also a concern during construction).

With increasing emphasis being placed on impacts to the environment, mitigating for these impacts will become more and more important. Assessing the success of the mitigation measures that are employed for a particular project will help determine which measures are valuable and which could possibly be used on future projects.

1.10. EXISTING STRUCTURES AND FACILITIES

1.10.1. Conversion of Existing Berths

1.10.1.1. Introduction

Modern port facilities serve as nodal points in the transportation chain where cargo is interchanged between two or more transportation modes. However, high costs associated with port labour, equipment and modern shipping dictate that port efficiency be maximised, which invariably leads to requirements of fast turnaround times for vessels and high interchanges of cargo volumes to be carried out in a cost effective manner. This has given rise to increasing vessel sizes and larger landside storage areas being required as had been demonstrated by containerisation.

In an attempt to respond to these challenges, older port facilities have in numerous cases been abandoned as port development has moved to less urbanised areas where more land and larger and deeper water areas are available. Many river ports have shifted downstream, where more favourable conditions exist.

However, rehabilitation and optimisation of existing facilities is often a cheaper option than new construction. Conversion of port land not at present fully utilised or conversion for higher priority use is often economically more attractive than schemes requiring large scale reclamation, particularly over soft material deposits. Also, it can often be more expedient to redevelop an existing port site as there are often less stringent environmental constraints on old locations than on a new area.

The retention and modernisation of old port facilities where considered as an acceptable alternative to redevelopment requires a number of crucial issues to be addressed. Some of the significant issues are:

- <u>Draft and manoeuvring requirements for vessels:</u> With possibly the exception of passenger liners, today's vessels have deeper draughts than their counterparts of the more recent past - necessitating dredging alongside berths, swing basins and approach channels to accommodate them. Although, the approach channels and swing basins could be worked with prevailing tidal conditions where the tidal range at a particular port permits this to take place, the consequences of such actions (namely higher ship costs and lower utilisation of the port assets) on the overall cost structure of the port need to be evaluated.

  Generally, larger vessels would require larger swing basins. The ability to widen swing basins depends to a large extent on the existing port configuration. Where existing structures such as breakwaters require repositioning, associated high costs need to be considered.

  Longer lengths and wider beams of modern vessels often require that improvements are carried out on the approach channels as well as possibly navigation aids. Improvements to the channels usually require deepening, widening and possibly eliminating undesirable changes in direction by means of dredging.

- <u>Landside facilities:</u> Usually, the main constraint faced in older port areas is the lack of adequate backup land to support modern cargo handling and storage facilities. In most port cities commercial developments encroach right up to the port's perimeter fencing thus precluding the possibility of obtaining more land. Where the port layout permits, land may be reclaimed in a cost-effective manner. However, the potential for land reclamation needs to be assessed together with the need for improving waterside facilities such as swing basins, approach channels, etc.

Deepening of the existing seabed through dredging has the potential to undermine landside facilities. A careful engineering assessment of the effect of such dredging on these facilities must be carried out and measures to mitigate adverse effects need to be implemented prior to carrying out the dredging. Where space permits, maintaining adequate safety distances is an inexpensive way of achieving this. In the case of existing berths, with the possible exception of structures founded on rock, it is virtually impossible to increase the alongside depth significantly without some form of prior construction to strengthen / extend the structures.

- Heritage considerations: Ports often contain large structures of historical significance, which need to be retained. This is a serious problem in a port situation, as the adaptive reuse of such structures is not an easy matter. With ports, the best option is to relocate the whole or parts of such structures to a location that would not interfere with port activities.

- Transportation links: Most existing ports have reasonable road and rail links but it may be found that existing transportation infrastructure is inadequate to service the needs of a modern port. There is not much point in achieving a fast turnaround time for the ships only to find that the cargoes are held up within the port or somewhere in the congested city road system through lack of suitable transportation infrastructure.

  Modern ports require 24-hour access as well as the ability to receive dual articulated vehicles. It is necessary to undertake an assessment of the origin and destination of the non-transhipment cargo destined to the port's hinterland. This should be complemented with detailed traffic projections showing expected daily as well as hourly peak traffic flows. Following this, a detailed traffic analysis may be carried out to determine the potential points of congestion and to determine the actions required to alleviate congestion.

- Site contamination: Many port sites that have been in use over a period of time are likely to show some degree of contamination. Some port facilities have even being constructed over old refuse dump sites, which introduces another possible source of contamination. Sources of land contamination in ports arise from:

  - Handling and storage of bulk materials such as coal.
  - Hydrocarbons spilled mainly from fuel and lubricant storage areas.
  - Lead contained in old paint work.
  - Arsenic deposited with the ash from coal burning steam engines.
  - Asbestos used either as insulation or roofing in old buildings.
  - PCB's from old transformer coolants used in electrical sub-stations.
  - Residues of pesticides used in control of pests such as rodents.

- Suitability of the intended use: Where ports are located adjacent to urban centres they impact on the quality of life of nearby residents and businesses, which are likely to occupy up-market real estate. Sources of irritation arising from port activities comprise:

- o <u>Noise:</u> Port noise is a major source of irritation to adjacent residents especially where 24-hour operations are envisaged. Noise is generated by plant and equipment, traffic, cargo handling activities and by ships themselves. Most planning legislation requires that that the increase in night time noise levels is to be limited to a certain fixed value, usually around 5 dB, over the prevailing ambient noise levels. Although, the reduction of noise levels from port equipment and operations and to a lesser extent from traffic, is within the operator's jurisdiction, control of ship-generated noise is difficult. Therefore, where feasible, options for using shore power to run ship's equipment while in port may prove beneficial. Consideration may be given to construction of appropriate noise barriers.

- o <u>Traffic:</u> Ports tend to generate heavy traffic. Where a proposed change of use has the potential to increase overall traffic numbers, measures to mitigate adverse effects need to be implemented.

- o <u>Emissions:</u> Generally, the main emissions generated by ports consists of dust, exhaust gases and odours. Bulk cargoes handled by way of open stockpiles tend to generate unacceptable levels of dust and should preferably be handled by self-discharging vessels through closed systems where ports are located within urban areas. Exhaust emissions may be made cleaner by regular maintenance of equipment and the use of low pollution type fuels. Use of electrical equipment could assist in reducing emissions significantly. Odour is more difficult to deal with and the intended use need to take into account possible irritations caused to nearby residents by such odours.

- o <u>Hazardous substances:</u> Ports located near urban areas need to be aware of safety distances required by handling and storage of certain types and quantities of hazardous cargoes. It is possible that this consideration will preclude handling and storing such cargoes in urban port areas.

- o <u>Light spill:</u> Ports generally utilise high lighting masts with a number of powerful light fittings that provide a high level of illumination. It is essential that these fittings are oriented in a manner that would not permit light spill to occur into adjacent residential areas.

1.10.1.2. <u>Upgrading of Existing Aprons</u>

Where transit sheds are too close to the quay face or if they are of unsuitable design (door openings too small; inadequate headroom for operation of forklift trucks and mobile cranes, or obstructed by columns) it may be beneficial to demolish them in order to open up the space they occupy. The paving will then need to be upgraded and provisions made for floodlighting, power supply, potable and fire fighting water, telephones, etc. Sheds of suitable design, i.e., constructed of steel or alloy frames, may sometimes be dismantled and re-erected elsewhere.

1.10.1.3. <u>Strengthening of Quays</u>

Existing quays may be upgraded to allow the use of modern cargo handling equipment such as quayside container cranes, straddle carriers, heavy duty forklift trucks, ro-ro tractors and trailers as well as for stacked cargo, including container stacks. Strengthening may be by introduction of additional piles, reconstruction of longitudinal beams to support crane rails, reinforcing aprons etc.

1.10.1.4. Widening of Quay

To allow dredging of berths to a greater depth or to increase the apron width and thus the working space available in front of transit sheds, quays may be widened by an additional open piled structure or by retaining walls in front of the existing structure.

1.10.1.5. Refurbishment of Corroded Steel or Spalled Reinforced Concrete

In case of reconstruction or major repair work, new load-bearing members may be introduced to carry all or part of the deadweight together with any new requirements for superimposed load. Existing steel members may be strengthened by welding-in new sections (having first transferred the load to a temporary support frame) or welding on a collar. Alternatively, the defective member may be cleaned down to solid material and then encased in reinforced concrete. Where corrosion is a particular problem, the refurbishment should be as maintenance free as possible. If structural steel is used it should be protected by a suitable and proven protective coating, perhaps with cathodic protection, or it may be encased in dense reinforced concrete with adequate cover for the reinforcement.

Corroded members which are still capable and required to carry load may be shot-blasted and coated with a modern special purpose paint or mastic. Alternatively, they may be encased in reinforced concrete as indicated in the previous paragraph.

1.10.1.6. Provision of Additional Land or Water Areas

Old dock basins which are no longer needed for modern shipping may be filled in to provide wider areas for container yards or parking of ro-ro vehicles. Similarly, redundant piers may be removed to provide a wider channel in front of the adjacent berths and more space in narrow basins. This could be of particular interest if the quay wall is being moved out, as described under the heading 'Widening of Quay' above.

1.10.1.7. Conclusions

Each situation needs to be considered on its own as the optimum solution is likely to vary according to local conditions and other factors.

In the case of bulk loading terminals, for instance, it may be possible to provide a small berthing dolphin in front of an existing structure to carry a new conveyor loading system and thus relieve the existing structure of any additional load.

Where the future of a disused or obsolete port facility is under consideration, the choices tend to be:

- upgrading or redevelopment for continuing use as a port facility
- demolition, to free the site for a totally new use
- adaptive reuse of the facility for commercial or residential purposes.

The key factors in deciding how best to deal with existing port facilities available for conversion are likely to be:

- Feasibility of upgrading: Costly engineering works are likely to be necessary to upgrade old facilities to accommodate modern shipping. However, the water depths available alongside old berths, in navigation channels and swing basins, as well as the areas enclosed by old breakwaters, are likely to be more than adequate for commercial redevelopments where only small craft are likely to be encountered.

- Availability of land: Lack of land for port expansion is often the main reason requiring ports to move away from urban locations. A port area vacated due to lack of adequate space can normally be made available for commercial redevelopment.

- Presence of contaminants: Presence of contaminants in the soil at sites where cargo has traditionally been handled needs careful evaluation as to the nature and quantities of contaminants present. Generally, sites to be converted for residential purposes require a much higher standard of remediation than sites to be reused for port purposes.

  Presence of contaminants in the seabed will need to be assessed where dredging is anticipated since strict criteria apply to the disposal of contaminated dredge spoil.

- Heritage considerations: Where the facility under consideration is a heritage structure it may be better suited for commercial redevelopment (adaptive reuse) than for upgrading and continuing service as a port facility.

- Traffic: The traffic impact on the surrounding road system will change if a site is withdrawn from port usage and redeveloped for commercial or residential purposes. A case specific evaluation will be needed to determine the use likely to generate the most acceptable traffic conditions.

- Environmental factors: A number of environmental factors need consideration before a decision is made on whether or not to modernise a port area. Commercial developments also require assessment of environmental impacts, which will be dependent on the specifics of the proposed development.

1.10.2. Under-utilised Waterfront Property

1.10.2.1. General Aspects

Two cases with different characteristics are considered. Firstly, land arising from the gradual recession of the sea or the accretion of certain areas owing to sea movements or rivers flowing into the sea, and secondly, land rehabilitated from port areas which are obsolete or in disuse.

1.10.2.2. Legal Aspects

The legal and regulatory aspects concerning the ownership of any such land acquired or recuperated will be determined in each case in accordance with the applicable legislation of each country. Generally speaking the land will be of "public state domain", except in the case of a private owner with adjacent land who may have a right to ownership. Public domain may be assigned by the state to a national or local public entity (Customs, Municipality, Port Authority, etc.) for its management and use, depending on what is best suited and subject to certain conditions. Legislation may allow the privatization and sale of this domain.

In the case of property from obsolete port areas, it is usually the port authority itself which is entrusted to manage this property, either on its own, in association with the municipality or with private entities through concessions, which is an administrative aspect usually appearing in all legislation.

In the case of concessions to private entities, clauses should be drawn up stipulating the rent to be paid and the maximum leasehold time, which can be 25/30 years for marinas and general buildings, and 40/50 years for parks and similar. After this concessionary period, the facilities must be returned to the port authority. Concessions to public entities may in some cases be rent-free and their terms can be indefinite or limited to 100 years.

To manage the land, it is possible to set up ad hoc public or mixed entities. Sometimes, the area in question is bound by an old concession and has lost the purpose for which it was granted (various handling facilities, old dykes, shipyards, wharves, railways, stations, etc. which have become obsolete), but their legal term has not finished. In these cases, it must he redeemed in accordance with the concessionary clauses, before any other action is taken.

1.10.2.3. Aspects of Usage

Before deciding on the usage, a comprehensive report should be drawn up which explores all possible solutions, to enable a detailed debate between the entities involved.

Without doubt, the usage of this land will be influenced by its location in relation to urban centres and by the demographic importance or culture and even sports and tourism in these centres.

If it is sufficiently far away from urban centres, it can be used for ecological reserves, wooded parks, selective sports centres, marine or environmental research centres, etc.

In areas near populated centres but which are not considered urban areas, usage can be extended to include marinas, recreation parks, nautical or general sports areas, zoological parks, etc.

They should, in all cases, be preferably for public use with little and very specific building.

The last usage generally corresponds to port areas, which owing to certain circumstances, have become obsolete for the trade activities previously carried out. In this case, because of their location they can be integrated into the urban centre. When considering these areas, social and public usage aspects should be in accordance with the profitability of investments needed to convert or refurbish them to new purposes.

The use of land enclaved in urban areas should preferably take into consideration aspects such as the greater opening-up of the city to the sea, together with the recuperation of its waterfront, or the building-up of old maritime districts, possibly with wide promenades which form real terraces overlooking the sea, always following an improvement project of the urban structure.

Depending on the space available, this structure can accommodate nautical sports, marinas, amusement parks, commercial-recreation centres, offices for various shipping agents, and even spacious residential areas.

1.10.2.4. Port-City Relations Concerning Derelict Port Areas

Many ports form part of large metropolitan areas, and because of this, the growth of port activities and urban development often leads to problems of compatibility.

The port has an increasing need for urban services or functions. At the same time, the economic activity carried out by the port and its condition as a port open to the world, are extraordinarily positive aspects to city development. Therefore, the evolution of both port and city does not have to be in conflict, as often occurs, but there should be an arrangement to develop common interests and to face any type of outside competition together.

The use of derelict port areas, no longer used for the customary purposes of the port, and which may be integrated into the urban centre, usually raises problems which must be resolved between the port authorities and the town council. Priorities may be conflicting such as the decision how to use the obtained land, its possible privatization and also its profitability, capacity and economic exploitation.

The conflicting aspects should be treated in accordance with the legislation of the country. However, consensus policies should be established to agree on a more rational use of the land, otherwise the solutions to be taken may be postponed so much that the opportunity is lost.

When determining usage, open cooperation should be established between port and the city, resulting in the building-up and revaluation of common land, once this has been agreed in debate.

One recommended solution is a specific Plan, along the lines of the General Urban Plan, that at least examines the following aspects:

- Analysis of the actual situation of the land.
- Study of the possible alternative courses of action.
- Zoning and definition of uses.
- Economic-financial feasibility.
- Fixing of rents and taxes if applicable.
- Administrative systems for the established uses.

The setting-up of a joint port-city entity to carry out and develop the Special Plan can simplify and satisfactorily solve many of the problems which usually arise.

In any case, mutual collaboration is essential, and it is the Municipality who should set the standards to regulate the urban use of the land, always bearing in mind the requirements of the port authorities, especially in aspects regarding compatibility and economic profitability.

The profitability must be safeguarded by the port when usage implies the privatization of the land, in any form.

The investments needed to achieve the preferred use of the land, must be specially regulated and fixed by both entities, and its financing will be in agreement with the different public or private destinations of the land.

For a more detailed discussion of Port-City Relations see Section 1.12.

1.10.3. Commercial Reuse of Obsolete Port Facilities

1.10.3.1. General

Complex processes of urban restructuring presently occurring in many cities worldwide, leading to regeneration of inner city areas, particularly waterfront sites, combined with the highly sought after locations of old port sites, represent substantial opportunities for redevelopment.

Additionally, there is community expectation that foreshore access for the public, long denied by the presence of port facilities, would be restored thus improving the social amenity of that part of the city.

Given the paucity of suitable sites for construction of new ports in contrast to the social benefits likely to accrue from redevelopment, the decision to either modernise and continue to use the facility for port purposes or to redevelop and integrate with the urban landscape requires careful evaluation. Whatever the eventual outcome, it is bound to have profound long-term effects on both the port and the port city.

1.10.3.2. Commercial redevelopment

Types of development

Waterfront redevelopments in various parts of the world come in many forms and shapes. The redevelopment process would ideally include the preparation of masterplans for the areas concerned and, where applicable, adjacent land to be integrated with the developments. The masterplans would normally identify land use criteria, outlines of built forms, landscaping, and access and egress and transportation links.

Most importantly, these masterplans become a vehicle for community consultation and, where required, a means of reshaping the project to take community concerns into consideration.

Generally, these redevelopments are undertaken on a commercial basis with little or no government funding made available and with no ongoing costs to the taxpayers. Most redevelopments that have taken place to date incorporate some or all of the following types of developments to varying extents:

- Hotels, shopping facilities and tourism oriented activities.
- Exhibition complexes, theatres, museums, aquariums or similar developments of public significance.
- Residential facilities consisting usually of upmarket apartments.
- Marinas and other water based areas for recreational activities.
- Terminals for reception of ferries and passenger vessels.
- Waterside promenades / boardwalks /pedestrian malls.

Constraints to redevelopment

Successful redevelopment of disused port facilities requires overcoming a number of challenges peculiar to this type of sites. Such sites can be broadly viewed as disused industrial sites, commonly referred to as "brownfield sites". Aspects that are of particular relevance comprise:

- Heritage considerations: Ports often contain large structures of historical significance, to which the community has become accustomed. There is a reasonable community expectation that such structures will be preserved and not demolished to make way for new facilities. Sometimes, the preservation of such structures is enshrined through some form of legislative framework, which makes such preservation mandatory.

- Over water structures: Many port structures consist of piled decks over water without any associated dry land. The retention of such structures requires costly engineering solutions. Furthermore, the marketability of dwellings constructed at such locations may be uncertain and needs careful evaluation.

- Presence of contaminants: Many port facilities exhibit presence of contaminants. Depending on the types and levels of contaminants present and the intended usage, remediation of these sites could prove to be costly.

- Tenure arrangements: Many of these sites are prominent government assets, which the public would be reluctant to transfer outright to private developers. This will invariably lead to some form of leasehold over periods long enough to enable the developers to obtain commercial returns.

- Foreshore access: Public access to foreshore areas is sometimes likely to conflict with water-based amenities such as marinas and requires careful management.

- Traffic access: Depending on the nature of development, there is potential for substantial increase of traffic numbers generated. The impact of increased traffic on the city road system needs to be assessed and appropriate mitigating measures implemented.

- Marine collision: Where facilities are located adjacent to shipping channels that will continue to be used as such, the potential for accidental impact by a stray vessel needs to be considered and appropriate safety measures need to be implemented.

1.10.4. Improvement of Environmental Protection Measures

Conversion of existing berths is an excellent opportunity to investigate possibilities to make the new sites environment-friendly. For example:

- Construct quay edge and terminal surface in such a way that, in case of fire, no (contaminated) fire fighting water can enter the river/sea. Instead, design leak proof storage/interceptors.

- Construct special liquid proof areas where leaking drums, tanks, containers etc. may be placed pending curative action.

Most ports, by virtue of their coastal locations, are likely to have discharge outlets either within or adjacent to the port for stormwater that is originating from outside the port areas. Such stormwater outlets have the potential to deposit a wide range of pollutants, depending on the industries served within the upstream catchment. As a minimum, it is reasonable to expect hydrocarbons and lead to be deposited on the seabed within the port area from this source. This is also true for river ports where a variety of pollutants may be conveyed from upstream industrial areas. Another source of water borne contamination arises from the older types of anti-fouling painted on ships' hulls, which tend to contaminate harbour sediments with tributyl tin.

This gives rise to the need for remediation of the site to a standard suitable for its intended use, which could be costly. Fortunately, most port sites lend themselves to capping, where it could be demonstrated that the risk of on-going groundwater pollution would be minimal. Contaminants on the seabed give rise to difficulties associated with disposal of dredged sediments. A possible method of disposal for such sediment is by deposition in deeper pockets and capping with clean fill material.

1.11. MAINTENANCE CONSIDERATIONS

1.11.1. Type of Port

The amount of infrastructure owned and operated by ports will vary widely depending upon whether the port is an operating port (i.e. owns all, or part of, the port facilities, warehousing, piers, cranes, cargo handling equipment, and has longshoremen, crane operators, equipment and building maintenance personnel on its payroll) or a non-operating or tenant port (which owns only the piers, roads and utility systems and leases land to tenants for warehousing, processing of seafood, storage of oil, etc). Container cranes for the latter type of port can either be port-owned and operated, port-owned and leased, or owned and operated by the tenant.

These various types of ports have in common in that they own, construct, and operate the piers, wharves and bulkheads. For all types of ports, future maintenance liabilities must be considered during the planning and design of the facilities using such analysis as first cost vs. life cycle cost.

1.11.2. Life Cycle Costing

No structure will last for ever and the time to consider future maintenance and repair liability is at the design stage. For example, in the construction of concrete piers, the slightly higher first cost of using coated rebar in the concrete may be fully justified when looking at the life cycle cost of the facility. When steel sheet piling is driven, consideration should be given to future corrosion in a harsh environment, for example, by either specifying greater steel thickness, placing the hardware for the tie back system on the outside of the wall, and coating the wall either to the mud line or through the splash zone. Cathodic protection is another option.

1.11.3. Periodic Maintenance

For all systems, whether for piers, warehouses, utilities, cranes, transport or weight handling equipment, it is essential to set up a periodic, ongoing inspection or condition survey programme with appropriate check lists using either qualified port personnel or outside consultants.

In connection with this continuing preventative maintenance programme, small discrepancies or problems can be identified early and steps taken using either contract or in-house forces to effect repairs before they become major problems.

For piers, facilities, buildings, warehouses, at least an annual inspection is recommended, the results of which give port management a list of major repairs required so that they can be prioritized and accomplished as budget and operational considerations dictate.

For rolling stock such as transport, weight lifting transport and cargo handling equipment, a preventative maintenance programme relying on manufacturer's recommendations should be instituted. Work can be accomplished either by port personnel or utilising contract services.

When equipment is in the shop, safety inspections on brakes, lighting and warning equipment should be conducted. For cranes and other weight lifting equipment, it is recommended that they be certified annually by a competent firm specializing in certifying weight lifting equipment, independent of the firm that does maintenance.

For all rolling stock, including cranes and weight handling equipment, a lubrication programme should be instituted in accordance with the frequency, type of oils and lubricants recommended by the manufacturer. This will ensure proper operation of equipment and extend the operating life.

As a prerequisite for annual certification, accurate records must be maintained of maintenance and repair of weight-handling equipment. Replacement of any load-bearing parts such as wire rope, sheaves, etc. must be followed by a controlled load test of at least 125% of the rated load.

Periodic maintenance programmes should also make provision for hydrographic surveys (soundings) to be undertaken to check whether the declared water depth in channels and at berths remains available. Where reduction in water depth is a recurring problem a maintenance dredging programme may be necessary.

1.11.4. Maintenance Budgets

Data and information derived from the inspection programmes and preventative maintenance programmes will be useful in preparing port budgets and justifying personnel for the maintenance and repair of port infrastructure, whether it be accomplished in-house or by contractor, and will additionally permit multi-year budgeting for major repair projects. Computer software programs often prove to be beneficial in managing maintenance programs and monitoring asset condition.

1.12. PORT-CITY RELATIONS

1.12.1. Port-City Relationship

The port-city relationship is centred on the urban waterfront, the interface between the port and the city. The area which is not necessarily dominated by the commercial marine industry as it once was, is the focal point for a new spectrum of challenges, all related to changing technology, changing urban dynamics and changing human values. The common element of these changes is land and the use of that land. That land is subject to many pressures, including: competition from multiple potential users; overlapping governmental jurisdictions; innovative or developing public policies regarding resource use and management; and evolving social values and perceptions regarding the use, development and preservation of a finite resource, waterfront property. Also on this pressure list are the requirements of the working waterfront for port infrastructure to meet trading and shipping requirements.

The port-city relationship is still primarily based on a functional linkage between the port and the city, that is, the industrial/commercial/ transportation partnership between the port and the city. This linkage is tempered by the changing perception of the waterfront and the role of that waterfront in a modern, environmentally sensitive urban complex. The port administration and the urban planner must understand the different roles to be played on the waterfront.

There are five major port-city challenges facing port administrators.

Firstly, there must be a vision for both ports and waterfronts. The harmonious coexistence of the working waterfront and the urban waterfront must be nurtured, ensuring both the future of the working waterfront and the economic revitalization of urban waterfronts. Secondly, there is a strong need for good port planning, taking into account the total port operating environment and the non-marine influences on the port. Thirdly, port administrators must understand the dynamics of the city in which they operate, and develop a multi-disciplinary understanding of the port-city linkages.

Fourthly, port administrators must fully understand the concept of waterfront property, viewed as an urban resource by the city and as a transportation resource by the port. Fifthly, port administrators must be environmentally sensitive and proactive to all types of pollutants, noise abatement, regeneration of former industrial sites, as well as heritage and leisure considerations because environmental concerns remain a high priority with the urban community.

1.12.2. Urban Expectations

Port administrators need to appreciate the city's expectations of the waterfront. Cities continue to reclaim some or all of their waterfronts as new development enhances property values and the image of urban communities. In many cases, waterfront redevelopment can be the spark for renewal of the city core, and is the basis for future development.

From the urban perspective, successful waterfront developments have several common features. Urban waterfronts must promote public access and recreation, with an emphasis on retaining the water's edge for parks, walkways and viewpoints. Urban waterfront renewal is linked to economic development, with waterfronts often becoming the focus of economic development plans. Marinas, catering to both transient and local recreational boaters, have become a feature of most waterfronts, as the boat becomes a floating meeting place.

Most port-cities, with a viable, commercial port operation, have recognised the need to sustain the working waterfront. Cities are recognising the economic impact of traditional port activities. Restoration of the waterfront environment is a universal priority and is becoming even more sophisticated with all-encompassjng understanding of watersheds, ecosystems and biospheres, with clean water as the essential ingredient. The creation of waterfront development partnerships between all waterfront communities and governments, is gaining prominence, concentrating on increased development coordination along the waterfront.

In most urban waterfronts, the working waterfront is given due and appropriate consideration. The working waterfront has been defined as "one which achieves a balance between protecting the efficiency of essential functions while preserving and enhancing the liveability and vibrancy of the waterfront experience". Essential functions include recreational opportunities, transportation corridor (rail, road, shipping, air) and economic opportunities related to industry and tourism. The primacy of water-dependent and water-related uses is acknowledged in a way which appears to be acceptable to the port community. The waterfront planning process includes a great deal of public consultation and interaction, and examines all waterfront functions and interrelationships. The working waterfront is viewed as an integral and necessary component of the overall urban waterfront.

1.12.3. Guideline Development

It is evident that a two-staged process for port-city guidelines is necessary. The two stages are related to port's internal preparation and its external implementation. The port must have a series of internal procedures or information sources developed and under control in order to enter into and cultivate a responsible external relationship with the city.

The port must have its "own house in order", understanding and defining the role and impact of the port and having the future direction of the port defined through a series of planning initiatives.

1.12.3.1. Role of the Port

The port must understand and be comfortable with its two-fold role on the waterfront. The first role relates to the port's traditional transportation requirements, providing and planning for the infrastructure required to respond to trade and transportation demands. The working waterfront must be sustained through the development of a long-term commercial vision for the port; the establishment of responsible development principles; the establishment of infrastructure development priorities; and the creation of a framework for implementation. The port must also appreciate its role as a component of the overall urban waterfront ensuring that its commercial function is permitted to exist among other competing uses for waterfront property. At the same time, for strengthening and enhancing urban functions, the port should be urged to actively provide waterfront areas owned or to be created by it, for such municipal or environmental protection purposes as housing projects for city dwellers or sanitary landfill sites.

1.12.3.2. Port Planning Instruments

The port's internal planning processes must be advanced in several directions in order to confidently and justifiably maintain its transportation-related position on the waterfront, including the creation and corporate approval of the following:

- corporate strategic plans (business plan) identifying mission, goals, objectives and strategies;
- port master plan identifying the long-term infrastructure port requirements;
- port land use plan identifying strategic land requirements and areas of potential conflict with the adjacent urban function;
- port environmental plan including environmental assessment guidelines for project development; environmental audit procedures to ensure the environmental sustainability of port operations; mitigation program to correct environmentally negative situations.

1.12.3.3. Economic Impact Statement

The port should develop an economic impact statement indicating direct, indirect and induced impacts as related to employment, salaries, taxes paid, goods and services consumed and provided by the port. This is essentially a marketing tool, permitting port officials to professionally portray the impact of port operations.

1.12.3.4. Understanding Urban Dynamics

The port must develop a multi-disciplinary understanding of the urban environment, particularly the urban waterfront; the city's expectations of the waterfront; the potential competing uses for waterfront property; land use and zoning issues, and planning requirements created by urban waterfront development proposals; and the local political implications related to and generated by urban waterfront development proposals.

It is only after the port has put its own house in order, or at least until it is moving significantly in that direction, that it can reasonably contribute to and participate in the overall waterfront development process.

1.12.3.5. Waterfront Planning Input

The vast majority of port-cities will have developed or will be in the process of developing a waterfront plan as an integral component of the overall municipal plan. The port must become actively involved in this process ensuring that urban planners understand the port's land use requirements, and the implications of these requirements. The port must be part of the waterfront planning process, on all levels; professional, political and public. On a reciprocal basis, it is also advisable that the city authorities be actively associated with decisions for development of the port. Appointment of at least one representative of local government to the board of the port authority can provide an avenue for integration of port and city planning.

1.12.3.6. Public Consultation

Part of the planning and development process is the public consultation process. The port must initiate a program which educates the public at large as well as specific waterfront interest groups and officials regarding port projects and significant planning directions, environmental issues and the economic impact of the port. Members of the community demand consultation.

The public consultation process is an exchange of information program in which plans and expectations are put forward and explained, debated and perhaps modified as a required element of the planning process. The port should initiate compatible consultation relationships, such as the port manager and the mayor; the port planner/engineer and the city planner/engineer; the port marketing and development official and the city economic development official. (See Section 1.13)

Communication with the public should stress the notion of the port city, underlining the fact that a number of port functions cannot occur if the partner city does not provide complementary services such as banking, roads, etc.

1.12.3.7. Waterfront Partnership Agreements

The waterfront issues, central to the port-city relationship, can often take on a life of their own in terms of planning requirements, staff participation and financial commitment. In an effort to rationalise the use of port resources, the port could pro-actively suggest the use of Waterfront Partnership Agreements to achieve common goals. These agreements facilitate a comprehensive approach to planning and resource management; tend to overcome the effect of fragmented and delayed decision making; reduce bureaucracy and increase public support; ensure equitable and efficient allocation of financial and other resources. The urban waterfront is perceived as a public resource and partnerships go a long way to ensuring the maximum use of that resource on an equitable basis.

1.13 PUBLIC INVOLVEMENT IN THE PORT PLANNING PROCESS

1.13.1. Introduction

Numerous people who live near ports wish the port could be relocated so that they can enjoy a peaceful residential environment. Many of them would prefer the waterfront to be developed as a place for recreation, not commerce.

Maps of the continents of Asia, Europe and North America demonstrate that there are many large, famous cities located hundreds of kilometres from the sea, with no ports of their own. Obviously, the problem of port/city relations do not arise in these cases. Because the world has so many cities located far inland, it can be difficult to justify to residents of coastal cities why their ports are so critical to the economy of the regions they serve.

Most port cities exist because of the port. The port was established first and the city grew around it. But history can be forgotten as a city grows. Over time, the people of a city can lose sight of why their city came to be located where it is.

In fundamental terms:

- cities historically were formed as centres of commerce.
- international commence depends in large measure on the availability of seaports.
- seaports involve a concentration of activities on a scale which dwarfs that of most other features of the built environment:
    - big ships.
    - vast storage facilities.
    - large land transport vehicles.
    - etc.

The noise and congestion which typically accompany port activities are serious irritants to neighbours of a port.

- city dwellers tend to aspire to a high standard of living, which comes with successful industrial and commercial performance but which involves pursuits in which greater interest is shown in comforts than in the means of survival.
- where a port and a city have to co-exist there usually has to be compromise. This may mean that nobody ends up <u>totally</u> satisfied with the way the city and the port relate to each other. The main aim should be to ensure that neither the city nor the port has to suffer to the extent that one has to give way completely to the other. A city can exist without a port but, if the port is the reason why the city was established in the first place then the city will probably be forever dependent on its port.

1.13.2. Role of Government

Reconciliation of the problems caused by expansion of port activity with the highly cultivated preferences of a mature urban population normally requires government involvement. One of the foremost roles of governments is to balance economic priorities against social priorities in order to establish the best mix.

However, even governments need guidance. This is where port administrators have a vital responsibility in reminding governments of the economic importance of ports. No matter how much dislike a community may have for the impacts of port activity - no matter how much pressure is directed at government to separate port from city - the economic disadvantages of dislocating port activity or placing constraints on it need to be impressed upon opinion leaders in the community.

1.13.3. Involving the People

The key to achieving an acceptable level of port/city harmony is to involve the people of the city in the planning for the port. While public involvement in the port planning process will not necessarily eliminate all the objections or resistance present within the community, opportunity for community members to exchange views with the port administrators and others authorised to act on behalf of government will normally improve the chance of consensus being reached.

Some countries rely on a legal framework, enshrining the principles of consultation and compromise, to institutionalise a public participation process. In such cases, it is mandatory for proponents of port development to document their proposals, and the expected impacts of the proposals, and to allow the public to study the proposals and comment on them before binding decisions are made.

Telling the public about a port development proposal and allowing the public to react before implementation is attempted tends to flush out the main concerns, thus identifying for the proponent's benefit the conflicts which need to be resolved for the development to gain community acceptance.

In the course of documenting their proposals for public consideration, some proponents prefer to put forward options, ranked in order of suitability for meeting the proponent's development objectives. However, if numerous options are offered, the planning process may become unduly complex because of divided public opinion as to which option, if any, will minimise community concerns. One method of exploring options with community members is to assemble, initially, small focus groups of opinion leaders and request these people to cull the number of options to a short list of 2 or 3 for subsequent presentation to the wider community.

Face to face discussion tends to be the most expeditious means of resolving differing opinions regarding port development proposals. Contentious proposals can consume a lot of public attention and time if debated by way of written submissions and bureaucratic procedures. While formal procedures are appropriate, in that they provide a consistent framework for the resolution of conflicts which often precede port development, the best mechanism for bringing debate to a conclusion is that of the public hearing. Where proponents and opponents are able to present their respective views to a panel of suitably qualified adjudicators, in an open forum, the opportunity to reach consensus or to negotiate a compromise is more immediate than it can be where decisions are formulated without the public involved.

Port administrators need to be alert to the importance of information and education in cultivating public understanding of the role of ports. Many ports employ public relations staff to continuously involve the community in the life of the port. Close, cordial relations between the port administration and the public help minimise the attitude that the port is a threat to the quality of residential amenity.

Ports which involve the public in their planning, from the stage where the plan represents a vision for the long term to the stage of construction and operation, generally succeed in having their plans accepted. As with any planning for which broad acceptance is sought, planning for the development of a port needs to be suitably justified and presented in a credible manner. The most senior administrator of the port should be seen to personally advocate the importance of the plan. The credibility of the senior administrator will have a significant bearing on the degree to which the public supports the plan. A visionary leader representing the port is a vital asset to any port administration.

Port-city relations may never be altogether free of tension but the tension will be less severe if there is a long term vision available to the community to demonstrate the vital importance of the port and how the port will need to be developed in order to meet the city's ongoing trade requirements.

Port administrators have to be particularly sensitive to community demands and at the same time particularly innovative in reconciling the needs of the port with the community's natural inclination to frequent the waterfront for pleasurable purposes. A well balanced approach to management of the port, as distinct from obstinate determination to put economic needs ahead of social needs at all times, will help the port administrator to maintain community respect and, in all likelihood, retain office. A community hostile to the port represents a major threat to a port administrator's hold on office.

It is important to understand the history of the port and city, particularly the interdependencies between the two throughout the course of development. A sense of the city's history may help a community to accept the significance of its port and thus moderate the tendency to drive the port away. A history-conscious community will see the value in preserving a working waterfront and will be unlikely to press for every metre of shoreline to be dedicated for urban waterfront projects.

1.13.4. Important Considerations

The things that matter most in port-city relations are:

- ensuring the port is not allowed to fail the community because it has been unduly constrained due to competition from other land uses; while also

- ensuring the port functions as harmoniously as possible with the other aspects of commercial city life.

The ideal port-city relationship will be one in which the port has not been banished to such an extent that the community ends up bearing excessive distribution costs as the price of enjoying a pleasant urban waterfront. Cities are commercial hubs which should be allowed to reflect a rich diversity of activities.

Port administrators can ill afford to ignore the fundamental human habit of congregating in large concentrations. Inevitable consequences of the clustering of population include trade. For a city which has been located so that its trade can utilise shipping, the public must be encouraged to accept that the city will lack the excitement and richness on which urban populations typically thrive if endeavours are made to develop it into a ‘dormitory beside a pond’.

1.13.5. International Level

Nowadays, industries seeking to set up in port zones, logistics services looking for sites for development, etc., tend to challenge a number of port cities to compete for their business. They make their locational decisions based on how well individual port cities suit their purposes, having regard to criteria such as cost of development, profitability of investments, skills available in the respective job markets, social peace, living standards, regulations in force, etc.

In order to present a coherent submission to such investors, the city and port need to communicate with a single voice.

Jointly produced information brochures, joint promotion missions, dual speakers at international conferences, etc., are important means of demonstrating to prospective new industries that there is harmony between port and city.

2. DIFFERENT TYPES OF TERMINALS

2.1. GENERALITIES

2.1.1. Conceptual Plan

Once a decision has been made to move from the masterplan to the design stage, the terminal's conceptual plan should be prepared. This Section covers the steps required to prepare such a conceptual plan.

2.1.1.1. Underlying Assumptions

A conceptual plan for a terminal is based on a number of assumptions that must be defined before beginning work on the plan. These assumptions include:

Terminal Throughput Goal

The terminal throughput goal should be based on a long-term traffic forecast that analyzes projected traffic levels by commodity and direction (import, export, transit, transhipment).

Projected Ship Mix

The ship mix should cover ship types and sizes, visit frequency and import/export parcel sizes. The design vessel(s) should be defined, considering the largest and smallest vessels (by type) expected to visit the port.

Projected Productivity Levels

Productivity levels should include production rates for various types of equipment utilized to handle cargo in the port.

Desired Service Levels

Service levels should define service levels provided to all interfacing modes of transport: truck, ship, rail.

Additional factors that need to be defined at an early stage include:

1. Cargo storage patterns and dwell time.
2. Ship, truck and rail arrival patterns and handling mix.
3. Economic data on investment and operational costs
4. Work schedules at quay, in yards and at gates.

Consideration should also be given to local operating preferences and business partner preferences (stevedores, shipping lines, truckers, railways, barge operators, importers/exporters, customs, etc.)

Once data covering the design assumptions have been developed, a series of alternative terminal layouts should be developed. These alternatives should be capable of handling the projected long-term traffic forecast and meeting the desired service levels. Constraints should be identified.

2.1.1.2. Principal Issues to be covered by Conceptual Plan

In developing the conceptual plan, the following areas need to be addressed:

1. Quay cranes.
2. Handling concept
3. Terminal layout
4. Traffic planning, including terminal equipment, road trucks and railways.
5. Support structures, including administrative offices, maintenance facilities, warehousing and operational facilities.

2.1.2. Site and Terminal Type Selection

A terminal should have available all the equipment necessary to allow ships to berth safely and to handle the goods efficiently, between the ship and storage area or land transport or barge.

The size of the ships to be accommodated is a major item in terminal design and this aspect is discussed in Section 1.3.

The choice between different terminal types depends mainly on economic optimisation. It is very important to compute the investments, the maintenance and operation costs, the berth life, the handling rates to be met, the necessary number of berths in the first stage and in subsequent development stages. Economic considerations are covered in Sections 1.2. and 1.9.

The detailed physical and economic factors affecting the development of a terminal are discussed in detail in 1.2. to 1.9. Some of the factors which are of particular importance in respect of terminal operations are:

- The availability of deep water (to avoid excessive dredging).
- The oceanographical and meteorological conditions should be such that shipping movements and port operations are interrupted very rarely.
- The port should offer good navigational aids, ready availability of tugs and pilots and salvage facilities at any time of the day or night.
- Loading and discharge equipment (cranes, conveyors, etc.)
- Adequate services should be available at the berth and there should be suitable arrangements for crew exchange.
- Good inland transport links are essential.
- Satisfactory fire and safety precautions and emergency services.
- Environmental protection and pollution control.
- Ease of administration procedures.

The layout of the berth depends mainly on the quantities and types of goods to be handled. A berth is generally provided with handling equipment, covered and open storage areas, roads and rail tracks.

The determination of the number of berths and the handling rates will always have regard to the minimisation of the cost per tonne handled. This, in turn, is dependent on the capital, operating and maintenance costs. The berth occupation ratio is of particular significance for its profit earning capacity.

Many factors influence the required storage capacity. These include traffic type and volume (both import and export), the distance between the port and the inland destination, the size of ships and their arrival pattern, the proportion of goods to be stored and their average dwell time.

2.1.3. Typical Capacities

2.1.3.1. Berth Capacities

For conventional general cargo, berth occupancy, intensity of working and mix of cargo has a great effect on the annual throughput and thus any figures given should also include the assumptions used. Typical figures are:

- General cargo — 150,000 tonnes per annum (3 shift working, berth occupancy 70%)
- Container terminal — 1,200,000 tonnes per annum (3 shift working, two ship-to-shore cranes, berth occupancy 50%)
- Multipurpose terminal — 325,000 tonnes per annum (2 shift working, berth occupancy 67%)

The indicators of area requirements are largely dependent on dwell times of cargo that can vary from a few days to weeks in different countries. Again indicators should be given with the assumptions for average dwell time:

- General cargo — 5 tonnes/sq.m/year (average dwell time 16 days)
- Container terminals — 10 tonnes/sq.m/year (average dwell time 6 days)
- Ores, coal — berth capacity is largely determined by the capacity of loading or unloading equipment. For loading the effective (mean) capacity usually is in the 2,000 to 8,000 tonnes/hr range. For unloading the effective capacity is appreciably lower and generally varies between 500 and 4,000 tonnes/hr. If, for example, this effective capacity at an unloading berth is 3,000 tonnes/hr, the annual capacity (assuming 24 hours, 7 days per week operation and 35% occupancy for a high capacity berth) is 0.35 x 3,000 x 24 x 360 = about 9 million tonnes.

* Oil and oil products — loading and unloading capacities are generally such that total vessel turn around time is 1 to 1.5 days. If, for example, at a crude oil berth the mean tanker size is 125,000 dwt, the annual capacity for a 35% occupancy rate will be about 0.35 x $^{360}/_{1.5}$ x 125,000 = 10.5 million tonnes. It is quite obvious that particularly for tanker berths, the capacity depends very much on mean vessel size.

* Grain — pneumatic or mechanical unloading systems are used,

depending on the type of grain. Effective capacities are mostly in the 100 to 400 tonnes/hr range per (continuous) unloader. Often two unloaders will be used per ship and per berth, bringing annual berth capacity under similar conditions as mentioned before in the 600,000 to 2,400,000 tonnes/yr bracket. Loading rates vary considerably, from less than 200 tonnes per hour to over 1,000 tonnes per hour. The most common loading methods include gravity feed from silos onto conveyor belts thence by chutes into the ship's hold.

2.1.3.2. Terminal Capacities

Very approximate indicators, expressed in terms of throughput capacity are:

Conventional general cargo terminals:	4 - 7 tonnes/sq m/yr
Container terminals:	6 - 12 tonnes/sq m/yr

The above unit capacities refer to the total area of the terminal including roads, and other non-storage areas.

For bulk commodities throughput-capacity indicators can hardly be given, because of very different transit times. For example, there are coal terminals that serve at the same time as strategic reserve, with a storage capacity equal to four months throughput. Other coal terminals have a pure transit function with a mean dwell-time of barely two weeks.

Land area requirements for ores and coal therefore have to be estimated based on anticipated transit time and a normal maximum storage height of about 10 - 12m provided that the subsoil has good bearing capacity.

2.1.4. Berthing and Mooring

Berthing loads can be absorbed by either the berth structure itself protected by fenders or by flexible or rigid berthing dolphins provided with fenders. The berthing energy to be absorbed depends on approach velocity. The probable maximum approach velocity depends in turn on ship size, current velocity, wind speed, ship exposed area below and above water, tug availability, availability of bow thrusters, and in some cases the use of berthing aids. The design approach velocity has to be assessed taking into account those factors and the sensitivity of the berthing structure and the ship. The berthing energy also depends on whether the vessel is loaded or empty when berthing. Berthing may not always be possible when extreme meteorological conditions occur.

Whatever the mooring rigidity may be, some berths are not tenable in extreme meteorological conditions, especially if the berths are located in an exposed position. It is necessary to define limits beyond which cargo handling must be suspended. It may be necessary for the ship to sail out and wait until the conditions improve.

2.1.5. Storage Areas

The storage areas smooth ship delivery irregularities. The major objective in storage area design is to maintain flexibility in the handling system, taking into account the different goods which are to be handled, the traffic volumes, future extensions, etc.

In order to facilitate handling operations, the storage area should be located as close as possible to the berth; its surface area should be adequate, and its foundation conditions adequate for heavy loads to provide the optimal storage efficiency.

The storage can be carried out:

- in open stockyards (containers, ores, etc.)
- in covered areas (sheds for general cargo also for grains and other dry bulk)
- in tanks for any liquid.

2.1.6. Shoreside Fire Protection

This important issue must be addressed in the planning and design of port facilities, whether they be warehouses, container yards, piers, office buildings, etc. Design should be checked against applicable fire and life safety codes to assure that access for fire fighting equipment is provided, that sprinkler systems are provided when necessary, and fire dampers, fire hydrants, and emergency access for personnel are designed into the structure.

Whether the port is an operating or non-operating port, annual inspections by competent, licensed fire inspectors is a prerequisite. Fire prevention is the most cost-effective method of fire protection. Although ports vary in size, each port must have access to fire departments, either through contracts with adjacent cities or municipalities, or by having their own volunteer or professional fire department. The use of cross-service agreements between the port and other fire-fighting entities provides increased resources at minimal costs.

For larger ports, it is not uncommon to have an emergency services co-ordinator qualified in fire inspections and fire-fighting techniques, including shipboard fire-fighting, to co-ordinate activities during fires and other emergencies, such as hurricanes, floods, etc.

It is not uncommon for a port to be faced with shipboard fires when ships are tied alongside their berths. In some cases, passenger ships have been known to come into port to discharge passengers with a fire aboard. Consideration should be given for using the emergency coordinator to cross-train local fire fighters in the techniques used in shipboard fires.

Tugs and port service vessels at the port should be fitted with fire nozzles to assist in this effort. Berths should be equipped with fire nozzles so that fire tugs can be connected to the shore system to serve as pump boats.

2.1.7. Classification of Terminals

The more important terminal types are discussed in the next section under the following headings:

- Bulk terminals, comprising dry bulk and liquid bulk.
- General cargo terminals, comprising break bulk, containers, ro-ro, ferry and multi-purpose use.
- Cruise terminals.
- Fishing harbours.

2.2. BULK TERMINALS

2.2.1. Site Selection

The first choice to be made is between off- and on-shore installations.

The on-shore terminal's main advantage is the high handling rate. A second advantage is better availability in bad weather conditions because such a terminal is generally more sheltered than an off-shore terminal where ships cannot be loaded or unloaded when the wave height reaches say 2 or 3m. Furthermore, the on-shore terminal offers all the services required by the ship (provisioning, bunkering, ballast cleaning, etc.) in favourable conditions.

The off-shore terminal's main advantage is that dredging of an access channel can be avoided and, in quiet seas, breakwater protection is unnecessary. With buoy mooring systems, the mooring operation can be carried out without tugs, which reduces the port operating cost. But the construction cost of marine structures and maintenance costs are relatively high.

As far as environmental protection is concerned, it is more difficult to control accidental leakage in the offshore situation.

2.2.2. Terminal Equipment

For the handling of liquid bulk, in general pumps only are used, either shore based or ship based.

Dry bulk terminals are provided with three types of equipment:

- quay handling equipment
- yard transport and stacking equipment
- handling equipment related to the land transportation systems.

2.2.2.1. Quay Handling Equipment

The selection of the equipment depends on:

- the annual traffic forecast including periodic fluctuations;
- the ship size and characteristics (specialisation, handling equipment availability, etc);
- the necessary handling rates;
- energy consumption of the equipment;
- bulk types to be handled (density, grain size, structure and abrasive characteristics, fragility, toxicity and risk of pollution, sensitivity to meteorological conditions, etc.).

The available equipment is:

- ship's gear;
- quay cranes, (on rail tracks or rubber tyres) or gantry cranes (on rail tracks). With grabs of different characteristics, the same equipment can handle many different bulk commodities;
- specialised equipment for dedicated terminals handling specific material (different for loading and unloading).

For unloading, pneumatic equipment for cereals and cements and elevators with chains, buckets, endless screws, shovel-wheels, belt conveyors, etc.

For loading, belt-conveyors, elevators on swivelling and telescopic jibs which can move along the quay side. This equipment is generally provided with telescopic spouts and dust extractors (cements, cereals, etc.)

2.2.2.2. Yard Transport and Stacking Equipment

The following equipment is suitable for the bulk transportation between the quay, the storage area and onto the inland distribution system:

- belt conveyors;
- pneumatic conveyors for cereals and cement;
- chain conveyors for the shorter distances;
- endless screw conveyors for powdered non-abrasive bulks;
- air slides for powdered non-sticking bulks.

The yard equipment design must take into account.

- the mean turnover time of the stored commodities, the volumes which are to be handled for loading and unloading, the delivery rate and the regularity of ship arrivals;

- the characteristics of the stored bulk (cereal heating, cement or sugar sticking) and hydrocarbon content (anti-combustion precautions);

- the sensitivity of the stored bulk to weather conditions: open or covered storage, stockyard or silo storage according to the tonnage and turn-over.

Vertical storage installations (in silos) are more expensive than the horizontal ones but can meet large handling rates for loading and reclaiming throughout the operation which leads to operating economies by high throughput.

The stacking and reclaiming rates influence the capacity of the whole storage installation.

2.2.2.3. Links with Inland Transportation System

The inland transportation characteristics which have to be taken into consideration when designing appropriate equipment for the yard area include:

a) unloading:

- for rail wagons and trucks: unloading pits with reclaiming equipment (belt or chain conveyors, hoists, etc);
- pneumatic equipment for specialised vehicles (for cereals and cement);
- for barges: grabbing cranes or gantry cranes, bucket hoists, shovel wheels and pneumatic equipment.

b) loading:

- for freight cars and trucks: hoppers supplied by belt conveyors provided with weighing system;
- for barges: grabbing cranes and gantry cranes and continuous handling equipment with belt conveyors.

2.2.3. Oil Terminals

This terminal type depends on the sizes of the tankers to be accommodated and whether for loading or unloading.

A 150,000 dwt crude carrier is on average 320m long with 45m beam and 18m draught. Some ships are larger in order to reduce the draught and others have been built in narrow docks and therefore have a relatively large draught with narrow beam.

Crude carriers characteristically have low power/displacement ratios and also have considerable inertia, restricted manoeuvrability and generally require tugs for berthing.

The berthing and mooring facility can be floating or fixed. The choice between the solutions depends on the local and operating conditions:

1. single buoy mooring systems (S.B.M.). See Figure 8.
2. jointed column mooring systems
3. multi-buoy mooring systems (M.B.M.)
4. fixed mooring towers
5. traditional berths with loading platform, mooring and breasting dolphins and shore connection (Figure 9). These are the only installations which can provide the ship with the required services (water supply, bunkering, tank cleaning, crew exchange, etc.) in favourable conditions. However, for smaller ports, S.B.M's may form a cheap and therefore attractive alternative.

Tug services are not normally required for oil terminals with S.B.M. but tugs may be necessary with M.B.M. and are essential for traditional berthings.

The number and power of the tugs depends on tanker size and local conditions (swell, wind, current). For the oil tankers up to 100,000 dwt, four 1200 - 1500 hp tugs are generally sufficient. For larger tankers, six may be appropriate. Satisfactory coordination between tugs is difficult if more than six are used.

As large crude oil carriers are very expensive, it is necessary to try to reduce the call time as much as possible and hence the oil handling system is a major element in oil terminal design.

The oil unloading operations are carried out by ship pumps with the oil loading operations by the land pumping station. The pumping rate should limit total turn-around time to 1 to 1.5 days.

Oil and oil products are stored in tanks surrounded by bund walls at such distances that the full contents of the tank can be contained within the bunds. For example, a 100,000 cu m tank typically would have 5m high bunds (4m effective) around an area 160m by 160m thus providing 25,000 sq m storage space.

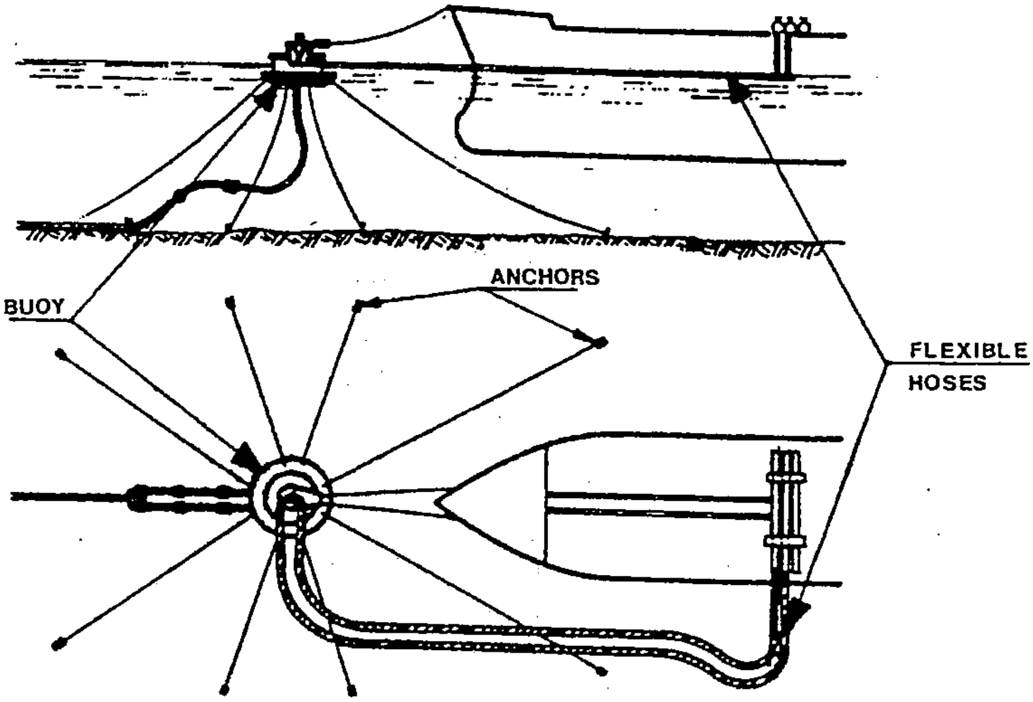


Fig 8 S.B.M. SYSTEM

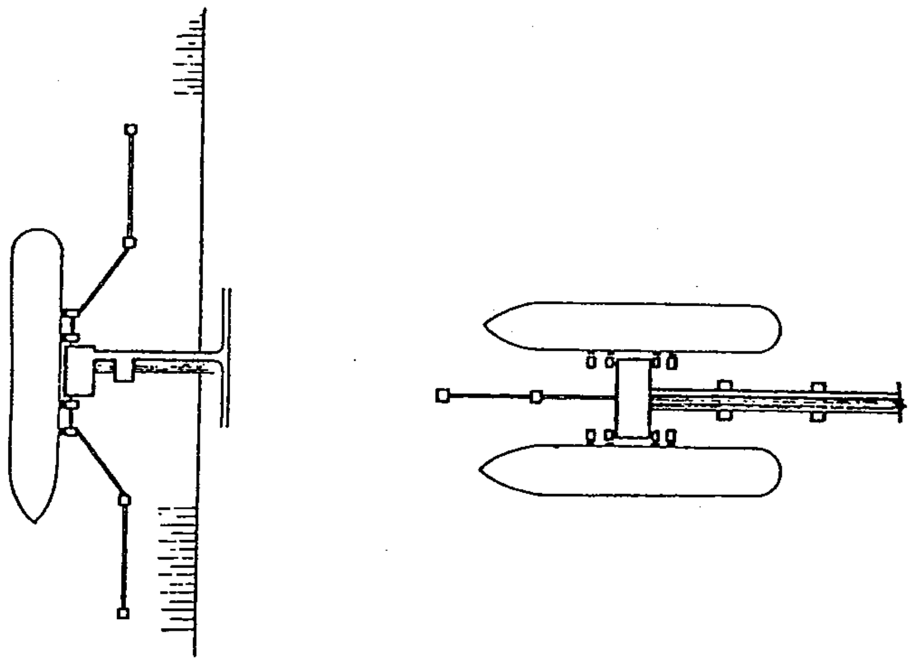


Fig.9 TYPES OF LIQUID BULK JETTIES

To combat pollution in oil terminals, preventative measures and equipment to control accidental leakage are required. The preventative measures include robust and well designed equipment and controlled discharge of storm water run-off and spillage via an oil interceptor, regular maintenance and automatic shutdown with safety devices in the main links between the oil carriers and the storing tanks.

The prevention of pollution is made easier by concise operational rules and checklist procedures, applied by well trained personnel who are supported by an effective communication system.

If accidental pollution does occur, the leakage has to be contained with protective booms and barriers. If they are not systematically set up before every handling operation, they should be deployed extremely quickly. The oil slick should be then removed by pumping. To complete the cleaning of the water surface, biodegradable chemicals may be spread if they are not harmful to flora and fauna.

Fire risks are a particular hazard at oil terminals and may be accentuated when booms are deployed. Well designed fire prevention measures and fire fighting drills must be established before the terminal becomes operational.

If the oil terminal traffic is heavy, the berths should be provided with tank cleaning and degassification equipment which should separate the oily waste for disposal. A traditional shore connected berth is very suitable for meeting these needs.

2.2.4. LNG/LPG Terminals

The LNG/LPG terminal design should comply with very stringent safety rules.

A LNG/LPG carrier is larger than a conventional carrier for the same dead weight, and carries tanks in which the LNG/LPG is maintained in liquid form at a very low temperature. The LNG density is around 0.5 and the LNG/LPG carrier has a shallow draught and high superstructure.

A 125,000m^3 LNG/LPG carrier has a deadweight of 65,000 dwt, is 280m long with 42m beam and 12m draught.

In order to undertake a satisfactory design for a LNG/LPG terminal, the following constraints must be taken into account:

- because of the high ship superstructure, it is extremely important to take into account the dominant winds when planning the berth orientation.

- due to the high cost of cryogenic pipework, the storing tanks should, wherever possible, be built, in the immediate vicinity of the berth

- the design should take into account the types of risk which might affect an area of several kilometres around the tanks.

Due to their high superstructure, the LNG/LPG carriers are very susceptible to winds and require tugs for port manoeuvres.

The berthing and mooring systems are of the same type as for oil carriers of comparable size.

The handling system for LPG and LNG consists of articulated cryogenic loading or unloading arms between the ship manifolds and the insulated pipes connecting to the inland tanks.

Pollution by the gas is dangerous because of the explosion risks. LNG/LPG terminal operations are extremely hazardous and require detailed study by specialist safety staff. This applies even more to LPG as the vapour is heavier than air at normal temperatures and tends to form a wide spreading blanket. Moreover, LPG is considerably more explosion prone.

2.2.5. Ore Terminals

An ore terminal requires more sophisticated equipment than an oil terminal: the handling and transportation equipment is very heavy and the loading and unloading systems are different. Typical ore terminals are illustrated in Figures 10 and 11.

The longer the transportation distance, the larger the optimum ship size. 150,000 dwt ore carriers are about 290m long with 42m beam and 17m draught.

Combined bulk carriers (OBO: Ore-Bulk-0il) are expensive to construct but may be economical to operate on some transport routes.

If several berths are projected, an 'L' shaped terminal layout may be suitable; one leg is the access trestle, the other the first berth. A second berth can be added to form a 'T' layout.

The ore terminal capacity depends on the handling rate of the equipment. As the ship size increases in order to reduce the maritime transport cost, so the handling equipment capacity must increase to reduce the ship's call time.

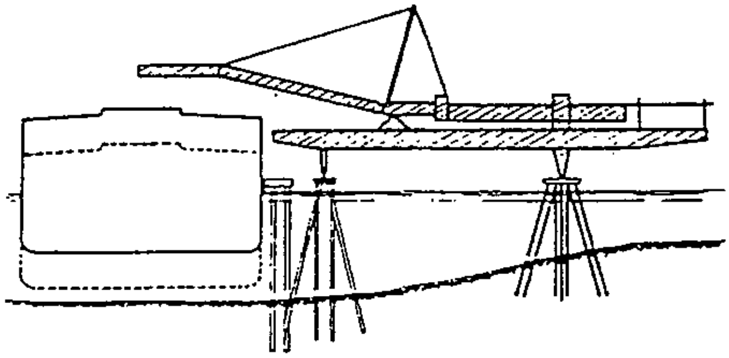
The loading point requires simple berthing and mooring installations and a fixed structure to support the loading equipment.

The loading rate may be high, as the ships are loaded by gravity and the loading operation can be carried out continuously by a belt conveyor running between the storage area and the berth.

Continuous loading equipment may be rail mounted gantry loaders or swivelling or linear swivelling loaders.

Ore carriers are loaded from quays or jetties, the length of which is around the effective length (distance between extreme holds) of the largest ship to be accommodated and the width is about 20m. The choice between quay and offshore berth is related to local conditions.

Unloading rates are less than those for loading especially towards the bottom of the hold, (see Figure 12).



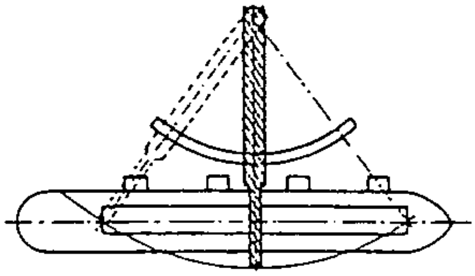


Fig 10 ORE LOADING TERMINAL
SWIVELLING LOADER

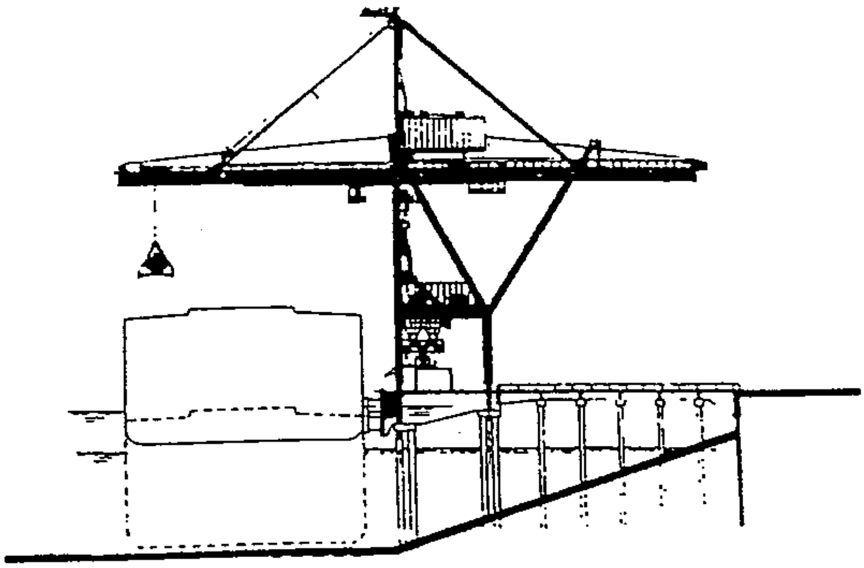


Fig 11 ORE UNLOADING TERMINAL

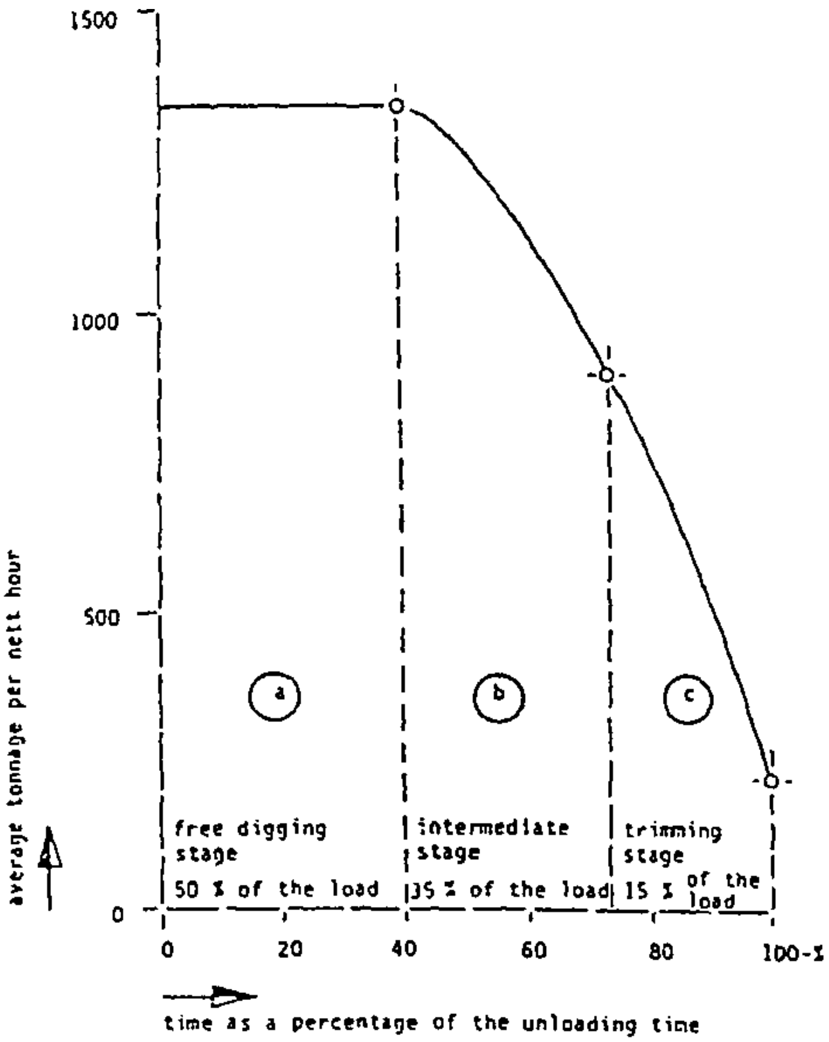


Fig. 12 Unloading capacity as a function of unloading time.

Unloading equipment is provided either with grabs (multi-purpose and flexible) or with shovel wheels (continuous operation). In some smaller ports, unloading equipment may also be converted to container handling in order to introduce additional flexibility to the port. Special equipment is needed to complete the unloading of holds.

In specifying equipment, capacity distinction is made between peak capacity, rated capacity and effective capacity:

- The peak capacity is the maximum capacity that can ever be attained and serves to dimension the down-stream system (conveyor belts, stackers).

- The rated capacities or free digging capacity is based on the cycle time of a full grab under average working conditions.

- The effective capacity is the average capacity over the full loading or unloading cycles of the ship and is the main parameter for port planning.

For unloading ships by grab the peak capacity is generally twice the effective capacity.

Transport between quay or jetty and the stockyard is carried out by belt conveyors, the capacity of which must be consistent with the peak capacity of the loading/unloading equipment.

The stockyard, the area of which depends on the berth capacity and ship traffic, is stocked by discharge conveyors on jibs which can be suitably orientated. The reclaiming operation is carried out by conveyors located in ducts, shovel wheel reclaimers or gantries spanning the stockpiles.

It is desirable to separate the cargo transfer operations between ship and shore and the inland transportation system. Direct ship loading/unloading from and to rail wagons would require large storage capacity in the mine or close to industrial plants and many wagons in the port.

Care must be taken to avoid spillage and contamination of the water and seabed during the transfer across the quay face. This can be achieved by suitable design of the handling equipment and its shrouding.

Dust is also a major problem; each time ore on a conveyor belt has to be transferred to another belt, there is dust generation which can be absorbed by dust extractors. The conveyors can also be protected by hoods,

Corrosion of the equipment is always a risk in a marine atmosphere and can be accentuated by chemical action or abrasion by some ores. Constant attention to maintenance (cleaning, greasing, painting) and a suitable choice of materials are the best means to combat equipment deterioration.

The maximum angle for the conveyor or belt slopes is not the same for all the ores and the different characteristics of the materials to he handled may limit the dry bulk handling equipment versatility.

2.2.6. Grain Terminals

The ship loading and unloading is carried out by pneumatic equipment, chain conveyors, endless screws and loading spouts on fixed or mobile gantries on the quay, or on floating pontoons.

The same gantry may support different equipment supplied by reversible horizontal conveyors.

Elevators can deliver at a rate of 500 tonnes/hr and the sucking systems at a rate of 1,000 tonnes/hr.

The grain is stored in silos or sheds linked to the quay equipment by belt or chain conveyors. Controls are required to prevent overheating and provision made for dust extractors, weighing. etc.

The silos or sheds may be well away from the berth (quay or jetty) if adequately linked with the berth by conveyors. This may permit occupation of areas unsuitable for other traffic.

2.3. GENERAL CARGO TERMINALS

2.3.1. Break Bulk Cargo

On quays assigned to break bulk general cargo, goods in different forms such as cartons, packing cases, drums, sacks, pallets etc. can be handled.

The ships which transport this general cargo, which is not containerised, are rather small and of the freight type. For example, a 20,000 dwt freighter is 160m long with 24m beam and 10m draught. These ships are generally equipped with derricks for loading and unloading their cargo.

There are two methods of cargo handling - direct and indirect loading. In the first method the goods are directly loaded on board from wagon, truck or barge, without passing through a transit area. Such an operation is attractive but experience shows that it is difficult to organise efficiently. The second handling method is generally more efficient wherein all the goods pass through the transit areas. This requires transit sheds, open storage areas and handling equipment, of which the most adaptable is the forklift truck.

2.3.2. Container Terminals

2.3.2.1. Container Terminal Characteristics

The development of containerisation revolutionised the technology and organisation of maritime transport. An example of the layout of a container terminal is shown in Figure 13.

Ports can receive containers transported by conventional ships moored at traditional berths and container loading and unloading can be carried out by ship's gear, floating cranes or heavy duty mobile cranes.

All these processes are acceptable if the container throughput is low or during a starting-up period. However, the operational cost of container ships is very high and long delays cannot be permitted. Ports which receive significant container traffic (upwards of say 40,000 TEU per year) should develop specialised installations in order to accommodate the container ships and to handle and store containers.

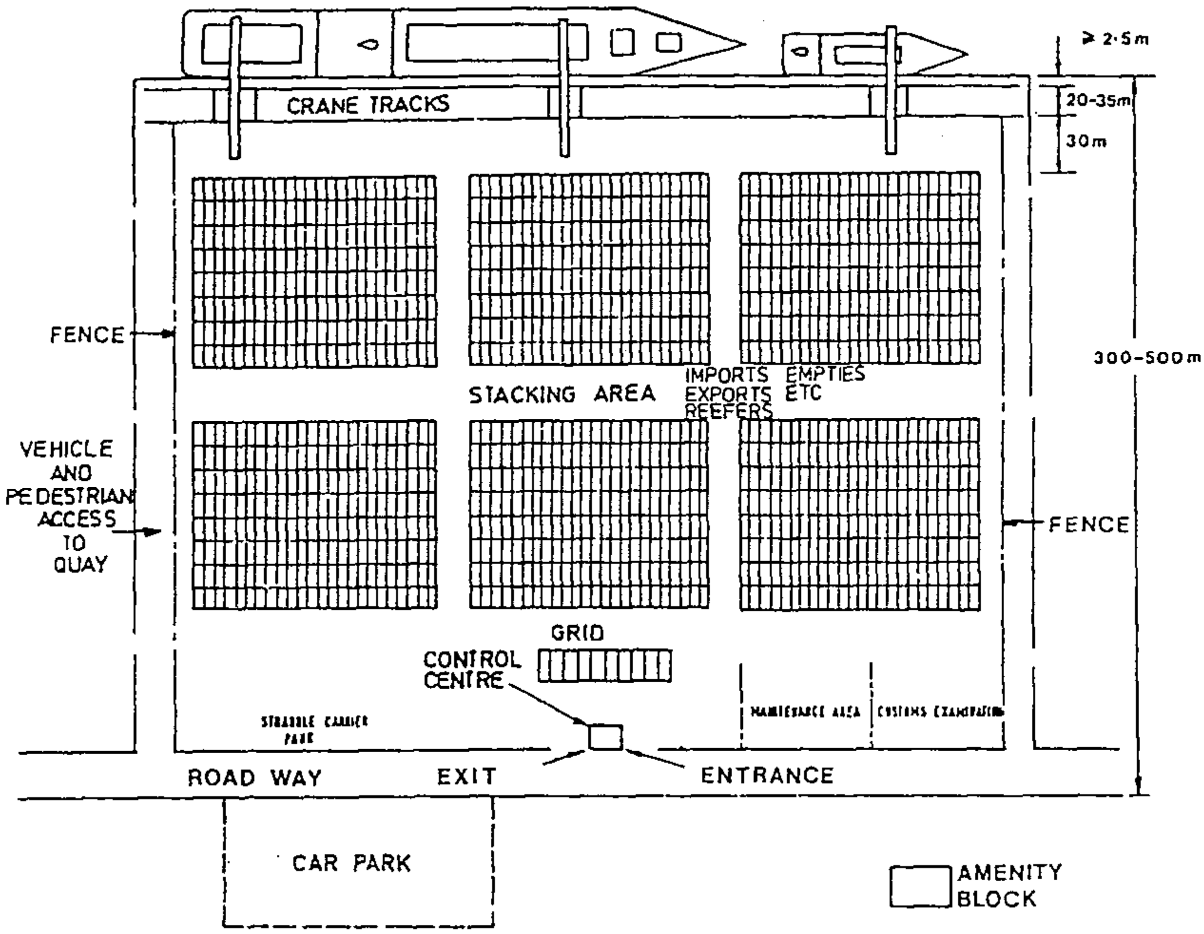


Fig.13 Layout of container terminal

2.3.2.2. Container Ships' Characteristics

Shipping containers are conventionally described according to their size in Imperial Units. The most common containers are 40 feet (about 13m) long, 8 feet wide and 8 feet 6 inches high (86 cubic metres, 34 tonnes) and 20 feet long (24 tonnes). The number of containers in any consignment is typically expressed in TEU (Twenty feet Equivalent Units)

The capacity of a container ship is also expressed in TEU. Container ships are classified in 4 generations corresponding to increments in the range of ship sizes. The first generation ships can transport up to 1,000 TEU. Their size is in the same size range as that of conventional ships. The second generation ships can transport up to 1,800 TEU, the third generation ships up to 3,000 TEU and the most recent fourth generation have a capacity of 4,000 TEU and more. The Ship Trends Committee of IAPH regularly reports on the latest developments in container ship design. Ships of approximately 7,000 TEU capacity are already in service.

The characteristics of particular container ships tend to reflect economic conditions and their effect on the shipping line as well as the nature of the service in which the ships operate. It is possible to specify three container ship categories:

- feeder ships which distribute and collect the containers in the ports which are not provided with specialised handling equipment.

- transocean ships, the size of which increases with the traffic and journey length;

- dual purpose ships able to transport both containers and other goods. They are generally provided with a ramp for ro-ro operation and sometimes with unloading equipment.

2.3.2.3. Terminal Type Choice

Terminals for container ships should service the ships as quickly as possible. It is necessary that:

- the ships do not wait for berthing and that the mooring facilities can be quickly reached;

- the container ships' handling operations are carried out on a 24 hour basis throughout the year;

- wide stacking areas are available, provided with excellent road and railway connections.

The terminal site choice must take into account:

- the draught of the largest ship to be accommodated;

- the forecast traffic. The necessary quay lengths and the open stacking area requirements often prevent conventional break bulk berths from being transformed into container berths;

- inland access potential (roads and railways or inland waterways) and the timescale for its development;

- protection against the dominant winds (container ships have a large profile above the water level) and against waves (container handling requires accurate positioning);

- the soil conditions (the loads are heavier than for a conventional quay).

The open area for stacking should be located where possible immediately behind the quay, the loading and unloading operations requiring the continuous length of the quay.

Container crane installations (see Figure 14) should be designed in conjunction with the quay itself because the handling gantries introduce very heavy loads (vertical loads due to gantry weight and horizontal loads due to winds).

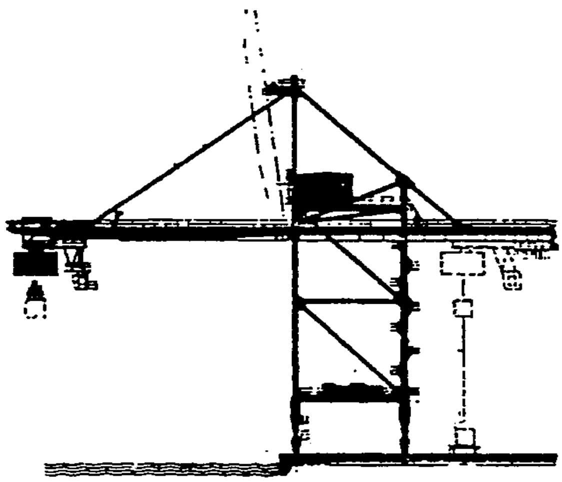


Fig. 14 CONTAINER CRANE

The average length of berths for large container ships should be 250-300m (150m for feeder ships). If several berths are required, it is preferable to build them in line in order to allow the cranes to work on any berth.

The development of dual purpose ships provided with end ramps introduces ro-ro traffic which may require a shore ramp at the quay extremity or a moveable floating platform.

Container traffic requires a large stacking area and a well controlled operational organisation. The necessary area depends on the traffic, whether space has to be provided for a Container Freight Station (CFS), the handling equipment, the adopted stacking height (containers stacked 1 to 5 high) and the average dwell time. In practice it is often found that loaded import containers are best stacked not more than 3 high for effective handling.

Generally, the more concentrated is the stacking, the more sophisticated should be the management control and the more expensive is the handling equipment (high lifting height).

The stacking area cost should always be taken into account in the economic studies, as it is often as important as the quay cost.

The container crane cost is high and conventional handling solutions should be adopted if the traffic level is low during starting up period.

A container crane can handle 15 to 25 containers/hour on average and 40,000 to 60,000 containers/year. The choice of crane size depends on the ship sizes and the operational conditions. The number of container cranes, which depends on the forecast trafffic, is proportionally greater for a smaller number of berths.

2.3.2.4. Terminal Operation

The terminal efficiency depends as much on the organisation as on the equipment.

The location of each container in the stacking area should be known at any time. The ship loading operation should take into account the order in which the containers will be unloaded in the destination port, the container weight (in order not to jeopardise the ship's stability) and the container contents (hazardous cargoes should be carried on the main deck and not in the holds).

Data processing systems simplify the ship loading preparation and the handling organisation.

Specialised installations and the appropriate handling equipment are necessary for a large scale container operation, but sophisticated port infrastructure is not sufficient because the results depend largely on the efficiency of the human resources.

In planning a port of call for container ships many operations are involved and detailed analysis between them is necessary to ensure operational efficiency.

If a decision is made to invest in a container crane, then it is essential that the handling operations in the stacking area adopt a rate in keeping with the performance of the crane.

2.3.2.5. Terminal Planning - Quay Cranes

The conceptual plan for a container terminal should define the type of cranes to be used (gantry, mobile, luffing, ship gear etc.). Where gantry quay cranes are to be deployed, the type of gantry quay crane (feeder, panamax, post-panamax, super post-panamax) should be determined based on the design vessel dimensions. Any decision in this regard should also take into account quay and channel water depth and marine manoeuvering limitations, as well as quay load limitations.

An initial estimation of the required number of cranes should be made (rule of thumb for gantry cranes: one gantry per 50,000 container movements per annum, one gantry per 100 metres of quay).

A simulation of quay performance should then be conducted. The simulation should consider total forecasted traffic levels, as well as visit frequency, vessel size and lifts per call by line. Crane allocation policy based on vessel size and lifts should be set. Crane productivity levels should also be set.

The simulations should compare performance results for varying numbers of cranes based on the quay length, productivity assumptions and anticipated traffic. The performance results to be compared include the following indicators:

1. mean quay utilization (average percentage of quay length occupied by vessel over set period of time)
2. ship queuing (percentage of time that at least one vessel is waiting for berth)
3. mean ship quay time (average total vessel time at berth).
4. mean ship waiting time for berth, mean total ship time at port (including waiting and berth time)
5. mean number of cranes utilized.

The final number of cranes required should be set following comparison of the performance results.

General crane operational performance requirements should also be outlined. This can include outreach, clearance parameters, lift capacity, twin-lift features, double trolley, speed and acceleration characteristics, etc.

Based on the number of cranes and expected traffic, the number of required traffic lanes between the legs of the crane should be defined. The number is generally between four to seven lanes.

The length between the seaside crane rail and quay edge should be defined based on need. For example, if only operational traffic will be allowed between the crane legs, then at least five metres must be set aside between the crane rail and quay edge for maintenance traffic and ship servicing. On the other hand, if this traffic can use the area between the legs, as little as 1.5 metres between the crane rail and quay edge may be sufficient. Fender width should also be decided in order to allow final determination of required outreach.

Area behind the landside rail should be allocated for the landing of hold covers. This requirement will vary based on the expected ship mix. Additional traffic lanes may be required behind the landside rail. The operational concept may also call for pre-staging export containers adjacent to the berth of an arriving vessel. If so, area will have to be allocated close to the quay for this purpose.

With the above information, the quay layout can be prepared as the first stage of the total terminal layout.

2.3.2.6. Terminal Planning - Handling Concept

Some examples of handling and storage concepts include the following:

1st. Wheeled storage (trailer/chassis system): Containers are discharged from ship directly to trailers which are then pulled into the yard and parked with the loaded container. Road tractors entering the terminal connect the appropriate trailer and pull out without use of terminal equipment. After discharge of the container at the customer's site, the empty trailer is returned to the terminal for reuse.

Since terminal equipment is not required to load the container on the road truck, this is one of the most efficient handling concepts. On the other hand, this concept utilizes limited terminal port land inefficiently and requires a fleet of trailers, either owned by the shipping lines, trucking lines or terminal.

2nd. Top/side loaders and front-end loaders (Fork Lift Trucks FLT's): Containers are delivered from the quay on terminal trailers. Upon arrival at the appropriate point in the yard, the loader removes the container from the trailer and places it in the appropriate stack. The loader is also used for delivering containers to/from road trucks.

3rd. Straddle Carrier: Containers are discharged from vessel to the quay. The straddle carrier picks up the container from the quay and delivers it to the storage area where containers can be stacked two to three high based on the straddle carrier design. In order to deliver a container to a road truck, a straddle carrier removes the appropriate container from the stack and travels with it to the road truck loading point where it lowers the container onto the truck.

This alternative allows for the stacking of containers, thus improving utilization of terminal area. However, the main advantage of this concept is that the quay operational bottleneck created when gantry cranes wait for terminal trucks is eliminated.

This results in higher productivity levels both at quayside and in the terminal since double handling is eliminated. The separation of road truck traffic from terminal traffic reduces congestion in the yard, leading to higher productivity levels. On the negative side, straddle carrier traffic presents certain safety concerns that must be addressed by safe work practices.

4th. <u>Rubber Tyred Gantry (RTG):</u> Containers are delivered from the quay on terminal trailers. RTG's then lift the container from the trailer and placing the box in a stack. The reverse takes place when delivering containers to road trucks.

The RTG option allows for further improvement in area utilization since containers can be stored four or even higher. The RTG also affords additional flexibility over the RMG in that it is easily moved from stack to stack to meet handling peaks at various points in the container yard.

5th. <u>Rail Mounted Gantry (RMG):</u> The handling process is similar to the RTG.

The principal advantages of the RMG are:

1) easier to automate movements.
2) higher stacking can be accomplished
3) safer operations since the crane moves along a fixed rail.

Since RMG's operate on fixed rail, a terminal is unable to move the equipment from stack to stack to handle peak demands. RMG's also cost considerable more than the previously mentioned equipment.

6th. <u>Bridge Crane:</u> Similar handling to RMG, although straddle carriers can be used to transport containers from quay to stack, thus eliminating the quay operational bottleneck. The bridge crane also affords the flexibility of the RTG since the crane section can be moved from stack to stack using a cross bridge. Because of the required bridge structures, this concept is quite costly.

Hybrid concepts are also possible such as the use of automated guided vehicles instead of terminal tractors in the RTG, RMG or bridge crane alternative.

Once appropriate handling concepts have been identified, some general characteristics need to be defined. This can include:

1. stack width (for example, RTG stack widths generally are six or seven containers wide)
2. stack height (for example, straddle carrier stacks are generally two to three containers high, RTG stacks four to five containers high and bridge cranes can

stack as high as 9 containers high)

3. number of traffic lanes required in the stacks and their dimensions, etc.

The advantages and disadvantages of some of the different forms of equipment can be summarised as follows:

Advantages	Disadvantages
Trailer (chassis) system	
- simple equipment	- very low degree of land utilisation
- simple organisation	- high investment in trailers
- low maintenance cost	- difficult to absorb peak loads
- no highly skilled operators required	- automation impossible
- cheap infrastructure	
- flexible operation	
Fork Lift Truck system	
- excellent for handling empty containers	- high pavement costs if used for loaded containers
- simple organisation	- fair degree of land utilisation
- relatively cheap and simple to maintain	- accident prone if used in conjunction with other transport and handling equipment
	- relatively low handling capacity
	- automation impossible
Straddle-carrier system	
- high degree of equipment utilisation possible	- complicated equipment
- fair cost of infrastructure	- maintenance requires highly skilled labour and is relatively expensive
- reasonable degree of land utilisation	- automation impossible
- high throughput and able to cope with peak loads	
Rubber Tyred Gantry	
- good land utilisation	- relatively high costs of infrastructure
- high degree of equipment utilisation	- relatively high maintenance costs
- relatively low investment in equipment	- highly skilled maintenance staff and operators required
- simple organisation	- safety requires close attention
- can be automated but not easily	
Rail Mounted Gantry	
- maximum land utilisation	- high investment costs in equipment and infrastructure
- good reliability	- fair throughput capacity
- low maintenance costs	- no flexibility in respect of layout changes
- medium skilled operators	- safety requires close attention.
- automation possible	

2.3.2.7. Terminal Layout

Based on average dwell time and expected annual throughput, the average daily container storage requirements should be calculated. The average requirement should be adjusted to cover peak requirements.

Once peak requirements have been defined, the length of storage stacks should be calculated based on the stack dimensions. Since stacks can never be utilized to 100% of capacity, the stack length requirement should take into account optimum utilization levels. (For example, optimum utilization levels for imports may be 80% of stack capacity and exports may be 60% of stack capacity based on the need for shuffling when digging out containers for delivery to ship or truck).

Alternative terminal layouts can now begin to be developed integrating the quay layout developed earlier together with required storage stack length and traffic lanes (see following section).

2.3.2.8. Traffic Planning

Traffic schemes should be developed between the major intercity and urban thoroughfares and the port gate, with the goal of minimizing disruptions to regular city traffic and delays to port traffic.

Similar schemes should be developed between the port gate to the container yard, between the container yard and operating quays and the container yard and intermodal yard.

Standards for lane widths and striping should be set for various types of roads (urban, port access roads, main port roads, secondary port roads, container stack lanes, intermodal yard lanes, single directional, bi-directional etc.) If queuing or parking areas are required alongside the roads, appropriate standards should be set for such areas.

Preference should be given to safer single directional traffic. Where bi-directional traffic is required, the use of island barriers between bi-directional traffic can enhance safety. Where the use of islands are not feasible due to cross-section limitations or traffic requirements, striping should clearly define allowable traffic flow.

These schemes should consider peak traffic volumes in order to determine the number of required lanes. If non-containerized traffic will also use the road, this traffic should also be considered in setting the required number of lanes.

For the most efficient traffic pattern, generally speaking container stacks based on RMG's, RTG's, FLT's, wheeled storage and bridge cranes should be designed parallel to the primary quay.

Container stacks serviced by straddle carriers should be designed perpendicular to the primary quay.

If an intermodal yard is to be included, the number and length of rail tracks needs to be set considering expected traffic, handling productivity and hours of operations. Once the number and length of required track is set, the yard needs to be located in a position which allows efficient traffic patterns between the yard and container stacking yard and quay, and, yet at the same time, does not overly interfere with other traffic patterns.

2.3.2.9. Support Structures

Structure requirements need to be defined. These requirements can include:

1. Administrative Offices
2. Marine Operations Offices
3. Maintenance Facilities
4. Infrastructure Facilities (Electrical Substations, Pumping Stations, Communications Centre, etc.)
5. CFS Warehouses
6. Employee Facilities (cafeteria, rest rooms, locker rooms etc.)
7. Gate Facilities.

A functional program should be developed for each structure in order to estimate required floor space. The dimensions of the building footprint should be formulated and the proposed location allocated in the terminal layout.

2.3.2.10. Simulation and Comparison of Alternatives

Once alternative terminal layouts have been developed for the alternative handling concepts, operational simulation of the alternatives should take place. Service levels to be checked by the simulations should be defined. These service levels could include, for example, quay crane productivity rates, road truck turnaround time, intermodal train turnaround time, amongst others.

The simulations should be based on forecasted gate/intermodal/ship traffic, traffic pattern policy, productivity levels of various types of equipment, stack allocations for various types and sources of traffic, hours of operation, equipment movement rates, etc.

Each of the alternative terminal layouts should be simulated a number of times until the optimum quantity of each type of equipment is defined. Consideration should be given to peak requirements, as well as normal equipment requirements, and maintenance replacements.

The simulation results for the various alternatives should be compared based on the follow factors:

1. Stevedoring productivity vs. target
2. Truck turnaround time vs. target
3. Intermodal yard productivity vs. target
4. Throughput capacity vs. target
5. Cost per lift (including capital investment costs, operational costs and maintenance costs of each of the alternatives)
6. Capital investment costs (up-front investment)
7. Labour requirements.

Additional non-quantitative comparisons can be made of the various alternatives, including:

1. Flexibility in the event of breakdown
2. Worker safety
3. Potential for future capacity improvements

4. Suitability for future automation
5. Compatibility with existing systems
6. Training requirements.

Following consideration of the above factors, the number of alternatives can be narrowed and further refinement of layouts and equipment levels can be considered and simulated until an optimal alternative is identified for implementation.

2.3.3. Ro-Ro Terminals

Ro-ro ships load or unload goods on wheels (roll on-roll off). Docks with constant water level are particularly suitable for these handling operations.

There are two main ship categories:

- complete ro-ro ships (car ferries, ro-ro cargoes and container ro-ro);

- dual purpose ships which are container ships provided with equipment for horizontal handling of part of the cargo (ro-lo).

These ships are provided, according to their traffic, with access ramps which are located fore, aft or on the ship side.

In cases of double specialisation, a terminal may be provided with yard areas for ro-ro and lo-lo traffic.

2.3.4. Ferry Terminals

2.3.4.1. General Planning Criteria

Ferry terminals are required to receive ferry ships, which primarily transport passengers and vehicles, but also some cargo. The terminals are to facilitate the transfer of passengers and vehicles between ship and inland routes.

The ferry ships expected to call at the terminal provide the most important criteria for the planning of the terminal. A projection of ships in this respect should cover at least a period of 10 to 20 years; by nature such a projection is difficult and uncertain. From such a projection, however, the following criteria have to be derived: length overall, width, draught, water displacement, vehicle transfer system, passenger transfer system and cargo transfer system (if any). Not only maximum parameters in this respect are important, but also minimum and consequently parameter ranges shall be specified.

In the transfer of vehicles and cargo (if any) between ship and shore and vice versa, the following systems may be distinguished:

- side way roll on/roll off
- side way lift on/lift off
- bow (or stern) roll on/roll off.

Each of the three systems calls for specific facilities in terms of berthing, ramp and quayside transfer equipment.

The number of passengers and vehicles to be moved through the terminal per day or part thereof, depends on the capacity of the ferry ships and the number of calls.

The economics of operating especially large scale ferry services call for fast transfer of passengers and vehicles. Consequently, high capacity transfer systems will be foreseen in the ferry design and the terminal facilities will have to match the high capacity and efficiency.

It has been mentioned before that the most uncertain criteria of the terminal is the number and capacity of ferry ships to be expected during the terminal's life time. Due to this uncertainty, a maximum of operational flexibility should be incorporated in the terminal elements affected by this uncertainty.

Therefore, the successful planning of a ferry terminal may be measured by the operational flexibility that can be incorporated in terms of accommodation of a wide range of ferries. Accommodation of a wider range of ferries will consequently affect the berthing facility and the capacity to move vehicles and passengers through the terminal. The flexibility should either be provided for at the time of initial construction or, otherwise, options for later implementation at reasonable cost should be kept open.

2.3.4.2. Detailed Terminal Planning Criteria

On the basis of the general criteria, the inferred requirements of the terminal will have to be formulated. Normally the following elements will have to be studied and the detailed criteria thereof to be determined:

(i) berthing facility
  (a) berthing manoeuvre
  (b) ramp for Ro/Ro
  (c) waterfront structure (incl. mooring, fendering, scouring of harbour bed)
  (d) gang way

(ii) parking facilities

(iii) service facilities
  (a) land access and gate
  (b) passenger terminal building

Expansion of the total terminal and also of components thereof should be studied and options in that respect kept open as much as possible.

(i) Berthing Facility

(a) Berthing Manoeuvre

The entry and departure of ships into the harbour should be safe and well controlled especially under adverse weather and sea conditions. The manoeuvring towards the berth should be convenient and safe taking into account other ship movements and activities in the harbour.

A special fender guiding system should normally be provided to bring front (or stern) loading ferries exactly in their designated position.

The berth should be well protected from seas and swell and in an area without currents.

(b) Ramp for Ro/Ro

For Ro/Ro ferries ship ramp(s) are either provided at the side or at the front or stern. These ramps are movable and normally vertical when sailing and horizontal when in port.

Standardization of ship's ramps above the waterline has been pursued by the relevant authorities in order to facilitate the definition of design levels of fixed and movable terminal ramps. Modern ferries have ample ballasting capacity to adjust the occasional difference in height between waterline and ship's ramp.

Fixed and movable ramps (sometimes referred to as 'link spans') may be single deck or double deck.

Fixed ramps are normally provided at the terminal's waterfront when the vertical tidal range is only small (say 0.5 - 1.0m). Movable ramps are provided when the tidal range (due to sea tides and also river water fluctuations) is larger than say 1.0m. The length of the ramp is determined by the tidal difference and a maximum inclination of the ramp (1:7 or less).

(c) Waterfront Structure

Waterfronts at and adjacent to the berth may either be vertical quay/wharf structures or protected slopes.

Vertical waterfront structures should meet the normal requirements of stability, durability, mooring facilities, fendering, etc. The height should be non-flooding in extreme circumstances or lower for practical reasons of (un)loading, in the latter case a non-flooding embankment (or barrier) should be provided further in shore.

Due to ship propeller action, harbour bed material may be scoured depending on the consistency of bed material and location relevant to the propeller(s). Adequate bottom protection may be required for stability of quay/wharf.

Protected slopes should be provided with mooring bollards and dolphins where appropriate.

Fender systems at the front of front-end loading ferries should be designed for the absorption of substantial energy. Also the adjacent fender guiding system calls for special care.

(d) Gangway

Facilities for embarkation and dis-embarkation of passengers should be made through movable gangways, fixed walkways, etc., of adequate capacity.

(ii) Parking Facilities

Sufficient open area adjacent to the berthing facility should be planned for temporary parking of vehicles (passenger car, bus, truck and wheel based cargo). Areas should be laid out for peak loading during a disruption of the transport system. Adequate utilities, like drainage, lighting, fire fighting etc. should be provided when undisturbed and continuous operations are foreseen.

(iii) Land-based Service Facilities

(a) Land Access and Gate

The ferry terminal is normally a fenced off area, in view of control by the terminal operator and possibly the custom authorities. Near the land access of terminal a gate house is likely to be operated for ticketing, inspection and control. Land access is most likely by road, but also rail access is possible.

(b) Passenger Terminal Building

The size and the capacity of a passenger terminal building should be in compliance with the planned peak capacity. A variety of services may be provided inside the terminal building: ticketing, immigration, customs, information, restaurant/cafeteria, shops, tax-free shops, official rooms, security checks, travel agencies, public telephone booths, etc.

Outside the terminal building, planning should allow for taxi stands, bus stops and any other facility.

2.3.5. Multi-Purpose Terminals

In ports where the existing traffic does not reach sufficient volume for assigning a berth for each transportation system (containers, ro-ro, general cargo), a multi-purpose terminal can be planned (Figure 15).

Such a terminal is usually equipped at least with a container crane for quick container handling, conventional quayside cranes for general cargo and a ro-ro ramp at the quay extremity.

The layout of the storage in the open area should be planned in relation to the traffic. One or two sheds behind the storage area can shelter the general cargo and the container stuffing and unstuffing operations.

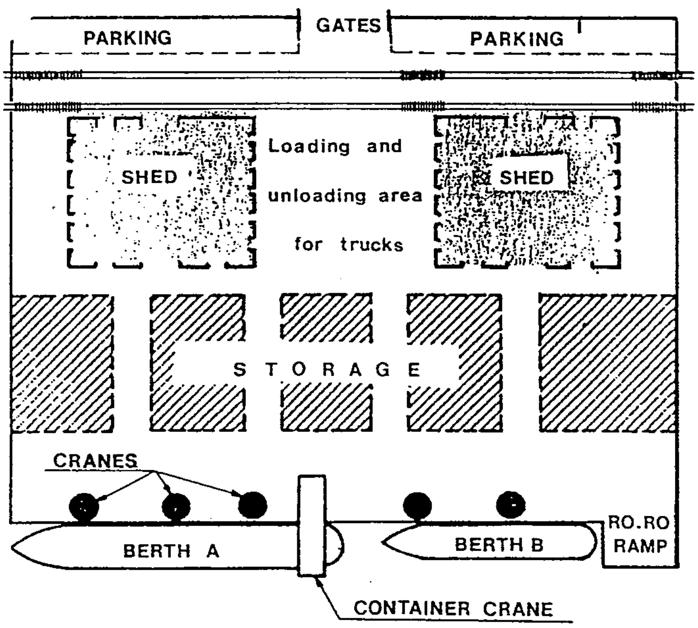


Fig.15 MULTIPURPOSE TERMINAL

2.3.6. Cruise Shipping Terminals

From the cruise operators' standpoint, cruise terminals, whether they serve as a home port base for the cruise ship or a port of call must be:

- Functional
- Safe
- Clean

Cruise terminals that serve as a home port for the cruise ships have to serve many functions. Normally, a cruise ship docks in the morning, disembarks its passengers who normally are required to go through Customs, then takes on a load of new passengers in the afternoon and sails early that evening. Thus, the ship is in port for approximately 8 hours during which time the operators have to remove garbage, load stores, take on water and bunkers in an efficient manner, without interfering with the passenger loading. Bunkers are normally handled by barge on the outport side of the vessel.

At least three to four water connections are needed at the pier site with adequate pressure and line capacity. Adequate pressure is needed at the pier outlets to enable the ship to take on 1,200 tonnes of water in an 8-hour period through three to four hose connections.

Most cruise terminals service many ships at the same facility, e,g., a 7-day cruise normally leaving on a Saturday or Sunday, with 3- and 4-day cruises using the terminal on Fridays and Mondays or Thursdays and Sundays. A terminal with two 3- and 4-day cruises and one 7-day cruise, for example, would be used Monday, Friday, Thursday, Sunday and the 7-day cruise sailing on Saturday, that is a total of 5 days. Obviously, the cruise terminal should he designed for the largest ship envisaged.

Generally speaking, the older cruise ships have deeper draught up to 10 metres, with passenger capacity ranging from 800 to 1500 and lengths overall of 150 to 215 metres.

The new ships require less draught, normally 7 to 8 metres, with passenger capacities ranging from 2,000 to 3,000 and typical lengths overall of 260 metres. The newer type ship is longer and boxier with a much greater wind area requiring heavier shore bollards.

For ships in their home port, it is necessary to have adequate covered kerbside facilities for arriving passengers to off-load their luggage at the terminal. Luggage is taken by porters to the ship loading doors.

Passengers normally arrive by bus, car or taxi. Thus car parking for the duration of the cruise may be necessary. The parking fees are revenue producers for the port. Adequate protection and surveillance should be provided to ensure that the cars are not damaged and/or looted. The mix between car and bus traffic is dictated by local conditions.

In many cases, given the large capacity of cruise ships and the long distance from business areas, passengers are transported by plane. So, it is often absolutely necessary to have an international airport near cruise terminals. In this situation, the service to passengers and their luggage carried out by cruise companies starts at the airport, where it is thus necessary to have large functional zones reserved for these companies, as well as a fast connection with the cruise terminal.

A home-base cruise terminal area should be as attractive as economics permit and be fitted out with adequately designed rest rooms, ticket counters for cruise lines and Customs stations.

It should be air-conditioned or heated as the climate dictates.

The terminal serves two main functions. In disembarking, it is normal practice to place all the luggage in the terminal, colour coded by sections of the ship, prior to letting the passengers off. They then claim their baggage and go through Customs. On the embarkation cycle the terminal is used for passengers to fill out embarkation cards, turn in their tickets, obtain a boarding pass, arrange for early or late lunch and dinner sittings on the ship and other administrative functions.

The first function requires greater space and is therefore controlling. The most cost effective design combines both embarkation and disembarkation areas on one level, thus using the same space for both functions. The rule of thumb for this type of terminal for three and four day cruises is at least 9 square metres per passenger and, for 7-day cruises with an attendant increase in luggage, 11.5 square metres per passenger.

When it is necessary to design a facility so that there is a waiting area for embarking passengers while passengers are disembarking, at least a 50% increase in area requirements is necessary. This can be accommodated by having two levels; a lower level for disembarking passengers and upper level for embarking passengers.

A logistics area whereby stores and supplies may be stored with direct access to the pier is necessary to keep this function separate from the passenger arrival and departure gates.

There is no standard as to the location, number or height of the various ship hatches as regards stores, luggage and passengers. Luggage and stores can usually be handled by fork lifts and/or conveyors from the dock to the various ship hatches.

The gangways for passengers pose the more severe problem in that they may vary from pier level to 12 metres above the pier. Gangway types vary widely. However, they all must accommodate three-dimensional movement, for tidal range, wind and movement along the pier.

The two-storey building assists in getting the passengers up to the level above the pier and thus ships with high doors. Another method is using escalators on the pier. Additionally, provisions for handicapped persons using ramps and other ship hatches at pier level are necessary. Gangways range from sophisticated aircraft type to the simple stair type. However, careful, creative design is necessary to ensure safety and passenger comfort.

Terminals for ports of call need not be elaborate. A safe berth must be provided for the ship, a well-lighted area free of hazards as well as providing ready access for taxis and/or buses to accommodate passengers. The ship will normally use a lower door or side swing gangway for off-loading the passengers. In many cases, warehouses can be fitted out as port of call cruise terminals offering passengers gift shops, rest rooms, etc.

In the wake of the Achille Lauro incident, additional security for cruise terminals has been instituted worldwide. Adequate fences should be provided to secure the pier and access to the cruise terminals other than the main entrance. Ship security forces and landside security forces are needed to control all access points to the ship. Passengers may be required to go through security monitors and possibly handbag searches prior to boarding. Provisions for X-raying of baggage should be planned in any new facility and possibly will be required as a retrofit to older facilities.

2.3.7. Fishing Harbours

Fishing harbours must be considered separately from cargo terminals. Although both offer shelter, berthing space and loading and unloading facilities, there are few other similarities.

Fishing harbours are bases for fleets of vessels which usually arrive in large numbers within a short space of time. Their 'cargo' is not just offloaded but it is handled, sorted, marketed, processed, packaged, stored and transported, and it is a very perishable foodstuff. A harbour may be designed to handle 150 metre factory-trawlers or it may service fleets of artisanal canoes of several hundred. Fishing is frequently a community activity, often based on family units, and large numbers of people may be involved in offloading, sorting and handling, and provisioning the boats.

Harbour capacity is defined by fleet size and the number of boats which are likely to be unloading at one time. Fleets, by nature, target particular species and consequently work similar distances from port at similar times. As the marketing must coincide with landings and vice versa, large numbers of vessels are likely to appear within a few hours of each other. With seasonal or migratory resources, the fleet may include vessels from a wide range of home ports.

The vessels need to be accommodated at the fish quay which must be long enough to accommodate perhaps half the fleet at one time. By-catch or fish meal catch should be unloaded in a separate area.

Adjacent to the fish quay will be the auction hall, merchants' stalls, and trading offices, transport ramps and ice and box factories. Auction halls are large, clean areas, where fish is displayed, boxed or not, on the floor, for auction to merchants, processors or retailers.

After unloading, vessels need a secure area to berth until the next trip, to carry out repairs and to provision and bunker.

3. DESIGN OF PORT STRUCTURES

3.1. PRELIMINARIES

3.1.1. Design Philosophy

The great cost of maritime structures both in direct and in maintenance cost, has led to modification of the basis for their design in recent times. It is now accepted that the design should be related to the risk of failure under adverse conditions of given probability. The effects of partial failures are then balanced between savings in initial constructional costs and the likelihood of subsequent remedial works including the effect of the latter on port operations (see also Section 3.3.2.).

A structural design should be the most economical for immediate and possible future requirements having regard to:

- the planned life of the structure;
- adaptability to future change of use or extension;
- ease of demolition (particularly if short life is expected).

3.1.2. Quality

It is especially important in the severe conditions which exist in a maritime climate to adopt simple robust construction with careful detailing in the design to:

- ensure minimum maintenance during the planned life;
- avoid spalling of concrete and corrosion of steel;
- facilitate ease of construction and possible remedial works.

3.1.3. Port Engineering Standards

A number of engineering standards have been formulated in various countries of the world. Any of the accepted standards will serve as a starting point for the planning and engineering of port development activities, but allowance should be made for local conditions: temperature, winds, waves, materials, material degradation and attack etc.

Concerning general guidance for port development, a UN publication "Port Development, A Handbook for Planners in Developing Countries" is available.

3.1.4. Choice of Structure

The use of locally available materials should be considered and adopted where appropriate. For example, reinforced concrete structural frames may be preferred to steel if cement and reinforcing rod is manufactured locally, but structural steel sections have to be imported. When comparing the foreign exchange element of construction, it is important to consider the foreign exchange in the basic commodity price (e.g., for armour rock or aggregate, the foreign exchange in quarrying machinery, explosives and transport to site). Some governments will apply a subsidy to encourage the use of local materials or charge an additional import duty on goods for which a local substitute is available.

Many factors influence the choice between steel piles and prestressed concrete or reinforced concrete piles. Amongst the most important are:

- design requirements
- cost (having regard to the foreign exchange element)
- durability/maintenance.

Steel piles are more adaptable in use. With suitable choice of steel grade and thickness, effective protective coatings and with cathodic protection, satisfactory design life can be obtained. Precast concrete piles are relatively cheap but require careful handling (particularly if long) and are vulnerable to damage in the case of hard driving. Lengthening is costly and time-consuming.

3.1.5. Construction Methods

For competitive tendering, a degree of flexibility is desirable to enable the design to be adapted to make the best use of contractors' expertise and resources. If heavy lifting plant is readily available, large precast sections for quay soffits, jetty trestle beams and units in the tidal zone can lead to savings in time and cost. Conventional construction methods from land (including temporary land access) may be cheaper than those requiring extensive use of floating plant, cofferdams or divers. Hence diaphragm walls constructed before dredging or structures such as breakwaters and jetties built using 'end over end' methods may be attractive.

3.1.6. Programming

When expensive plant has to be employed, careful programming is required to take advantage of any natural or temporary bund protection from waves etc. to avoid delays or damage to partly completed structures in bad weather. Appropriate start dates and prior mobilisation to make best use of weather 'windows' is important.

The duration of construction requires planning. Adequate time for consolidating soft strata using vertical drainage and/or surcharging may avoid the need for piling, soil replacement or expensive resurfacing at a later date. The need for early completion may incur a cost penalty but this is not always the case if essential expensive plant can be moved off-site quickly for redeployment. Hence, in breakwater construction, very large cranes for placing armour stone are frequently used round the clock, in the same way as dredgers.

Cost will also be influenced by the degree of priority, if any, to be given to port traffic over constructional plant. Any delays to dredgers passing through locks or pile driving pontoons which may have to lower moorings to allow passage of other vessels, will be reflected in the contract or final price.

3.2. DREDGING AND RECLAMATION DESIGN

3.2.1. Soil Conditions and Planning

A detailed knowledge and understanding of the nature of the materials to be dredged and those which are available for reclamation is essential to ensure correct design and control of the operation and to allow the selection of appropriate dredging equipment. Mobilisation of such equipment is expensive and this should be taken into account when considering the dredging of small quantities as excessive unit costs may result. Advice on dredging techniques and equipment, handling of contaminated material, design aspects having regard to sideslope stability, etc., can normally be obtained in the planning phase from reputable dredging companies. The final quality and cost of a dredging project tends to depend on the extent to which site conditions and appropriate dredging methods are investigated during the planning phase.

If it is practicable to use the dredged spoil for reclamation, economies will generally result. If time is too short to allow for adequate consolidation of reclamation material in the immediate project, the material may still be valuable for reclaiming a site to be developed later. If the design permits a balance between cut and fill, costly disposal or the need for winning and importing fill materials may be avoided.

All seabed materials can be dredged but different considerations will apply. Appropriate plant should be used to allow efficient dredging and disposal, having regard to the protection of the environment and taking into account soil types, depths, volumes and shapes of areas to be dredged, distance to the disposal ground, and method of disposal.

The design specifications may need to restrict the use of some types of dredger to avoid disturbance of underwater slopes. Particular methods of disposal may also be required.

Hard rock dredging when rock blasting is required is very costly and should be avoided when possible. However, softer types of well fragmented rocks and coral can sometimes be dredged by a powerful cutter-suction dredger.

3.2.2. Dredger Instrumentation

Dredging now can be a tightly controlled and efficient operation. Reliable navigation control systems with electronic display will show the position of the dredger superimposed on a contoured plan with channel limits, buoys, etc. together with the position and depths of areas still to be dredged. This can be updated continuously. Used in conjunction with production data (e.g. Doppler ultrasonic flow metering of slurry for suction dredgers) the operation can be maintained at maximum efficiency.

3.2.3. Existing Obstacles

There may be a risk of projecting timber piles from historic works or extraneous steelwork from wrecks or materials/equipment dumped during construction which could cause damage to the hulls of ships moored on a falling tide. Consideration should then be given to carefully controlled sweeps of the sea bed, side scan sonar and magnetometer surveys (to detect steelwork) in addition to normal post dredge echo sounding.

3.2.4. Dredging Tolerances and Slopes

The nominal depth alongside quays must be increased by a dredging allowance together with an over-dredge allowance. These are needed to ensure all dredging is taken down at least to the nominal depth. The size of the allowances will depend on depth, relative costs of capital and maintenance dredging, accessibility for maintenance dredging, extra cost of deeper foundations for the structure, tidal range and wave heights, type of material and likely damage to a ship if it grounds. Over dredging below the allowances should not be permitted if there is a risk of damage to structures or slopes.

The design of dredged slopes and the permissible extent of step-cutting beyond the nominal dredge line will be based on analysis of the soil data, including laboratory tests and from knowledge of similar slopes in the locality.

3.2.5. Contract Documentation

A sample form of contract for dredging and reclamation works is available from the International Federation of Consulting Engineers (FIDIC). The document is listed in the literature references in Section 6 of these Guidelines.

3.3. BREAKWATERS

3.3.1. Basic Types

3.3.1.1. Introduction

Breakwaters are commonly constructed to provide shelter from wave action, but they are also provided to ensure freedom from currents, to exclude silt or for a combination of these. They may be either shore connected or isolated in the form of an offshore island and are of three main types illustrated in Figure 16 and commonly referred to as:

i) Vertical breakwaters
ii) Sloping breakwaters (Rubble mound)
iii) Composite breakwaters.

The design of any breakwater may allow for it to be over-topped to some extent by waves. A completely non over-topped breakwater design is seldom economical or necessary, unless port operations facilities and buildings are constructed against the lee face of the breakwater, using it as a seawall.

There are in addition a number of special types such as floating breakwaters, but their application is normally restricted to fairly sheltered areas to improve conditions at marinas and similar facilities in locations not affected by longer period waves.

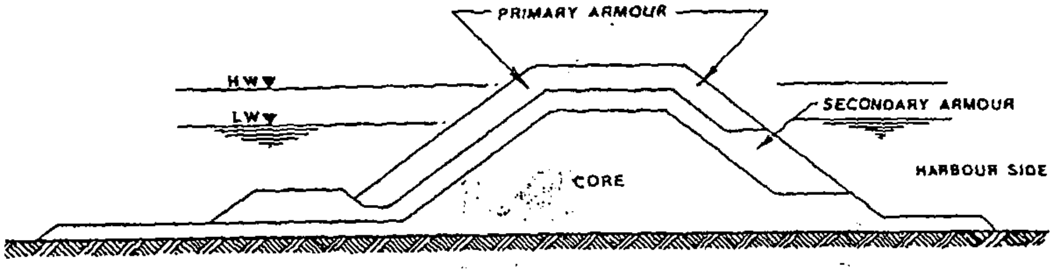
The choice of breakwater depends on many related factors, those of most consequence usually being the cost of supplying durable stone of the required size range, the nature and depth of the seabed and the prevailing wave climate. Careful consideration must also be given to the method of construction which will depend upon the availability of plant, accessibility of the site and the length and size of the breakwater to be constructed. This will in turn influence the choice of breakwater type.

3.3.1.2. Vertical Breakwaters

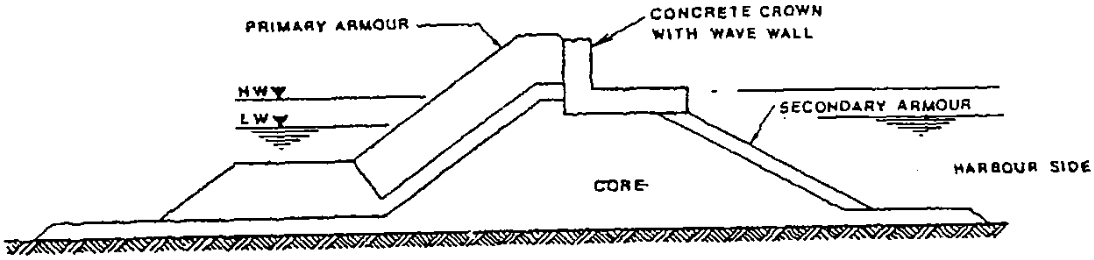
Vertical breakwaters are those with a vertical, or near vertical, seaward face. These may be constructed in a variety of ways, using, for example, concrete caissons or blockwork, or in very favourable conditions, sheet piling.

They have historically been used for very aggressive sites (e.g. Peterhead, UK, 20m depth 12m waves) and may still be a suitable form of construction for such sites. In fair weather vertical breakwaters can provide additional (seasonal) areas for berthing and port operations.

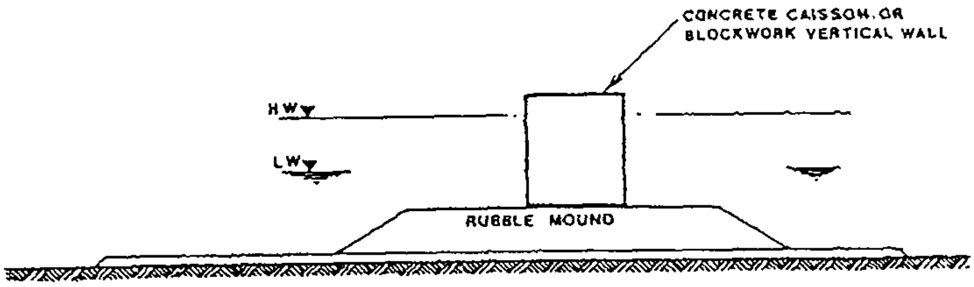
They are generally more suited to milder wave climates and may prove appropriate for construction in relatively shallow water where natural stone is in short supply or where weather conditions are unpredictable. They require good or improved foundation conditions.



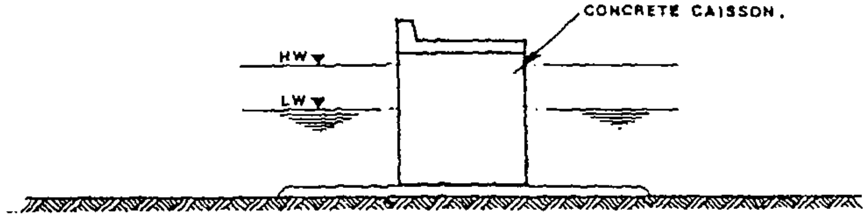
RUBBLE MOUND BREAKWATER



RUBBLE MOUND BREAKWATER
WITH CAPPING BLOCK



COMPOSITE BREAKWATER



TYPICAL VERTICAL BREAKWATER

Fig. 16 TYPICAL TYPES OF BREAKWATER

3.3.1.3. Rubble Mound Breakwaters

Rubble mound breakwaters are formed from a mound of suitable sized stones. The stones may be all of the same grading, or the structure may be layered from run of the quarry material for the core through layers of progressively larger stones (filter layers) to an armour layer of selected grading designed to be stable in the wave climate predicted at the site. Each layer serves to contain the material below it and prevent it being washed out by wave action. Where rock of sufficient size or durability is unavailable, either practically or economically, artificial armour units made from concrete are used. In rare instances, artificial underlayers have also been used.

Concrete armour units have evolved into a number of different types, from the original paralleliped rock replacement units (cubes, Antifer Blocks etc) through deadritic units (Tetrapods, Dolosse, Tribars) to more formal units which are placed in array (Tribars) and of tougher form (Akman) capable of being placed in single layer with an adequate factor of safety (Accropodes).

In recent times the benefits to the structural form and array have been developed in such units as the hollow cube (Cob, Shed) and hexagon (Seabee).

All of these units except the Seabee obey the same cubic law as the original rock armour.

The rubble mound concept has undergone much development in the past thirty years throughout the world. It is an area of engineering where damage under design loadings has been, in many cases, economically acceptable, provided that it can be contained within reasonable limits.

It is now well accepted that the susceptibility to damage is inversely related to the thickness of the dynamically porous layers of the structure. The corollary of this is that structures using layered construction, especially with concrete armour units, need to be constructed with a load factor greater than 1 when compared to homogeneous mounds.

Homogeneous or thick-layer breakwaters, also commonly known as berm or beach breakwaters, are now designed on the basis of dynamic equilibrium whereby the profile of the structure is changed by successive storms towards a more stable curved profile. This is a very practical form of construction in exposed sites with a ready supply of durable material, but some concern exists regarding the stability of such structures under oblique wave attack and of the long-term durability of the dynamic particles.

3.3.1.4. Composite Breakwaters

Composite breakwaters are those in which a caisson or a concrete structure is constructed on a submerged rubble mound and also where a rubble mound or a concrete block mound is placed in front of the caisson to minimise wave forces. These breakwaters are only utilised where the water depth is large and are normally adopted where limited availability of stone makes them more economic than a full height rubble mound breakwater.

The height of the rubble mound is determined from economic considerations, but will generally be kept well below the water mark to avoid heavy wave attack on the mound itself, particularly as it has to be finished with rather fine stone so as to provide an even and level foundation for the caisson or blockwork above it. On the other hand, the surfaces of the mound on the seaside should usually be covered with armour stone well durable and resistant to wave action.

3.3.2. Probabilistic Design

Design of breakwaters to avoid any possible failure is not necessarily economic. Natural forces cannot be forecast accurately, and any attempt to estimate their maxima would have to include an allowance for rare events. To meet this situation, it has become good practice to design for a certain probability of failure. Monolithic structures can be designed so that they will not fail under conditions that are likely to be met within a chosen time - say 100 years. This does not guarantee that the structure will not fail at any shorter time, but indicates that failure conditions are estimated to recur, on average, once in 100 years. This may be better expressed as an annual risk of failure of 1%. (The probability of the occurrence of the 1 in 100 year event in the 100 years is actually 61%). Random rubble breakwaters of quarried stone or non-interlocking concrete blocks, if damaged, can be repaired relatively easily compared with more complex structures. The cost of such occasional repairs together with the initial construction costs is determined, by probabilistic methods, to be lower than the cost of building a structure that would be expected to survive intact. This probabilistic approach is acceptable only when the failure mode of well-designed structures is not catastrophic; partial failure is unlikely to cause severe damage to harbour installations; and repairs can be made quickly and economically.

3.3.3. Design & Testing

3.3.3.1. Hydraulic Models

If poorly located, breakwaters can cause intensification of wave action at neighbouring sites or even at points on the breakwater itself. Careful planning with the aid of mathematical and/or hydraulic models is essential.

In addition to the need for modelling of the breakwater layout, the structure of the breakwater also needs to he carefully analysed. This is usually done with the aid of hydraulic models which can reproduce the action of waves on alternative designs. It has been the practice to build a model of the cross-section of a proposed breakwater in an hydraulic channel or flume and to subject it to suitable wave action. This was often acceptable when random-shaped quarried stone was used for primary armour against wave forces.

The evolution of concrete armour units has enabled rubble-mounds to be constructed even where wave height requirements are beyond the economic or practically available supply of large rocks.

Whilst these units comprised simple prismatic blocks and were placed in a random multi-layered construction, their behaviour was little different to that of angular rock. However, with the advent of more complicated geometry the mechanisms of armour stability were altered and internal structural effects became more important. This is particularly so with the second generation of legged armour units in random array (Tetrapods, Dolosse) and large scale three-dimensional testing of such structures, including roundheads should be included in the test programme, which should reproduce the critical conditions for the site.

3.3.3.2. Wave Climate

The initial stage in any breakwater design is the estimation of the wave climate at the site of the structure. It is not sufficient to estimate the spectrum of waves that will occur offshore or at a nearby point, as sea bed topography, tidal currents and the configuration of the shoreline may cause waves to be modified. Refraction of waves from particular directions is of particular concern and has contributed to some spectacular and very costly failures. The problem can be identified nowadays by conducting a comprehensive computer study of wave patterns, backed by suitable field measurements.

3.3.3.3. Foundation Conditions

Large breakwater structures impose high stresses on the underlying soil, aggravated by wave induced dynamic stresses. To prevent foundation failure a full geotechnical investigation using borings is required to establish the nature of the strata beneath the structure. Flatter profiles and phased construction sequences can assist in distributing the stresses but it may also be necessary to improve or replace weak foundation materials. The internal stability of the mound during construction and after completion must also be checked.

3.3.3.4. Core Material

Rubble mound breakwaters usually have cores of inexpensive material, generally quarried stone of variable size. A secondary (filter) layer of stone is required to prevent the smaller core material being washed out and to provide a key for the armour layer. Loss of core material results in settlement of the structure and damage to any crown capping.

Since the volume of rock material is approximately proportional to the square of its height, significant savings can be achieved by lowering the crest elevation. This is possible by allowing a degree of overtopping where and to the extent possible.

3.3.3.5. Armouring

Armour units are either natural rocks or artificial blocks, usually of concrete. All armour units are governed by an essentially linear relationship between the wave height and the typical dimension of the unit. The critical dimensions for stability are the slope and normal thickness of the unit and the armour layer. This means that for any particular shape the mass of the armour unit is proportional to the cube of wave height. This has great significance in the planning and construction of rubble mound breakwaters.

It has been found that the shape of quarried rocks can be important and proper utilisation of shape can lead to significant economies.

Artificial armour units vary from simple cubes to geometrically complex shapes. The necessary voids for drainage of the mound may be formed either interstitially between units, within the individual unit, or in combination.

The earliest units were simple parallelipeds using simple tapered rectangular forms to provide replacement rocks. These were succeeded by a second generation of legged units of various forms which had both increased interlock and increased porosity, giving improved stability (smaller units) and economy (less material).

However, these units required careful placement and were more susceptible to significant structural damage during construction and service, both rocking under wave attack and under compression during structural settlement. Once damaged or broken, unit stability is substantially reduced and further damage may occur to adjacent units. Thus the failure mode can be significantly different from that for rock armour and this must be allowed for in the design.

More recently and to overcome these problems there have been two emerging trends. The first is towards a third generation of more robust units, some with legs, others with internal voids, generally placed in an array in a single layer and designed with a significant factor for safety against movement or extraction. The other, especially for larger units in deep water, has been a trend back to shapes approaching the simple cube in random two layered construction. These units can be several times the mass and use nearly twice as much concrete as the later, third generation, armour units.

The size of the armour unit and the volume of material in the breakwater can be reduced by allowing overtopping but the stability of the armour units on the crest and lee side of the breakwater must then be considered.

The stability of armour layers can be increased and the size of stone decreased by using thick armour layers which can be reshaped by wave action without exposing the underlying filter layers. This is due both to the more absorbent nature of such structures and the greater tolerance to particle movement as well as the more stable profile and particle orientation achieved. In the extreme these breakwaters consist of a wide berm of relatively small rock in front of a narrow mound of quarry run material. They are susceptible to overtopping and breaching and require substantial quantities of material.

3.3.3.6. Toe Protection

Underestimation of the wave climate or a failure to protect the toe of the breakwater by means of a mattress or toe berm can result in the erosion of material at the toe of the breakwater. The resulting damage may lead to complete failure of the structure. This is a particular hazard in relatively shallow water and soft subsoils in which waves cause considerable movement of the bed.

Toe berms may also be required to the lee slope of low crest breakwaters to resist the downslope drag forces caused by the overtopping water.

3.3.4. Failures

A number of breakwater failures illustrate pitfalls that have to be avoided in the design of breakwaters. In virtually all instances, the breakage of slender interlocking armour units (dolos, tetrapods) constituted a major cause of the failure. Subsequent research coordinated by a PIANC Working Group demonstrated that, in fact, slender units of more than 40-45 tonnes can break under static loading such as caused by breakwater settlement. Above 15 tonnes, damage can occur due to rocking, and hydraulic damage criteria are no longer applicable.

In some instances the wave climate also was under-estimated in the absence of records over a sufficiently long period. Although the wave conditions when the damage occurred generally did not exceed the original design criteria, subsequent measurements and studies led to the acceptance of appreciably higher design waves for reconstruction or redesign purposes.

Sines, Portugal

Significant wave grouping and the resulting occasionally very high waves must have occurred due to the interference of two wave systems (combination of sea and swell). The dolos layer disintegrated, whilst geotechnical instability probably contributed to the overall damage.

Arzew, Algeria

Rocking and breakage of the tetrapods led to settlement and partial disappearance of the armour layer, and subsequent severe damage to the concrete crown wall and breakwater heads.

Tripoli, Libya

The original design and model tests did not take into account the irregular foreshore topography which led to local refraction and concentration of wave energy and/or to wave breaking on the breakwater's weather-side slope. However, the main cause of the failure was the underestimating of the design wave height Hsd for the breakwater with the result that due to the very high wave height (8 to 9m) compared with the Hsd (about 6m), rocking and breakage of armour units occurred. Moreover, insufficient attention had been paid in the design to the pressure build up below and behind the crown wall which caused extensive dislocation and collapse of the crown wall.

San Cyprian, Spain

Loss of integrity of the dolos layer resulted in erosion of underlying material. The damage was attributed to long period waves causing failure at wave heights far below those for which it was designed.

Gioia Tauro, Italy

Due to the breakage of waves on the armour layer, rocking and breakage of armour units occurred during a storm corresponding to the design storm.

3.4. OUAYS, JETTIES AND DOLPHINS

3.4.1. Elements Influencing the Design

The following are of special importance for port structures:

- Vulnerability to damage by vessels and assessment of duration of loss of use due to accidents of different probabilities.

- Design of quays should avoid the risk of vessels being trapped under the deck and causing uplift.

- Protective measures to combat corrosion etc, should be suitable to the situation especially in the inter-tidal and splash zones.

- Sea bed scour protection should include for currents induced by ship's propellers and bow thrusters.

- Adequate fendering systems to minimise risk of damage where vessels make contact or lie alongside, particularly small vessels.

- Exceptional drawdown of water in an impounded basin due to damage to lock gates or the need for emergency works.

- Excessive loading during construction e.g. when erecting equipment of from heavy constructional plant and on partially completed structures.

- If settlement is expected, provision for relevelling crane tracks may be required.

- Drainage for aprons (typically sloping at 1 in 60 to 1 in 100) and recesses should be designed to allow for anticipated settlements. Drainage falls [on surfacing] should not be so severe as to inhibit the use of cargo handling plant (i.e., straddle carriers, fork lifts).

- Uplift on foundations, deck structures and relieving platforms must be taken into consideration.

- Drainage behind retaining walls.

- Tie-back systems are frequently a cause of failure and need careful design including prevention of deflection of tie rods by vertical loads.

- The effect of movement on the functional viability of the structure should be considered, e.g. slight horizontal yield to develop passive pressure.

3.4.2. Functional Requirements

During the planning stages, the indicative layout, functional and maintenance requirements will have been determined. Different design requirements apply to marginal quays, finger piers, jetties (with or without approach roadway trestles), dolphins and single point moorings and whether within an impounded dock, protected by breakwaters or exposed. The range of sizes and types of vessel (coastal, oceangoing, scheduled service etc) to cater for container, ro-ro, dry bulk, break bulk, oil or other liquid cargo or a combination thereof will be known.

Detailed requirements for cargo handling equipment (quay cranes, bulk handling equipment, loading arms for liquids, mobile equipment) and for stacked goods together with services can then be determined.

3.4.3. Forces to be taken into account

The most severe combinations of all forces acting on the structure must be considered, excepting those combinations which are mutually exclusive. Where an unlikely combination of forces may occur simultaneously, it may be permissible to use reduced safety factors.

The loading combinations might include those which would arise due to foreseeable modifications to the structure, its usage, additional dredging affecting the foundation, etc.

Extreme load conditions for which reduced factors of safety may be considered include:

- unexpected deepening by temporary over dredging or scour.
- reduction or increase in superimposed dead load.
- environmental loads with a return period exceeding the design life of the structure.

Load types may conveniently be subdivided as follows:

- dead load.
- superimposed dead load (not part of structural elements).
- imposed loads (cargo handling equipment, stacked cargo, vertical and horizontal components of berthing, mooring and anchor loads).
- differential water and soil loads, including down drag on piles and uplift.
- environmental loads, including storm winds, vortex shedding under steady currents, wave slam forces, seismic loading, tsunamis (long period waves generated by submarine earthquakes and other disturbances), all generally related to a return period equal to the design life of the structure.
- accidental loads.

3.4.4. Fenders and Fendering Systems

3.4.4.1. Berthing Forces

The docking and mooring of a ship alongside a berthing structure generates large and complicated forces. Fendering systems are provided to absorb the energy and to reduce or spread out these forces so as to prevent damage to the ship and/or berthing structure. In addition to the large impact forces normal to the ship and berthing structure, shear forces parallel to the ship and structure are also common. The details of planning and design of a fender system must be accomplished by professional engineers with experience in these areas and are beyond the scope of this text. However, general considerations will be discussed herein.

Speed of berthing is very low, of the order of 0.10 to 0.25 m/sec. The berthing forces and energy generated are very high owing to the large mass of the ship. The kinetic energy generated is given by the formula:

Kinetic Energy = ½ Mass x Velocity^2

The mass in this case is the displacement of the ship plus the displacement mass of the water that accompanies the ship. Thus the mass involved may be twice the displacement mass of the ship. Note also that the velocity is a square factor, thus by doubling the velocity the energy increases four-fold. The other aspect involved with berthing is the conservation of momentum.

3.4.4.2. Protection of the Ship

Protecting the ship should be given equal consideration in designing fenders as protection of the berth structure. For large, strong ships, the unit hull pressure should be held below 20 tonnes/sq.m. to avoid permanent deformation to the hull. This can be accomplished by using large face or large area type fenders which will spread the load over a large area of the hull. Use of low friction type materials will also assist in the reduction of shear forces, which tend to scar the ship.

3.4.4.3. Protection of the Berth Structures

As in protecting ships, the concept here is to rely on the fender to absorb the energy and to spread the loads. For piers this can be accomplished by transmitting the load to the deck structure and in turn, transmitting it to a large number of piles so that the loads are dispersed to manageable levels. Indeed, design of the pier itself is conditional upon berthing impact loads and proper fender design.

3.4.4.4. Energy Absorption and Selection of the Fender System

The berthing energy to be absorbed by the fendering system is normally the most important consideration in designing any fender installation. The generally accepted design practice is to require that each fender in the system has sufficient energy absorbing capacity to absorb the largest anticipated impact load. Each fender must be capable of absorbing the full impact load since ships almost always contact only one fender on initial impact. Also, it is possible in some instances to have a second impact which is even larger in magnitude than the initial one.

A number of parameters go into establishing the design berthing energy. The most significant parameter is the berthing velocity, or the speed at which the vessel is closing with the dock and fender system. The second most important factor is the size or mass of the berthing vessel. Other factors entering into the berthing energy determination are the method of docking to be used, the berth configuration and wind, sea and current conditions.

The information needed to properly select a fender system is:

a) The type, kind and size of a vessel (displacement tonnage) and draught.
b) Berthing velocity (measured normal to the hull at the point of contact with the fender) and berthing angle.
c) Distance between the berthing point and the vessel's gravity centre measured along the face of the pier.
d) Installation pitch of dock fenders.
e) Water level, depth and tidal range.
f) Direction and velocity of wind currents.
g) Strength and elasticity of the berthing facilities.
h) Drawing or sketch with the dimensions of the structure.
i) Allowable hull pressure.
j) Other peculiar conditions (such as required energy and reaction of a fender, whether utilizing tugs or not for berthing).

3.4.4.5. Types of Fenders

Fenders are intended to absorb the kinetic energy developed by a vessel against a docking structure, preventing damage to either. Several types of materials have been used for this purpose, including timber wales, rope coils, steel springs, and old tyres. Rubber has several properties which make it ideal for use in marine fendering systems. Rubber's elastic properties allow it to deform under load, absorb some of the energy of impact and return to its original shape when the force is removed.

In designing fender systems there must be sufficient margin of safety to allow for most circumstances and still make the fendering system economically feasible.

Types of modern rubber fenders in common use include:

- Extruded cylindrical, rectangular, trapezoidal, vee and dee shaped fenders mounted directly on the quay wall or ship's hull or used in conjunction with timber.

- Buckling column types (moulded columns of rubber bonded to steel end plates).

- Pneumatic or foam-filled floating fenders.

- Air-filled mountable fenders.

- Shear fenders (rectangular blocks of rubber bonded to steel end plates designed to react to loads in shear).

- Cell or composite fenders (hollow cylindrical or trapezoidal shapes with strong resistance to shearing, with frontal steel plate upon which is mounted a low friction rubbing pad).

Many other types of fender using rubber and other materials together or separately are also used.

3.4.5. Equipment, Deck Furniture and Services

The design will make provision for the following:

- cargo handling equipment (including mobile crane pad loads and wheel loads of fork lift trucks and straddle carriers). Some typical wheel loads are given in Figure 17.
- crane rail tracks with end stops and storm anchors.
- tracks and turning plates for rubber tyred gantry cranes.
- loading arms and pipelines for handling liquid cargo.
- mooring bollards, rings, capstans, quick release hooks, fairleads.
- ladders, handrails, kerbs, stairways, life saving equipment.
- berthing and mooring aids for large vessels (e.g. speed of approach and mooring line tension indicators with displays on the bridge and in the control tower).
- electric power (suitable phases, voltages, frequencies).
- the need for flameproof equipment in hazardous areas, including special precautions w ith cable ducts.
- cathodic protection (sacrificial anode or impressed current systems).
- area lighting; navigation lighting.
- fresh water mains with metering and with protection against frost where necessary.
- fire water mains.
- bunkering oil with metering (different grades but not at every berth).
- telephone (including ship to shore), facsimile and telex.
- storm water drainage and sewerage (disposal may be via pipeline system or by road or marine sludge tanker).
- special services such as compressed air, steam etc. may be required on some berths, particularly repair berths.

The design may be particularly influenced by loading imposed by container cranes or bulk handling cranes and by the requirements for galleries or ducts and outlet pits for services.

If considering use of steel hawsers as mooring lines, caution should be exercised - particularly if vessels tend to range back and forth at the particular berth. Numerous cases have been recorded where steel hawsers have snapped under load, with a consequential whipping effect endangering personnel working on the berth.

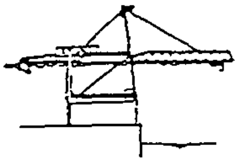
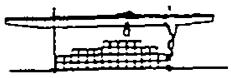
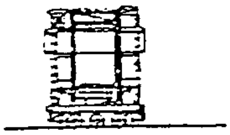
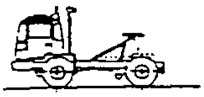
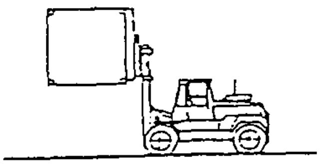
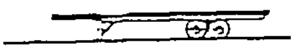
	EQUIPMENT	WHEELLOAD MAX. in KN	WHEELLOAD GEM. in KN	WHEEL-TYPE	TIRE/WHEEL SIZE
	CONTAINER CRANES:				
	1° gen. Paceco	300	250	steel	∅ 509 mm
	2° gen. Conrad Stork	600	350	steel	∅ 800 mm
	RAILWAY GANTRY CRANES:	200	150	steel	∅ 710 mm
	RAILM. STACKING CRANES:	350	250	steel	∅ 610 mm
	RUBBERM. STACKING CR.	400	250	pneumatic rubber tire	16.00x25
	STRADDLE CARRIERS:				
	3-high stacking Nellen	170	110	" "	16.00x25
	4-high stacking Nellen	160	90	" "	16.00x25
	TERMINAL TRUCKS:	65	50	" "	10.00x20
	MULTI-TRAILER SYSTEM:				
	trucks Floor	40	40	" "	12.00x20
 Floor truck & 6xchassis	chassis 2x20' of 40'	65	45	" "	12.00x20
	FORKLIFTTRUCKS:				
	20KN electric Linde	26	20	solid rubber tire	v: 23x9-10; a: 18x7-8
	40KN diesel Linde	44	35	pneumatic rubber tire	250x15
	120KN Kalmar	71	60	" "	12.00x20
	420KN Taylor	200	150	" "	18.00x25
	TERMINAL CHASSIS:				
	20' 1-axle	35	25	" "	9.00x20
	2x20' 3-axles	30	20	" "	10.00x20
	40' 2-axles	30	25	" "	9.00x20

Fig.17 Wheel loads of terminal equipment

Hydrodynamic interaction between the berthed vessel and other vessels passing at close quarters is a common cause of movement of the berthed vessel. Bollards, mooring lines and cargo handling installations may need to be designed to take account of the possibility of longitudinal movement of the berthed vessel or any tendency for passing traffic to 'suck' the vessel away from the berth.

3.4.6. Structures for Marginal Quays, Finger Piers, Jetties (with and without Approach Trestles) and Dolphins

3.4.6.1. Classification

Structures may be solid (gravity and sheet walls) or open with suspended deck (generally open piled). A solid structure may have a greater influence on the hydraulic regime, contributing to residual waves and reflection and possibly to siltation or scour. Hydraulic or mathematical modelling is used to evaluate these effects. Sheet walls and piled structures may have relieving platforms to reduce the horizontal forces transmitted to the wall. Typical cross sections of quays are given in Figure 18.

3.4.6.2. Gravity Structures

Gravity structures require a strong foundation to resist high bearing pressures and avoid excessive settlement (weak soils can be replaced or improved at a cost). Such structures will often provide an adaptable apron capable of supporting high loads anywhere on the apron.

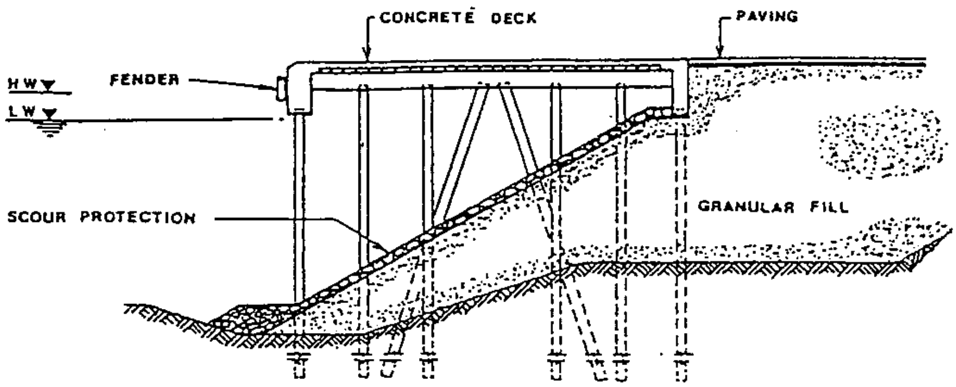
Gravity walls may conveniently be classified according to method of construction:

- Underwater construction, e.g. concrete blockwork, precast concrete walls, caissons floated into position and requiring a casting basin or dry dock, cellular sheet piled structures. To regulate positional differences between units, all types are normally finished with an in-situ concrete capping which may include crane rails and ducts or galleries for services.
- In the dry, e.g. in-situ mass concrete or reinforced concrete walls.
- From land, e.g. some types of diaphragm walls and monoliths, also known as open caissons.

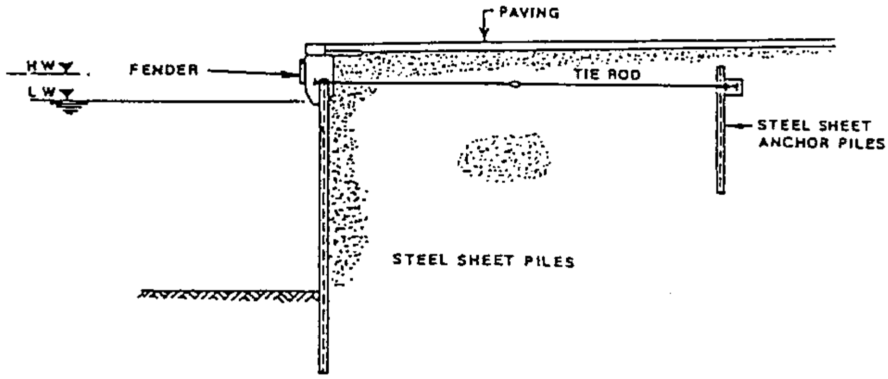
The design will have regard to the likely mode of failure, e.g., deep slip, overturning, foundation failure, sliding (a silt deposit on horizontal surfaces which reduces frictional resistance may be difficult to remove).

3.4.6.3. Sheet Walls

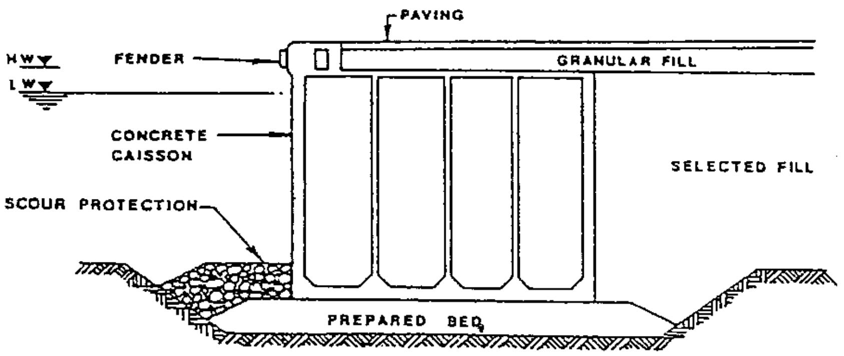
Sheet walls have been widely used for quays in medium or dense granular soils or firm to stiff cohesive clays. Deeper walls are now viable using composite sections (e.g. steel sheet walls incorporating box piles or universal beams and tee sections for diaphragm walls). If founded on rock, a trench has to be cut to provide a toe-in for piles. Sheet walls are normally anchored by ties at one or more levels. Ties which extend beyond the quay apron will often inhibit future developments due to the difficulty of supporting new structures over the ties.



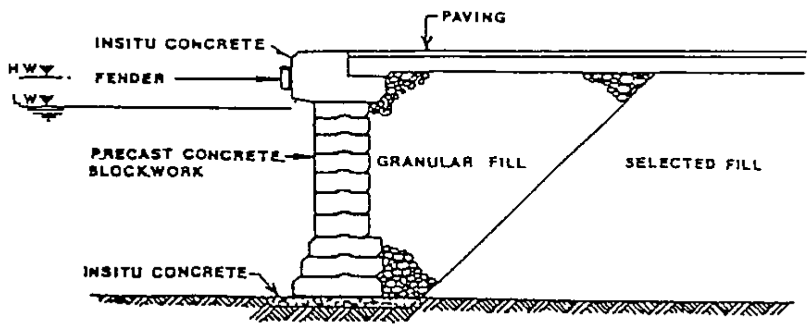
OPEN PILED QUAY



ANCHORED STEEL SHEET PILE WALL



CONCRETE CAISSONS



BLOCKWORK RETAINING WALL

Fig. 18 TYPICAL TYPES OF QUAY STRUCTURE

Sheet walls include the following types:

- Anchored single walls restrained by tie rods anchored to deadmen, ground anchors or raking piles, sometimes with relieving platform.
- Cantilevered single walls (for limited height only).
- Double walls.
- Cellular construction.

These types may be constructed in sheet piles (steel or concrete), in-situ concrete piles, diaphragm walls (sometimes with tee elements), soldier piles and sheeting.

3.4.6.4. Suspended Deck Structures

Suspended deck structures are generally supported on an open pile grid with end bearing and/or shaft friction piles, but may also be supported on barrettes or small caissons.

Open piled structures may be flexible or rigid, the rigidity being provided by raking piles or from the land mass behind. A slope, designed to avoid horizontal loading on the piles and erosion of the surface, is sometimes employed under marginal quays to support the land mass sometimes with a retaining wall to reduce the width of the suspended deck. Flexible quays are able to absorb part of the horizontal forces of berthing and mooring by flexing of the structure making them unsuitable for heavy gantry cranes, but reducing fender requirements. This form of construction is also suitable for widening or lengthening existing structures.

A wide choice of piles is available in steel, prestressed or reinforced concrete (precast or in-situ) and timber. Depending on soil conditions, displacement or bored piles may be used. Piling operations including obligatory pile testing require careful control.

Deck construction may be in the form of flat slab in-situ concrete, cross beams and slab, composite precast slabs with in-situ topping, and may incorporate relieving platforms, service galleries, etc.

Breasting dolphins and sometimes mooring dolphins are particularly susceptible to accidental damage due to uncontrolled collision. This should be borne in mind when planning the layout and in the design to minimise the risks and effects of damage. Common types of mooring dolphins are rigid groups of raking piles and flexible single large diameter tubes of high yield steel and varying wall thickness.

3.5. PAVEMENTS

3.5.1. Introduction

Many types of pavement are available for port use; those which will stand up to the arduous conditions which obtain are generally expensive. All requirements should be considered before deciding the best pavement for the particular situation. Initial construction cost (having regard to locally available materials and labour), design life and maintenance requirements all contribute to the total cost. Reconstruction time and loss of use of an area during repair may be of equal importance.

More economical surfacing will result if different paving specifications are used for areas with different duties. This may result in lack of flexibility in operations when there is a change in duty or give rise to failure if there is poor control of the more damaging plant which must be restricted to areas with heavy duty paving.

3.5.2. Soil Conditions and Settlement

New port areas are frequently developed by reclaiming over compressible soils. Whilst it is usual to ensure that the major part of the settlement is complete before paving (using special acceleration techniques where necessary), some residual settlement may have to be allowed for in the design of the pavement. Two solutions are appropriate:

- temporary flexible paving which will last long enough for the primary settlement to be virtually complete

- flexible paving which can be adjusted by surface overlays (e.g. asphalt) or by relaying (e.g. concrete blocks)

- If negligible settlement is expected, the choice widens to include rigid paving (normally in-situ concrete).

3.5.3. Formation of Pavements

The pavement is made up of a number of layers (sometimes combined) over the sub-grade:

- Sub base (granular or stabilised)
- Base (preferably lean concrete)
- Surfacing (binder course and wearing course)

The surfacing must not soften or rut in hot weather, nor crack or deform under slow moving or repeated loading. It must drain quickly in wet weather and resist frost damage. It should have a dense surface resistant to damage by spillage of liquid or dry cargo and (especially) hydraulic oil from cargo handling equipment and should have good skid and abrasion resistance.

3.5.4. Pavement Uses

For design an analysis is required of traffic types, speeds and densities, together with gross wheel loads and number of repetitions of the application of dynamic loads. The usage includes:

- Port roads and road vehicle parking with or without trailers with dolly wheels
- General cargo stacking and handling areas serviced by medium or light forklift trucks or cranes
- Heavy duty cargo stacks (including for steelwork) serviced by heavy forklift trucks or side loaders
- Container stacking areas serviced by straddle carriers and heavy forklift trucks or side loaders
- Container stacking areas serviced by rubber tyred gantries
- Container stacking areas for empty containers only.

Special arrangements will be necessary for surfacing between flush rail tracks, where services are laid under surfacing and at storm water channels, gratings and manholes.

3.5.5. Types of Paving

3.5.5.1. Rigid

In-situ concrete may be lightly reinforced with frequent expansion joints or heavily reinforced continuous strips with few joints. Concrete of high strength and density can resist local stresses and have good durability for all types of loading if there is no settlement to cause cracking. Repair of cracked slabs and installation of additional services is difficult. Concrete or bituminous overlays may be applied to extend the life of slabs when cracking is not extensive.

3.5.5.2. Flexible

(a) Precast concrete rafts (typically 2m x 2m with angle iron edging)

These can provide a durable surface but the cost is high. Rafts can be relayed after settlement. If uneven settlement is not regularly corrected, riding qualities will deteriorate rapidly. High local stresses can lead to broken corners.

(b) Concrete Blocks (typically 120mm x 240mm x 80mm thick)

These provide a very durable surface and once interlock between blocks is developed, provide a structural as well as wearing layer. Blocks are normally laid in a herringbone pattern subdivided into small areas by concrete restraining strips. Shaped blocks perform better than rectangular blocks but are more liable to breakage if settlement is excessive. Blocks may readily be relaid to correct for settlement or for the installation of additional services. Concrete blocks provide the best flexible pavement for the heavy loads imposed by straddle carriers and heavy duty fork lift trucks in container stacking yards and for trailers with dolly wheels. They can be damaged by tracked vehicles and by excessive discharge of water.

(c) Asphalt

For port use, a dense pavement is required. It will have a degree of flexibility but excessive settlement will lead to cracking. A softer mix which is more flexible will deform under point loads and develop ruts in heavily trafficked areas, particularly in hot weather. Dolly wheels on trailers and corner castings on containers may cause severe indentations. Spillage of hydraulic oil has proved to be especially damaging in areas traversed by straddle carriers due to softening of the bitumen binder. Some improvement can be obtained by the use of special mixes or surface hardening treatments and asphalt will then perform quite satisfactorily if repeated applications of point loads can be avoided.

(d) Granular Paving (Crushed Aggregate)

Crushed aggregate will form an excellent load-bearing layer where there is no moving traffic. Hence its use to support railway sleepers and more recently in container stacking yards serviced by rubber tyred gantries. The aggregate must be contained within a concrete perimeter edging and the sub-base provided with good drainage. Coupled with reinforced concrete running strips for the rubber tyred gantries (supported on piles if necessary) granular paving has proved to be very satisfactory and economical for container stacking yards. There is a danger of gravel sticking to containers put on the ground level and which may fall off when lifted. Depending on the size of the gravel this may cause bodily harm (head injuries).

4. PORT SERVICES

4.1. LIGHTERAGE

4.1.1. General

For countries wishing to develop their ports and expand trade, lighterage offers a practical means of avoiding the massive capital costs of creating deepwater berths and the associated transport infrastructure. In the simplest form, lighters provide a link between ships anchored in the closest deepwater location an local harbours and transport systems. This link may entail considerable distances where the draught of ships cannot be accommodated without extensive capital or maintenance dredging. Also, shallow depth waterways and rivers extending inland may be navigable only to a limited degree and may be further restricted by seasonal factors. Lighters can be designed and constructed to maximize local opportunities for navigation. Lighters also provide a means for storing cargo, where facilities on land are limited or expensive.

The location, the type and volume of throughput, the development of alternative transport systems, the availability of land and supply of manpower are factors which affect the degree of development or scope of lighterage systems. Ports located at the mouth of navigable rivers, or on extensive inland waterway networks will have a relatively higher dependence on lighterage as will some ports that have been long established.

Modern single commodity ports which are situated in close proximity to natural resources, e.g. oil, coal, ores, etc. or to well-developed road and rail transport networks, tend to avoid dependence on lighterage. Nevertheless, lighterage is versatile and requires low capital investment. It provides opportunities for small companies to participate in port services. It is responsive to market demands. Continual modifications to lighter size and design will result in improved operations.

4.1.2. Types and Functions

Lighters range widely in size and function. They may be constructed of wood, steel or concrete. They may be self propelled or dumb. Propulsion may be by machinery, wind, animal or manpower.

Lighters include open top cargo barges, oil and fuel barges, chemical barges, dangerous goods lighters, container barges and bulk cement barges.

4.1.3. Associated Craft

Craft which operates in close association with lighters include tugs, work boats used in a wide variety of servicing activities, passenger boats for transporting manpower, floating cranes, bunkering barges and water boats.

4.1.4. Sheltered Anchorages

According to the nature of the port, sheltered areas are required to protect lighters during adverse weather conditions. They should be suitably located and may take the form of natural bays or creeks, breakwaters, buoys or seawalls. Easy access is required. Fairways and fire lanes for access by fire boats and other emergency services should be provided.

Where seawalls or water frontage is provided, access points such as landing steps should be installed. Water and fuel supply points should be provided nearby.

In ports which experience typhoons, cyclones and other extreme weather phenomena, dedicated shelters must be provided for all lighters and associated craft. The area required may be calculated using the following formula:

(average length x average breadth of lighters x 2 x total number of lighters) + $^{1}/_{3}$ of foregoing for fairways and fire lanes.)

A similar calculation should be made for associated craft if they are to be accommodated. The shelter should be sited to be readily available. It should offer sufficient depth of water to accommodate fully-loaded lighters at low tide. However, care must be taken not to over provide depth. One metre under the keel of the deepest vessel at low tide is normally adequate.

4.1.5. Associated Facilities

Slipways and repair facilities for lighters should be available. Fair weather anchorage areas should also be provided.

Depending on the operating mode of the port, areas of seawall or water frontage will be required for the loading and unloading of lighters. These areas should be strategically located for land transport infrastructure, canals or waterways.

4.1.6. Inspection, Licensing and Control

The port's system of inspection, licensing and control of local craft will influence the numbers, size, design, manning and operation of lighters. For example, it is common practice to limit the number of lighters that may lie abreast each other when alongside a vessel. There may be size limits for lighters entering the shelters. Sea frontage will have to be made available for inspection and licensing functions. During such inspections the hull, machinery, cargo gear, life saving and fire fighting appliances will be examined.

4.1.7. Limited Operating Areas

Local regulations will determine the permitted extent of operating areas for lighters. These areas may vary according to size of the lighter, its construction and function, crewing and sea conditions.

4.1.8. Bulk Lighterage

In a few regions which handle dry bulk cargoes such as coal, grain, soya, etc., and which do not have sufficiently deep water to allow large bulk carriers to fully load within the inner port area, geared topping off barges are deployed in deeper areas outside the port to allow the ocean-going carrier to load to her limits. The very significant additional freight so generated can present a strong case for such an investment.

4.2. BUNKERING

4.2.1. General

The provision of bunkering services may be a significant activity undertaken by a port. Ships will call specifically to bunker. At other ports bunkering is a peripheral activity. Whether or not a port wishes to promote itself as a major bunkering centre is a decision for the port authorities, which may depend partly on the location of the port relative to major shipping routes. Shipowners will be looking for fast turnaround times as well as competitive prices.

4.2.2. Bunker Sources

Bunkers may be supplied from a local refinery. However, most ports import refined products which require tank farms for storage. This means that the port will have to provide berthing facilities, pumps and piping systems to accept deliveries as well as the means to supply bunkers to visiting ships.

4.2.3. Bunkering and Associated Services

Fuel is supplied to visiting ships via a fixed pipeline at an alongside berth or from a barge. The latter alternative can take place at an alongside berth, at an anchorage, or at a harbour mooring. Fuel is generally pumped into a ship's tanks by pumps on the pipeline or bunker barge. Gravity transfer is also used in some ports. Other services include the provision of fresh water, marine stores and food supply.

Over and above a port's normal demand for tug and pilotage service, the active promotion of bunkering services will create additional demand. The extent of any such additional demand will depend on the degree of bunkering which takes place in the port. Numbers and sizes of berths, moorings, anchorages and fuel barges will have to be decided bearing this in mind. The mode of bunker deliveries to the port will influence the provision of these facilities as will the anticipated numbers of ships requiring bunkers.

4.2.4. Oil Pollution Prevention

Formal and documented procedures should be established to minimise the occurrence of pollution during bunkering operations.

Contingency measures to deal with oil spills will be required. Equipment to put these plans into effect include oil booms, skimmers, absorbent material and oil dispersant chemicals. Storage in strategic locations will be required for this equipment. Boats and land transport will be needed for rapid development, plus manpower to match. It should be anticipated that these resources will be needed to cope with oil spills at any stage in the chain of activities involved in bunkering.

4.2.5. Oily Waste Reception and Treatment Facilities

To comply with MARPOL Annex 1, reception and treatment facilities will be required to accept oily wastes such as oil sludge and oily slops from ships visiting the port.

4.3. TUG/PILOT BOAT TERMINALS

4.3.1. Terminal Design

Tug and Pilot boat terminals share many common features. This means they can potentially be combined, but a number of factors influence the degree to which this possibility of sharing facilities can be exploited. These factors are operation, location, economic and political considerations.

4.3.1.1. Port Operation Considerations

The size, complexity and type of the port, its approaches, the number, size and type of ships using it, including frequency of visits, all combine to influence port authorities when they decide the most appropriate level of tug and pilot services that must be used. This level of services determines the number of tugs and pilots, (and thereby their boats), which have to be available for normal port operations.

An additional component may be provided for emergency services such as salvage, search and rescue, and ship accidents. The total number of tugs and pilot boats will be adjusted from time to time according to changes in demand. The size of terminal is therefore decided by the demand it will have to meet over its anticipated life-span.

4.3.1.2 Location Considerations

The location of the terminal is normally dictated by site availability. Considerations to be taken into account are: sufficient depth of water at all tides, shelter from prevailing winds or extreme occasional winds (typhoons), shelter from extreme wave and current conditions, close proximity to the functional location, and accessibility for crews to public transport, road, rail, etc.

Other location considerations include: availability of fuel, water and stores and proximity to repair and maintenance facilities. The number of such terminals envisaged in one particular port will also influence the chosen site location. These will all influence the size and nature of the terminal.

Depending on the type of services which are to be provided, a communication radio or telephone centre will be needed in the terminal. Accommodation including recreation, messing, and overnight capabilities and possible incorporation of administration accommodation for back up staff may also be needed. Access via landing steps and /or seawalls will be necessary for crews to board the tugs and pilot boats day and night in any state of the tide and in all weather conditions.

4.3.1.3. Economic Considerations

The capital and recurrent costs of creating and operating a terminal will be a major influence on terminal design. For example, where land costs are high, or a suitable land site is not available, terminals may be created at buoy moorings with some facilities being provided on a pontoon. Alternatively, the nature of the tug and pilot operations may be such that the tugs are self sustaining and pilots are based on on-station vessels.

4.3.1.4. Political Considerations

The nature of the port authority and whether or not it directly supplies or controls the tugs and pilots will influence the creation of terminals. There may, for example, be commercial independence of all three, with competing entities supplying tug and pilot services. On the other hand, all three may be under state or military control which will allow a varying range of alternative arrangements to be possible, for example, combined tug and pilotage services, or transporting pilots by helicopter to supplement the use of pilot boats.

4.3.2. Size of Terminal

This will depend on the size and number of tugs and pilot boats to be provided for during normal operating conditions and whether or not an additional function of providing shelter during adverse weather conditions has to be incorporated. The berthing arrangements will also influence design, for example, this may be alongside a seawall or secured to a mooring buoy or at anchor. The mix of different sizes of vessels should be considered carefully so as to avoid the risk of damage, collision and difficulty in navigating into and out of the terminal. Enough space for safe manoeuvring must be provided, especially if more than one organisation is supplying the tugs and/or pilot boats.

5. PRIVATE PARTICIPATION IN THE PORT INDUSTRY

5.1. Background

All great ideas go through three stages: In the first stage, they are ridiculed. In the second stage, they are strongly opposed. And in the third stage, they are considered to be self-evident. Now, privatization has reached the third stage.

Although such a term as Build-Operate-Transfer is relatively new, the practice of permitting the private sector to develop and operate infrastructure projects has been around for several centuries: the history of the Suez Canal would serve as a good example. In recent decades privatization attracted worldwide attention when the U.K. government began transforming its ailing economy by selling public holdings in industry, transportation, and other service sector areas, including the port sector in 1979. Since the mid 1980s privatization has increasingly been a fashionable concept throughout the global port community.

A decision to privatize ports can be driven by a variety of forces: tighter public budgets and increasing fiscal needs have led many countries to seek private participation in ports; and relatively inefficient port operation, bloated port labour forces, and lack of proper competition in conventional ports are another powerful incentive to privatize ports.

5.2. Facts of Privatization in the Port Industry

5.2.1. Rationale of Port Privatization

In recent decades, profound changes have occurred in maritime transport that have modified the balance between capital and labour at ports. Whereas port operation used to be very labour-intensive, current ports are increasingly becoming capital-intensive industries. The container transport system has resulted in significant cost reductions in cargo handling but this was prerequisite to refinements in port infrastructure such as terminals with deep-water depth, gantry canes, and the computer system. This has led to the need for a huge scale of investment in the port industry.

Container transport has brought about another change in the port industry. Modern ports no longer enjoy monopoly status in specific areas. The major shipping companies are calling at fewer ports due to economies of scale. Ports cannot survive any longer without sufficient infrastructure to accommodate large vessels and perform efficient port operation. All these technical changes have generated a highly competitive environment in the port industry, especially among large container ports. The fact that modern ports have to be very competitive yields the need for high efficiency in port operation.

Private participation in the port industry thus became an alternative option for the following reasons:

(2) To relieve financially strapped governments by turning to the private sector to provide the capital to modernize and improve port infrastructure;

(3) To seek economic benefits from improvement of operational efficiency by cutting labour costs, eliminating the public monopoly, reducing bloated port labour forces.

The U.K. government, for example, had five major reasons for transferring state-owned port assets to the private sector. These were:

(1) to improve the management of the ports

(2) to improve efficiency

(3) to raise revenue for the government

(4) to encourage employee share ownership which would help to further motivate port management and employees

(5) to reduce the power of trade unions.

5.2.2. Types of Port Authorities

Many different activities are performed simultaneously within the limited spaces of port areas including pilot service, cargo operation, and so forth. In most ports a port authority acts as the coordinating agency of various activities, though ports can be observed where all the port related activities are done by a port authority or conversely completely by the private sector. The current role of a port authority (ie. the kind of activities a port authority is responsible for) should be made clear before determining which port activities to privatize.

One can categorize port organizations into three types,depending on the role of port authorities: landlord port, tool port, and service port.

(1) Landlord Port

In this model, the port authority owns port infrastructure and is also in charge of its management. Private firms that own the assets of the port superstructure and all equipment required for service provision provide the remaining services.

(2) Tool Port

As in the landlord model, port authorities are the owners of infrastructure, but they also own the superstructure and the equipment. Private firms provide services by renting port assets through concessions or licenses.

(3) Service Port

In this model, port authorities are responsible for the port as a whole. They own the infrastructure and superstructure, and they also hire employees to provide services directly.

5.2.3. Types of Privatization in the Port Industry

In choosing the best form of private participation for a port organization, several alternatives are possible, depending on port size, objectives of privatization, and initial conditions. These are shown below in increasing order of private involvement:

(1) Government Department

The traditional method of providing infrastructure-based service including the port sector is directly through government departments.

(2) Public Authority

Public authorities are common for port, power, and water service in most countries in the world.

(3) Service Contract

Specific services associated with the port sector (e.g. port operation) may be contracted out to private firms.

(4) Operation and Maintenance Contract or Lease

A private partner operates and maintains a publicly owned port facility under management contract with the sponsoring government (port authority), which owns the facility.

(5) Cooperative

A nonprofit, voluntary, cooperative association assumes responsibility for the port service.

(6) Lease-build-operate (LBO)

A private firm is given a long-term lease to develop (within its own funds) and operate an expanded facility. It recovers its investment plus a reasonable return over the term of the lease and pays a rental fee.

(7) Build-transfer-operate (BTO)

A private developer finances and builds a facility and, upon completion, transfers the legal ownership to the sponsoring government agency (port authority). The agency then leases the facility back to the developer under a long-term lease, during which the developer operates the facility and has the opportunity to recover his investment and earn a reasonable return from user charges and commercial activities.

(8) Build-operate-transfer (BOT)

A private developer is awarded a franchise (concession) to finance, build, own, and operate a facility (hence this is sometimes referred to as BOOT – build, own operate, and transfer), and to collect user fees for a specified period, after which ownership of the facility is transferred to the public sector.

(9) Buy-build-operate (BBO)

An existing public facility is sold to a private partner who renovates or expands it and operates it in perpetuity under a franchise.

(10) Build-own-operate (BOO)

A private developer finances, builds, owns, and operates a facility in perpetuity under a franchise, subject to regulatory constraints on pricing and operations.

Since most port authorities in the developed countries fall, more or less, within a landlord type, it is not unusual to observe operation or lease contracts in ports. Privatization as advocated today goes much further than these simple contracts. In this Section, BOT and BTO (concession contracts) are mainly discussed because they attract most attention among the various forms of privatization.

5.3. Managing the Privatization Process

5.3.1. Management Guidelines

Privatization such as BOT and concession is more a political than an economic act. Long-term well-defined strategies are needed to implement privatization including research and public relations efforts to press for internal and external support, e.g. tax reforms to encourage it, legislation to allow it, and strong coalitions of stakeholders.

Government must organize and manage the process. A useful set of management guidelines for the privatization process is summarized below:

1. Ensure that the political exists and is understood throughout the government.
2. Assign unambiguous responsibility for the process
3. Establish clear objectives for the privatization program
4. Select the appropriate form of privatization
5. Enact necessary legal reforms
6. Develop clear and transparent procedures for the process
7. Estimate the value of assets and enterprises
8. Deal fairly with current employees
9. Address fears that privatization will harm the poor
10. Gain public support by educating the public about privatization.

5.3.2. BOT Contracts in Ports

BOT contracts can be considered as an intermediate form, lying between public ownership and full privatization. When designing a BOT contract several aspects have to be carefully addressed: the object of the contract, exclusivity of the facility, obligation and payment of the BOT developer, the term of the contract, penalties and fines, and risk allocation.

1. to clearly define the object of a contract, e.g. which party is responsible for access roads and other affiliated facilities and so forth.
2. to specify what services the BOT developer provides exclusively and what services are open to the public. In some cases the BOT developer must be offered guarantees that they will be able to recover their investment costs. Therefore, the contract could prohibit the same kind of facility in neighboring areas, or guarantee the minimum traffic.
3. to explicitly mention the obligations of the BOT developer in terms of level and quality of service, how charges to users are to be determined, and what payments are to be made to the port authority.
4. to clearly specify the starting and completion dates of the operation as well as the moment when ownership of the facility is transferred to the port authority.
5. to address the technical issues about infrastructure building such as materials and designs.

6. to specify the term of the contract: the average term is around 25 years.
7. to specify a series of penalties and fines that the BOT developer must pay to the port authority in the case of default. Since the contract has a long life the port authority should establish a strong position from the beginning of the contract.
8. to appropriately allocate each type of risk to the party that can take better action to avoid it. The following types of risk are involved in BOT: design/construction risk, operation cost risk, revenue risk, financial or currency risk, and environmental risk

5.3.3. Bidding and Renegotiation Processes

The usual process of bidding involves two phases: pre-qualification (selecting qualified developers based on experience in the port industry, financial status, etc.) and contract award (selecting one of the pre-qualified developers based on the proposal that defines the implementation program, fee payment to the port authority, charges to the users, etc.).

Renegotiation of a BOT contract is usually the rule not the exception, and should not be considered a failure. Because BOT contracts are typically long-life documents, the parties cannot foresee all possible future contingencies when signing the contract. Knowing this in advance, the parties should consider several future conflict scenarios and ensure that some provisions are included to establish at least basic renegotiation rules.

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