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UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Port development

A handbook for planners in developing countries

Second edition
revised and expanded

UNITED NATIONS

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT
Geneva

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Prepared by the secretariat of UNCTA D

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UNITED NATIONS
New York, 1985

NOTE

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ABBREVIATIONS

Names of bodies and organizations

API	American Petroleum Institute
FAO	Food and Agriculture Organization of the United Nations
FIDIC	Fédération internationale des ingtnieurs-conseils (International Federation of Consulting Engineers)
IAPH	International Association of Ports and Harbours
ICHCA	International Cargo Handling Co-ordination Association
IDA	International Development Association
IMO	International Maritime Organization
IS0	International Organization for Standardization
PIANC	Permanent International Association of Navigation Congresses
UNCTAD	United Nations Conference on Trade and Development
UNIDO	United Nations Industrial Development Organization

Other abbreviations

BACAT	Barge aboard catamaran
CFS	Container freight station
dwt	Dead weight tonnage
FCL	Full container load
f.o.b.	Free on board
GNP	Gross national product
grt	Gross registered tonnage
IRR	Internal rate of return
LASH	Lighter aboard ship
LCL	Less than full container load
LNG	Liquid natural gas
LPG	Liquefied petroleum gas
n.a.	Information not available
NPV	Net present value
PERT	Progress evaluation and review technique
ro/ro	Roll-on/roll-off (of cargo loading and unloading)
r.p.m.	Revolutions per minute
TEU	Twenty-foot equivalent unit
VLCC	Very large crude carrier

INTRODUCTION

(i) For many years the UNCTAD secretariat, through its Ports Section, has made consistent efforts to help developing countries in their task of extending and modernizing their seaports. which form a vital link in the chain of transport. The training of competent personnel, for both port management and port planning. has been one of the main goals. Port training courses, fellowships and a number of technical publications have been widely used by UNCTAD for this purpose.

(ii) It became apparent during the course of this work that there was a real need for a reference book in which the basic principles of modern port planning were summarized in an easily understood form. The present handbook is intended to meet this need.

(iii) **The paramount importance of a far-sighted port development policy does not appear to have been fully appreciated in the past by many governments. As a result, ports have often been unable to keep up with the rate of expansion of a country's overseas and coastal trade.**

(iv) The consequences of a failure to provide proper port capacity *before* the increased traffic arrives are clearly illustrated by the frequent congestion which occurs in ports in both developed and developing countries. The enormous sums of money lost through congestion would often have been sufficient to build an extensive system of modern ports.

(v) Seaports can, moreover, play a major role in promoting international trade by generating commercial and industrial activities which directly assist the economic progress of the country. The history of many ports shows how a bold policy of extending and modernizing ports can revitalize the economy of a region.

(vi) The immediate aim of the handbook is to offer daily guidance to port planners and decision-makers in their difficult task of formulating a national port development policy and preparing realistic programmes for the extensian and improvement of individual ports. The long-range purpose is to contribute to the training in developing countries of competent port planners, able to co-operate on equal terms with international experts and foreign advisers.

(vii) The first part of the handbook deals with general principles of port planning and with procedures to be applied for establishing a practical and consistent programme of work, for forecasting traffic and productivity, and for studying various problems that have a direct impact on the development of ports.

(viii) The handbook suggests that the preparation of a port development programme should follow a definite sequence of steps, which are outlined, so as to ensure that the work of planners is more systematic and efficient and that nothing of importance is forgotten. However, since it is impossible to deal adequately in one volume with the myriad problems that affect the planning of a major port, it was felt necessary to concentrate, in the handbook, on those points that appear to be least familiar to planners in developing countries, and to refer only briefly to other subjects. It is recommended that port planners should endeavour to build up a reference library on the subject of port development, and to this end a list of publications by private specialists, international organizations and the secretariat of UNCTAD is appended to the handbook, in annex III.

(ix) In the second part of the handbook, methods of planning various kinds of port facilities are discussed. Procedures are described for the preparation of plans for general cargo berths and for specialized terminals where containers or bulk cargoes are to be handled. Sound and realistic decisions on port investments must be based on accurate numerical analyses of several alternatives and on correct procedures for selecting the most advantageous plans.

(x) The use of sophisticated methods has not been recommended. Instead, a set of straightforward methods has been developed by UNCTAD, mainly in the form of curves and diagrams based both on empirical data and on mathematical calculations. They offer a degree of numerical exactitude comparable to that of many of the advanced computer-based approaches and are more satisfactory for general use.

(xi) The decision to recommend simple manual methods was taken after several years of testing the computer-based approach of the UNCTAD secretariat's early work in the simulation of seaports. Although that early work made possible the development of the simplified methods recommended in the handbook, and served as a basis for the UNCTAD research programme on port development, it became clear to those engaged in the work that the use of computer-based methods by port planners in developing countries would be too costly, both in time and in scarce skills, to be justified in the majority of cases. This conclusion has been reinforced by the realization that, during the present period of rapid technological change, the input information in those countries will continue for many more years to be uncertain and inexact.

(xii) Port planners ought, rather, to bear in mind that there is no substitute for experience and sound judgement. Diagrams and formulae are merely an auxiliary tool for their work, a means of relieving them of time-absorbing calculations and of freeing their minds for creative work. Port planning is a challenging and complex task but not an exceptionally difficult one. It requires a full understanding of the way in which an efficient port works, a sound knowledge of the general economic conditions of the country, a good deal of common sense and a certain talent for visualizing the future.

(xiii) It is hoped that this handbook will prove to be a useful contribution to the common international goal of establishing a world-wide system of efficient ports.

(xiv) The continuing heavy demand for this handbook has called for several reprints. Rather than continuing to reprint unchanged, it was decided to issue a second edition. This allowed a number of improvements and corrections to be made, and several chapters to be brought up to date. The second edition takes into account the many valuable comments received and the experience gained in using the handbook as reference material for a number of training courses.

Part One

Chapter I

THE MANAGEMENT OF PORT DEVELOPMENT

A. The need for a national ports plan

1. Technological improvements in recent years have made it essential to plan the transportation system of a developing country as a whole, in order to achieve a balance between the capacities of the various parts. In maritime transport it is sometimes possible-particularly for bulk and unitized cargo movements-to include the shipping. port and inland transport facilities in one co-ordinated plan. In other cases the ship traffic is not under the control of the planner and it is only possible to co-ordinate the port facilities with those of inland transport and distribution. Planning a sea-port without considering the connecting road, rail and barge facilities may lead to serious faults in national communications. This is particularly true in the case of developing countries. in many of which the freight traffic is rapidly growing and changing.

2. Within the ports sector, a balanced plan is needed for each class of maritime traffic. The number of ports, their,specialization and their location have to be considered. Smaller ports which play a special local role may not develop to the same extent as the main general cargo ports. but they contribute to the country's trade and need to be included in the national plan. It is sometimes convenient for planners in a major port to be given responsibility for planning the development of the minor ports on their part of the coastline.

3. Although some countries still permit free competition between their ports. this is no longer seen as acceptable where national resources are limited. For example, the trend towards handling bulk commodities at specialized, high-throughput terminals (the annual throughputs of which are measured in millions of tons) means that the whole national traffic flow of a particular product may be handled at one terminal irrespective of apparent geographical requirements. To allow this traffic to spread over a number of ports. as may happen without national planning. will mean either that each can only afford to install low-volume equipment. which will not allow the country to take advantage of the economies of scale obtainable through the use of large bulk carriers, or that each port has to invest large sums in under-utilized terminals. Either alternative will lead to steep increases in unit costs which may often far outweigh the increased land transportation costs resulting from the development of a single. specialized, high-throughput terminal.

4. For all classes of freight. there is a growing need to avoid the over-investment which can result from competition in a context of increasingly expensive cargo-handling technology. These technological changes in transportation methods require such specialized cargo-handling facilities that there is a strong case for the regional co-ordination of investments in specialized terminals. The joint planning of port investment by countries sharing the same hinterland can clearly he economically advantageous. but in any case it is now virtually obligatory for each country to develop its own national ports plan.

5. The factors which should be taken into consideration in the preparation of a national ports plan are illustrated in figure 1. It would be advisable to use this figure as a check-list to determine which aspects require further study before any major port investment decision is taken. The amount of work involved in a country with several ports would justify the maintenance of a small permanent nucleus of professional planners. to be augmented by an additional professional team when a full revision of the national plan is needed.

6. The main activities indicated in figure 1 are the forecasting of the national demand for maritime traffic transport. the surveying of existing ports and the national surveying of the means of transport available for maritime traffic. In addition, where major new terminals are under consideration, it would be advisable to make preliminary surveys of coastal geology and hydrography.

7. A number of related plans will result from this examination: a maritime traffic assignment plan: a national port investment plan: an inland routing plan and a coastal shipping plan. All of these will be conceived at a broad strategic level only, the planning of detailed facilities being left until each specific port development project is prepared.

8. In summary. three main duties can be identified:

(a) National port planning: this leads to several policy decisions which define the role of each port, and ensure that national resources are used in the most economical manner;

(b) Port master planning: this gives the long-term pattern of development for a port, without specifying the time at which any one step in this development will take place. It also sets in motion *work* which will be needed later:

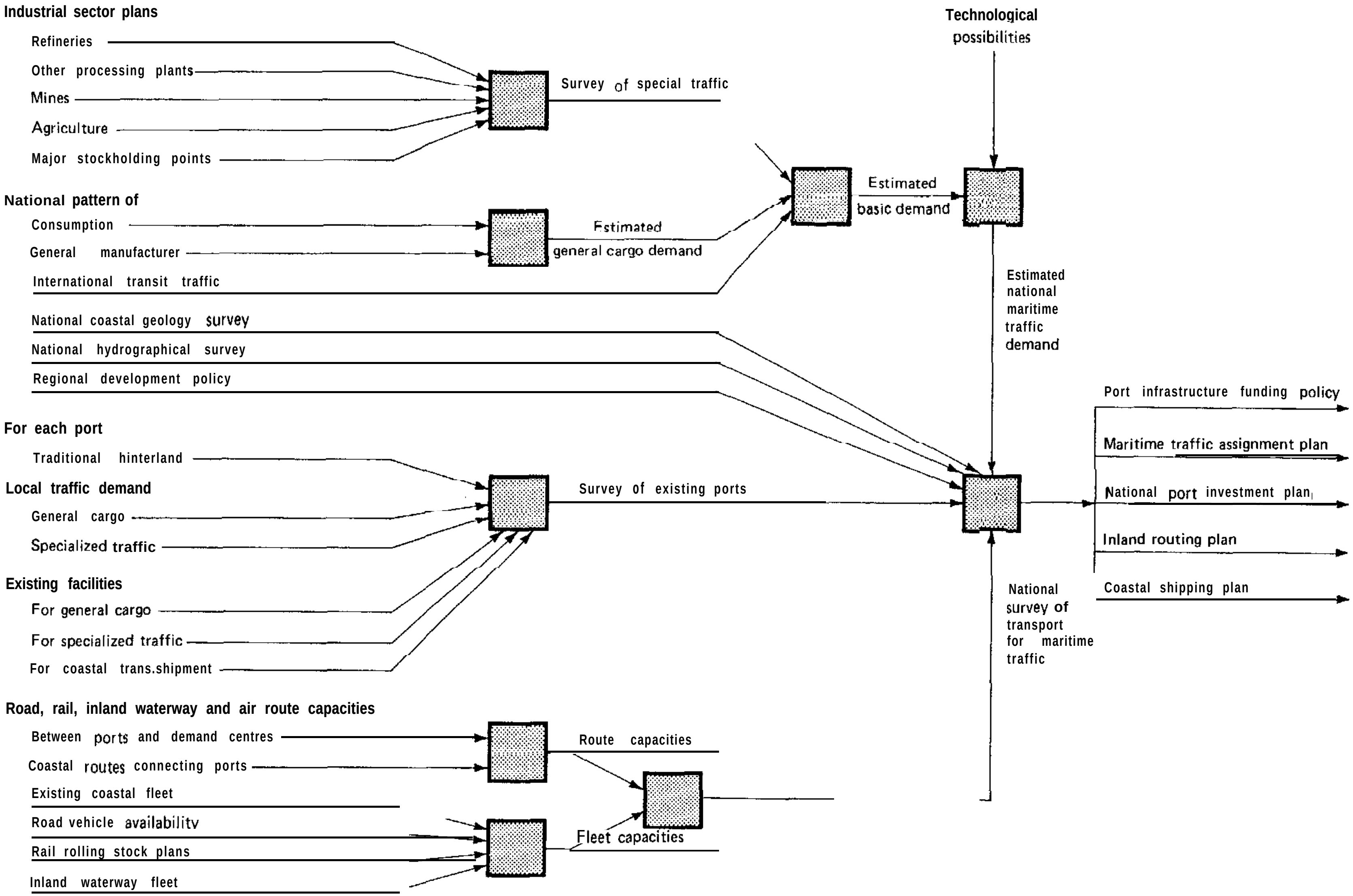
(c) Port project planning: this aims to turn each part of the master plan into reality at the right time, and in the right form.

B. The national ports authority

9. A further requirement at this point will be a decision on the policy as to which parts of the port infrastructure will be paid for by the central government and

FIGURE 1

National port planning



which by the individual port authority from its own revenue. There may be certain large capital expenditure items that would place too heavy a strain on port finances if they were to be supported from income while charges were maintained at a reasonable level. Some would argue that only the connecting road and rail systems should be excluded from financing by the port. and others that major long-term structures such as breakwaters and work such as approach channel dredging should also be partly or wholly charged to the central or regional government. It is for each government to decide this policy according to the financial capacity of existing ports and the expected profitability of planned new ports.

10. In deciding to what extent the central government should retain the responsibility for setting port development priorities, it should he borne in mind that an individual port authority may be limited by its physical boundaries from finding what is economically the right location for a new terminal. In times of change, a port authority is likely to place emphasis on those alternatives which preserve or enlarge its level of activity. Modern technological developments make such tendencies undesirable from the point of view of the country as a whole. as the location of existing port facilities may be inappropriate for the use of the new technologies.

11. For such reasons there is a strong case for setting up a specialist government agency with the overall responsibility for co-ordinating port policies at a national level. To build up and maintain the capability needed, and to allow a free interchange of ideas with the many interests involved. it may be more appropriate for the agency to be separated from the central government ministry concerned and to take the form of a national ports authority with defined statutory powers, such as those listed below. There is a close parallel to the move in a number of countries towards national airport authorities, national oil authorities and so on. A small permanent secretariat would be appropriate.

12. For efficient management of port activity, the operational decisions should be taken locally; it would normally be wrong to give a national ports authority any operational responsibilities. Its main function should be one of co-ordination and regulation, the principal aim being to prevent the undesirable duplication of investments. The statutory powers which it may be appropriate to give to a national ports authority are as follows:

(*a*) Investment: power to approve proposals for port investments in amounts above a certain figure. for example, $5 million. The criterion for approval would be that the proposal was broadly in accordance with a national ports plan. which the authority would maintain.

(b) Financial policy: power to set common financial objectives for ports (for example. required return on investment defined on a common basis). with a common policy on what infrastructure will be funded centrally and what locally; advising the government on loan applications.

(c) Tariff policy: power to set a common tariff structure (local conditions will determine to what extent the authority should also regulate tariff levels).

(d) Labour policy: power to set common recruitment standards, a common wage structure and common qualifications tor promotion; power to approve common labour union procedures.

(e) Licensing: where appropriate. power to establish principles for the licensing of port employers, agents, etc.

(*f*) Information and research: power to collect, collate, analyse and disseminate statistical information on port activity for general use, and to sponsor research into port matters as required.

(*g*) Legal: power to act as legal adviser to port authorities.

13. It would be advisable for such an authority to set up a method of obtaining advice from persons with wide experience in the matters of harbours, shipping and inland transport, in industrial. commercial, financial and economic matters. in applied science and in the organization of labour. An appropriate method would be to co-opt such persons on to the Board ot the authority or on to its subsidiary committees. Liaison would also take place with national bodies representing shippers, shipowners. etc.

14. The risk involved in giving such an authority powers over port investments and tariff policy is that additional delays may be introduced. It would be essential, therefore, to institute in addition an emergency procedure to speed up or even bypass the normal decision process when, for example, there were sudden changes in traffic or rapid increases in congestion.

C. Port development

1.5. Within the broad national strategy, the development of each individual port must be comprehensively planned. The development of a port consists of a combination of medium-term and long-term planning of new facilities plus-in the case of an existing port-a programme of short-term action to improve the management, the present facilities and their use.

16. For each investment there must be, first. a planning phase, which ends in a recommendation on which course of action the port should follow, giving only a broad treatment of each technical aspect; secondly, a decision phase, which can be substantial and includes the securing of funds: thirdly, a design phase, which turns the chosen plan into detailed engineering designs, and lastly, the construction or implementation phase. This handbook is concerned mainly with the planning phase. and goes only into sufficient technical detail to supply the information necessary to produce preliminary cost estimates. Final cost estimates are predominantly dependent on the engineering difficulty and magnitude of the project. These estimates must be made, and the subsequent engineering design and construction work carried out. after the conduct of more detailed investigations by qualified civil and mechanical engineers. in consultation with the port authority. This handbook makes no attempt to provide a substitute for the use of such professional staff.

17. The long-term plan-the master plan as it is often called-consists of a view of the future situation

as it will be after a series of individual developments have been carried out. However, it does not try to say whether and exactly when each of them will occur, since this will depend on traffic development. The master plan will be set within the framework of the national ports plan and in turn will provide a framework within which the medium-term plans for action can be drawn up and specific projects defined. This principle of going from a broad long-term plan to a detailed medium-term proposal should be a standard procedure.

18. The programme of immediate practical improvements for the use of existing facilities can, however, go ahead independently of the medium- and long-term plans. There will always be an urgent need for moderate technical and operational improvements, such as the extension of available storage space, the introduction of additional cargo-handling equipment or the purchase of pilot boats or lighters. Improvements of this kind are independent of future capital investments and should not be delayed until the main investment plan is finalized.

19. For example, the identification and removal of bottle-necks which impede the productive flow of goods may be studied by the methods indicated in the report of the UNCTAD secretariat on berth throughput.[1] This approach can be undertaken at any time independently of the planning project, but it would be advisable for sufficient analysis of throughput to be made by the middle of the planning phase to give reasonable practical estimates of future productivities. The establishment of these estimates is one of the most important and difficult tasks of the port planner.

D. Long-term planning

20. In order to prepare both the national ports master plan and the master plans for individual ports, the planner needs to ascertain the development framework within which each port will be operating. To do this he should consider the following aspects:

(a) The role of the port, which may include some or all of the following tasks:

- (i) To serve the international trading needs of its hinterland as reflected by traffic forecasts, either in total for all needs or excluding specific commodities (e.g. bulk commodities which are to be handled at special terminals outside the port's responsibility);
- (ii) To assist in generating trade and regional industrial development;
- (iii) To capture an increased share of international traffic either by trans-shipment or by inland routing;
- (iv) To provide transit facilities for distant hinterlands not traditionally served or for neighbouring land-locked countries.

(*b*) The extent of the port's responsibility for infrastructure needs, as follows:

- (i) Marine responsibility, which may be total, from landfall to berthing, or may exclude estuarial, river or canal approaches or the financing of major marine works (e.g. main breakwaters, capital dredging);
- (ii) Landward responsibility, which may be total, including road/rail links between port and inland depots, etc., or may exclude either links shared with other users or local connecting roads/sidings.

(c) The land-use policy for the port, which may have freedom within fixed boundaries, or freedom to acquire or dispose of adjoining land either on the open market or with compulsory purchase, or freedom to acquire non-adjoining land for storage, for inland clearance depots, or for additional berths at new coastal locations.

(*d*) The financial policy as regards the port, which may be either fully commercial, self-supporting and with freedom to set tariffs as necessary, or subject to restrictions on tariff policy linked to a limitation on commercial accountability or subject to public control as an instrument of national development.

21. The long-term plan will place more emphasis on what is desirable than on what the trends seem to show to be likely. The planner needs to place himself in the future situation, even if this is 20 years hence, and try to draw a consistent picture of all that he will find at that time.

22. This picture will allow the planner to lay out a sensible future situation which is at least feasible and far-sighted, even if there can be no certainty that its details are correct predictions. The land-use aspect and that of the major water areas and channel developments are the most vital features of the long-term plan. These must be provided for in a manner consistent with the expected increase in traffic, which over a long period can be quite substantial (for example, a one-million ton level increasing by 10 per cent each year for 20 years becomes 6.7 million tons). Modern technological developments have made the need for ample land space still more imperative than was the case in the past. A container terminal or a major terminal for ores requires an area of tens of hectares. Clearly, failure to earmark substantial land areas may mean that residential and other forms of development may use them up first.

23. The industrial planning policies of government-central, regional or municipal-together with the national ports plan when available should give much of the framework necessary to set each port's objectives. But it would be unreasonable to expect those responsible for such policies to be very precise at the outset since their understanding of the possibilities of port development is likely to be incomplete. Therefore, after talking to the authorities concerned, and collecting what views exist, the port planner will almost certainly be left with some unanswered questions., He will then be forced to fill these gaps by making his own assumptions on the long-term role of the port. It is far more important to reach a reasonably comprehensive interpretation of this role, within perhaps one month of starting the project, than to attempt to get an accurate and formal official statement.

[1] ***Berth Throughput: Systematic Methods for Improving General Cargo Operations*** (United Nations publication, Sales No. E.74.II.D.1).

24. Ship-repairing facilities (dry docks, floating docks, slipways, etc.) are often also **under** the control of a port authority and need to be planned at the same time as the cargo-handling facilities, in the master plan. It will be necessary to ask first whether such facilities should bc located within the port area. and if so, what impact they will have on zoning, ship movements. etc. This subject is not covered in this handbook; advice in this field can be obtained from IMO and from UNIDO.

25. Bearing in mind the above comments, the steps to be taken in drawing both the national ports master plan and the individual port master plans may be suggested. Tables 1 and 2 set out one way of carrying out the full task and refer to individual steps shown as a sequence in figure 2.

TABLE 1

Procedure for national ports master planning

The eight main tasks (Al to A8) are as follows.

1. Define natmnal economic objectives in so far as they affect ports.
2. Define the financial responsibilities of the ports.
3. Define the planning responsibilities of the ports
4. Prepare a broad national traffic survey.
5. Assign traffic to Individual ports
6. Prepare a preliminary investment plan
7. Co-ordinate and obtain approval of individual port master plans
8. Prepare and publish the natmnal ports master plan.

Each of these tasks is described in more detail below.

i-ask AI Define natmnal economic objectives as they affect ports

1. Hold preliminary discussions with national economic planners.
2. Collate published reports, etc.. and extract material relevant to maritime traffic and to the connected networks.
3. Summarize the broad impact of economic policies on port development in a draft policy paper.
4. Discuss draft with national economic planners.
5. Revise and circulate policy paper.

Task AZ Define financial responsibilties of ports

1. Review existing orders and legislation.
2. Obtain views of port authorities.
3. Spell out new policy in detail (e.g. common tariffs, required return on investment. funding)
4. Discuss proposal with higher authority.
5. Draft new orders or decrees.

Task A3. Define planning responsibilities of ports

1. Review existing planning responsibilities.
2. Analyse need for regional or other structure.
3. Consider methods of planning any new ports.
4. Consult with port authorities.
5. Propose new structure. Discuss with higher authority and revise as necessary.
6. Draft any new orders or legislation needed.

Task A4. Prepare a broad national traffic survey

Chapter III of Part one discusses this in detail

Task A5. Assign traffic to individual ports

1. Prepare broad origin/destination diagrams for each principle cargo class.
2. Examine scope for concentration of cargoes in each region or at national level.
3. Construct several alternative feasible traffic assignments.
4. Roughly evaluate alternatives and prepare paper on most economic solutions.
5. Circulate paper to all departments/organizations concerned.
6. Draw up plan reconciling comments received and submit for approval
7. Issue approved plan

Task A6. Prepare a preliminary investment plan

1. Obtain port estimates of future productivity for each cargo-handling technique in question.
2. Compare traffic assigned to each port with its rough *existing* capacity for each class of traffic and cargo-handling technique.
3. Roughly estimate scale of additional facilities needed.
4. Roughly estimate investment imphcations.
5. Compare with Ministry of Finance targets or other ***constraints*** and report any divergence.
6. Revise figures as necessary
7. Notify ports of figures to give framework for their master planning.

Task A7. Co-ordinate and obtain approval of individual port master plans

1. Tabulate traffic forecasts used by each port and check for inconsistencies and duplications.
2. ***Carry*** out broad economic comparison of any competing plans.
3. Carry out rough check of all capacity calculations.
4. Revise plans as required.
5. Calculate natmnal port investment total.
6. Discuss long-term port investment requirements with Ministry of Finance and revise as necessary.
7. Visit ports to discuss final master plans.
8. Issue authorizations.

Task A8. Prepare and publish the national ports master plan

1. Assemble individual port master plans into a national plan.
2. Publish the master plan in a form which can he easily revised.

A diagram showing these tasks and how they are related to master planning is given in figure 2.

E. The sequence of investment

26. Strictly speaking, since the short- and long-term investment plans form part of the same sequence of financial investment and of economic benefits, the whole sequence should be considered as one programme, and the planner should look for the overall economic optimum for the whole series of investments.

27. But this is an ideal which cannot yet be realized, since the methodology necessary to calculate such a complex economic optimum is not yet satisfactory.[2] The best that can be done at the present time is to try to set out a series of the main investment alternatives and to calculate at each main date of investment and of

[2] The mathematics involved are not complex, but the interaction of costs and benefits of varying sequences of investment produces a heavy load both on analysts and computer time which, in view of the uncertainty in the forecasts of traffic, productivity and costs, is not justified

TABLE 2

Procedure for individual port **master planning**

The 11 main tasks (B1 to B11) are as follows:

1. Set up an ongoing traffic analysis (if this does not already exist).
2. Prepare a broad long-term traffic forecast.
3. Initiate any broad engineering surveys needed.
4. Analyse the port's role as laid down by the national authority.
5. Determine the long-term phased area requirements.
6. Determine the long-term wafer and channel requirements.
7. Assign traffic to major port zones.
8. Calculate the rough cost of each terminal/berth group in each phase.
9. Prepare the draft master plan and submit for national approval.
10. Revise and publish the port master plan and obtain local approval.
11. Install a control system for initiating a project at the right time.

Each of these tasks is described in more detail below.

Task B1. Set up an ongoing traffic analysis

The data required are shown in chapter III, "Traffic forecasting". The UNCTAD "Manual on a uniform system of port statistics and performance indicators"" contains a complete system for collecting the data both for planning and for operational purposes.

Task B2. Prepare a broad long-term traffic forecast

Strictly speaking, the ports cannot start forecasting until their role has been defined at national level, but there is a lot of preparatory work and simple projections which need not wait for this. At the master planning stage, forecasting is to be broad and long term only.

Task B3. Initiate any brood engineering surveys needed

The surveys that should be initiated for master planning are those which provide a broad picture on which major zone decisions can be based, plus those [like siltation studies) which are themselves of a long-term nature. The range of surveys which may be needed are described in chapter VII, "Civil engineering aspects."

Task B4. Analyse the port's role as laid down by the national authority

If the national plan has not been prepared, it may be necessary to analyse the port's role as seen locally and submit this as a proposal.

Task B5. Determine the long-term phased area requirements

For each of the traffic streams likely to result from the defined role of the port:

1. Review characteristics of each class of traffic (transport, storage, ship size and draught, pollution).
2. Review industrial development plans and possibilities in port area.
3. Calculate broad land area requirements for the range of feasible long-term cargo throughputs.
4. Estimate land area requirements for long-term industrial development within port limits.
5. Estimate land area requirements for ancillary land-use (housing, amenities) within port limits.
6. Tabulate the various area requirements phased according to each traffic alternative.

Task B6. Determine the long-term water and channel requirements

For each class of ship traffic, calculate the broad water area and depth requirements for the range of ship types and sizes expected in the long term.

Task B7. Assign traffic to major port zones

This task is discussed further in chapter V of this handbook. The following is a sequence of work which is appropriate at the master planning stage:

1. Examine environmental impact of each class of port activity (both independently and as they affect each other).
2. Survey existing water areas and approaches and compare different ways of deepening and extending these, including new land cuts.
3. Survey existing and available land areas and compare alternative ways of extending them, including reclamation.
4. Draw alternative zone configurations with corresponding communications corridors.
5. Broadly evaluate alternative phased configurations for transportation economy, capital cost and flexibility.
6. Prepare zoning plan for the preferred solution.
7. Draw outline charts of water depth for the chosen zoning configuration, corresponding to the successive phases of each alternative.

Task B8. Calculate the rough cost of each terminal/berth group

1. Identify likely terminal or berth group developments, in each zone within the zoning plan, for each future alternative.
2. Estimate the rough costs of each terminal development.
   N.B. Although it will be difficult to obtain such cost estimates, it is important to find any indicative figure, however rough. This is because without such figures it will be impossible to build up a long-term investment plan, which is essential to show whether the master plan is feasible.
3. Tabulate the results.

Task B9. Prepare the draft master plan and submit for national approval

The contents of a master plan should include:

(a) The long-term forecast and its rationale;
(b) The planning maps;
(c) The investment implications.

One way of organizing the preparation of the plan is as follows:

1. For each class of port activity, combine the successive stages of development in the alternative cases into a single framework independent of time.
2. Draw planning maps showing the proposed zoning and alternative development sequences within the framework.
3. Prepare order-of-magnitude investment cost figures for the development sequence of each activity.
4. For the time-scales both of a conservative and of a radical alternative, calculate the total investment implications over the period.
5. Assemble this material into a draft master plan, with a supporting commentary on assumptions and rationale.

Task B10. Revise and publish the agreed port master plan

This should be published in such a form that it can be easily revised and amended each year.

Task B11. Install a control system for initiating a project at the right time

It is essential to initiate a project feasibility study as soon as there is an indication that, by the time the development is complete, there will be enough traffic to justify it. Master planning is not complete until a routine is established for checking when projects should be initiated. The following procedure is one way of doing this:

On completion of the master plan

1. Identify each individual investment project within the plan over the next ten years.
2. For each of these projects, estimate the likely development time that will elapse between initiating project action and bringing the facilities on stream. This will include: the whole sequence of project planning; funding and time for decision-making; tendering; design and construction.

Every year

1. Bring the traffic forecast up to date, for each traffic class.
2. Estimate the future growth rate of traffic in that class, taking account of latest developments and customer requests.
3. At this growth rate, calculate the traffic level a number of years in advance of the date at which the project capacity is needed. This is the triggering level.
4. Activate the project if the triggering level has been reached.

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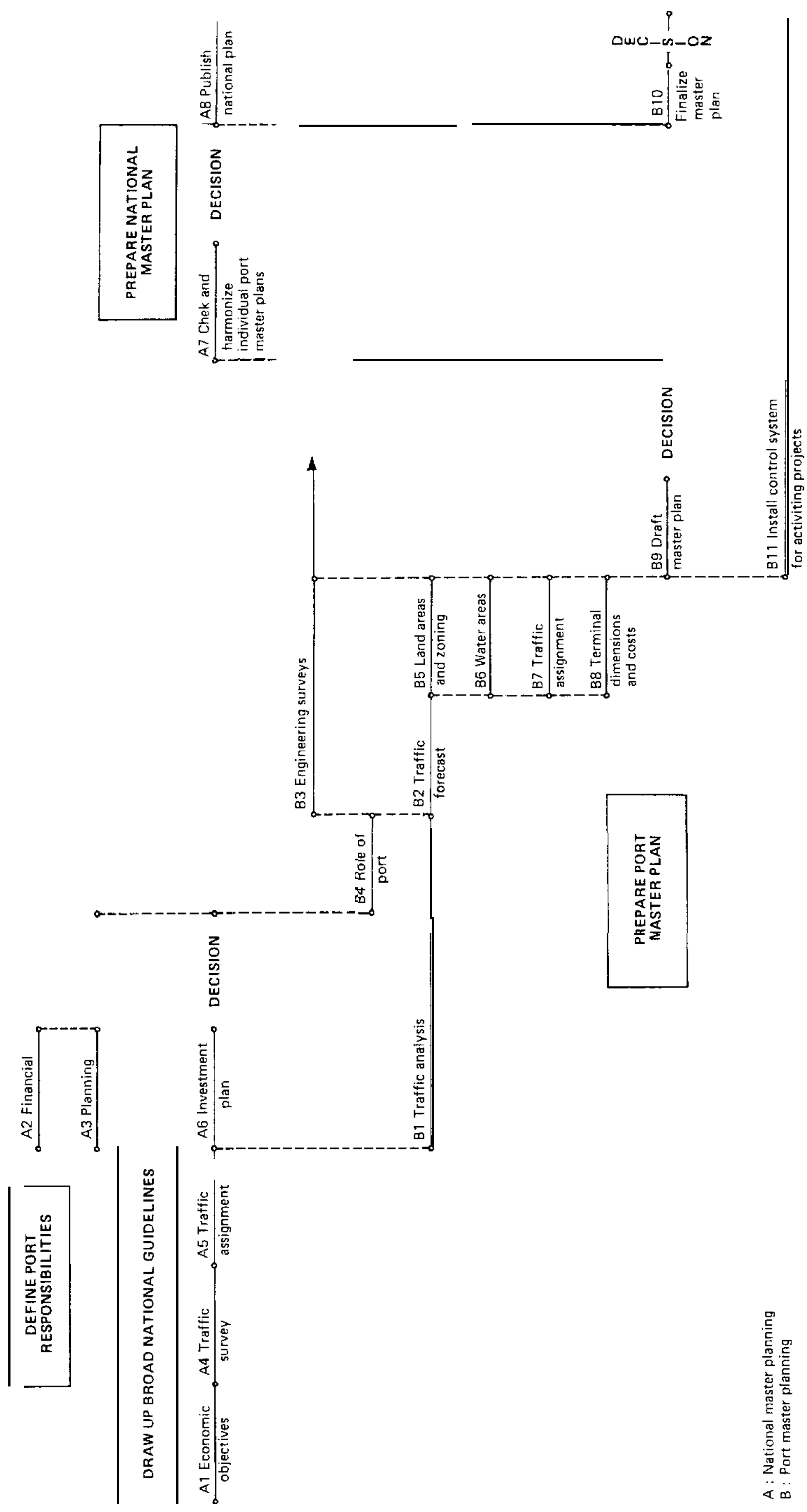
[a] UNCTAD/SHIP/185/Rev.1.

FIGURE 2
The planning sequence—I



commissioning what will be the costs and the benefits. Planners may be assisted by research units or consulting firms in making a broad pre-investment study of the country. The basic aim will be to determine the general direction of expansion and to quantify the tonnage to be handled and how it will be shipped. By making calculations for a range of possible investment programmes for this traffic, the planner may succeed in devising a programme which is not too far from the optimum, although even this will entail a good deal of work. To simplify the process, only rough calculations need be made during the initial phase of filtering out options mentioned above. The long-term plan can be based on a definite sequence of investments. largely irrespective of the rate at which trends develop, so that, although the sequence itself may be fairly firm, the timing of them will be flexible.

28. The master plan should have a continuous existence as a formal port reference document. It should be modified periodically, either as a result of a definite decision to take a fresh look at the whole future situation at a given date (and in the present rapidly changing technological stage in shipping a three- to five-year revision would be advisable) or as a regular activity within an annual traffic review.

F. Maintaining capacity during engineering work

29. An existing port must continue to provide an undiminished service during the execution of an improvement or extension project. It is usually the expectation of more traffic than can be handled that is the justification for the project, and it will be self-defeating if the project work itself is allowed to cause congestion from which it may be difficult to recover,

30. An operational programme must be prepared, showing, for the whole duration of the work, how the growing traffic is to be handled in spite of any closures or obstructions. This may show that there will be a need to provide additional temporary facilities purely to maintain capacity during the execution of the project. Such facilities are a financial charge to the project and it may be that their cost will swing the balance over to the choice of a different engineering option. In any case, there will need to be a careful phasing of the engineering work and the commissioning of temporary facilities.

31. The difficulty of maintaining capacity may even cause the port development strategy to be modified. For example, the construction of a new group of berths in two stages may cause less interference in operations than closing a larger area of the port to build them all in one project. Conversely, the faster completion of the group in one project instead of in two consecutive partial projects may in certain cases be less disruptive.

G. Project planning; the feasibility study

32. A project plan usually takes the form of a feasibility study of the best way to satisfy a particular requirement, and it is followed by the design phase. The project plan must be consistent with the master plan and it must be seen as one step in its implementation. A feasibility study claiming to show the need to deviate from the master plan must produce strong evidence in support of this claim. If the deviation is accepted, the master plan will need to be revised to take account of the possible effects on other facilities. All these processes take time, and there may be instances where during the time-lag a clear case develops for a change of direction-for example, if there is a development in technology. It could then be fully appropriate to make the necessary changes even in mid-project, provided that the cost implications are clearly analysed and accepted.

33. Each feasibility study should preferably cover only one proposal. For example, the decision to build a container terminal should be studied as a separate issue from the decision to enlarge the storage capacity of the general cargo berths. Very often, however, both for reasons of administrative convenience and because of physical relationships within the port, several such projects are combined in one feasibility study and one report. Although this is acceptable, the numerical analyses for the various projects should be separate. It is not helpful to include in one economic or financial appraisal several different investment proposals. For example, a combined proposal for two additional break-bulk cargo berths and a new bulk cargo terminal will confuse the decision if only one set of cost and revenue figures is given. It may be that the break-bulk cargo berths are economically justified but are financially loss-makers; the joint proposal will hide this fact and conceal a cross-subsidy from the profitable bulk cargo terminal. This subject is discussed further in chapter II "Planning principles".

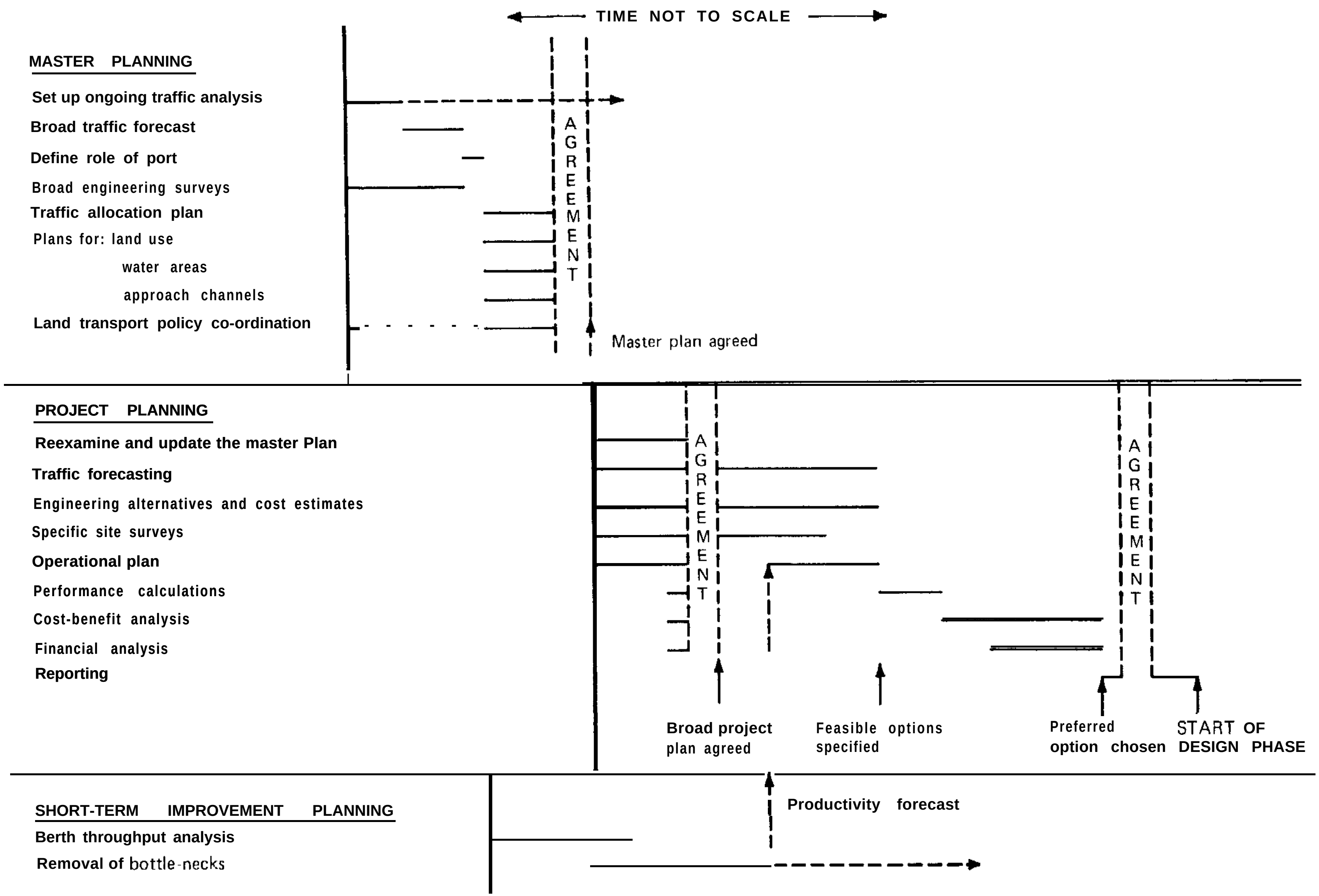
34. Inevitably there will be several areas where technological changes are taking place which might markedly affect the investment plan. Some of these will lie outside the port personnel's own experience, and the project leader of a port development project should seek external advice on these subjects. For example, it should not be his responsibility to carry out an extensive review of the trends in ship technology or cargo-handling methods. Much work has already been done on these topics, and he should be able to refer to it. In the case of any difficulty, reference can be made to the UNCTAD secretariat, which will help wherever possible.

35. Similarly, in economic forecasting, it is not the job of the port planner to carry out an international or even a regional trade forecast, however important these are for him as a basis for calculation of the expected traffic. He should go to other sources for such economic forecasts-normally, the national economic planning agency. However, having pursued those sources as far as possible, he is likely to be left with incomplete information and to have to collect further data himself through various sources such as traders and banks.

36. The procedure of devising a project plan involves finding the solution to a specific requirement and culminates in a justification for investment. It is normally carried out as a clear-cut project with a well-defined programme of work. It is advisable to prepare a summary bar-chart of the full range of project activities, in a form similar to that shown in figure 3. Dia-

FIGURE 3

A typical port planning sequence



grams of this kind show a sequence of activities, pointing out which ones have to be terminated before the next one starts, and thus need to be given priority; they are useful in setting out the range of tasks and skills needed. But they should not, once published, be treated as sacred. In particular, it is not advisable to prevent a subject from being considered before its scheduled time on the chart.

37. The central portion of the bar-chart in figure 3 dealing with the project plan has three main stages indicated by the vertical arrows. The first stage which, after a period set aside for agreement by the authorities, leads to a broad project definition, should take perhaps 10 per cent of the time available, although if little thought has been given to the needs of the future port before starting the project, 20 per cent might be more advisable. Furthermore, if no master plan exists, it may be necessary for a substantial amount of time to be allocated first to the collection of traffic data and to the carrying out of preliminary geological and hydrographical surveys.

38. The work of the second stage includes the preparation of detailed traffic forecasts and broad engineering studies, and the specification of all the feasible alternatives, together with rough cost estimates for each. It also includes the important task of considering, for each alternative, what operational plan and cargo-handling methods will be used. In order that the answers to these practical questions should be realistic, a productivity forecast should be made on the basis of progress recorded to date in consequence of the short-term improvements. This stage should take at least 30 per cent of the project time.

39. Bearing in mind the above remarks, a procedure for planning individual projects can be followed. One step-by-step procedure is shown in figure 4. It consists of two passes through the tasks, the first at a broad level and the second in more detail. In practice planners will rarely be able to follow the procedure exactly in any particular case, and many of the activities will be going on in parallel. There may also be the need for more repeated recycling and improvement of data and analysis. Nevertheless, it is advisable to bear in mind the theoretical sequence and structure of the planning process. The steps are listed and explained in table 3.

TABLE 3

Procedure for port project planning

The 18 main tasks (Al to A18) are as follows:

Task Cl. Derailed traffic *forecast*

Revise master plan forecast and detailed figures for the economic life of the investment proposed.

Task C2. Survey of cargo-handling ***techniques***

For each class of traffic that has been forecast, examine the alternative port-handling techniques and their impact on future productivity, bearing in mind the expected form of presentation of the cargo.

Task C3. Rough dimensions

Group together traffic classes with similar handling characteristics and, for each berth group or terminal, find the approximate level of additional facilities needed and make a rough estimate of their dimensions.

Task C4. Alternative locations

For the berth groups and terminals concerned, propose alternative water and land areas in locations that will not interfere with traffic in adjoining zones and that will provide safe berthing.

Task C5. Engineering surveys

For each location, carry out the engineering studies to quantify the main works required and adjust site locations where necessary to avoid excessive costs. Although engineering surveys should be carried out after task C4 and before task C6, in practice they may need to be continued for the whole period, providing more accurate results as the survey proceeds.

Task C6. Rough costs

Estimate the cost of constructing and equipping each of the facilities under consideration.

Task C7. Selection of promising options

Eliminate the less attractive alternative solutions, discuss conclusions with the decision authority and obtain agreement on a short list of alternatives to be further studied.

Task C8. Labour constraints

Consider the labour questions and manning problems which may arise with respect to each alternative technology in parallel with task *c7.*

Task C9. Preliminary design

For each alternative retained, design the layout of all facilities in sufficient detail to discover access, operating or storage problems.

Task CIO. Operational planning

Prepare plans showing the equipment and operation of the new facilities, and the productivity targets.

Task C11. Capacity calculations

Calculate the alternative levels of facilities needed to accommodate the range of capacities and services that is feasible.

Task C12. Union consultation

Initiate consultation with trade unions on any new cargo-handling techniques proposed.

Task C13. Cost estimates

Refine the cost estimates for all works, equipment and services to produce a basis for the economic and financial analysis.

Task C14. Cost-benefit analysis

Analyse the economic case for each of the alternatives.

Tusk C15. Financial analysis

Analyse the financial viability of each option and review the available methods of achieving sound financing.

Task C16. Draft proposal

Consolidate all analyses and compare advantages and disadvantages of each option in a draft report.

Task C17. National and local approval

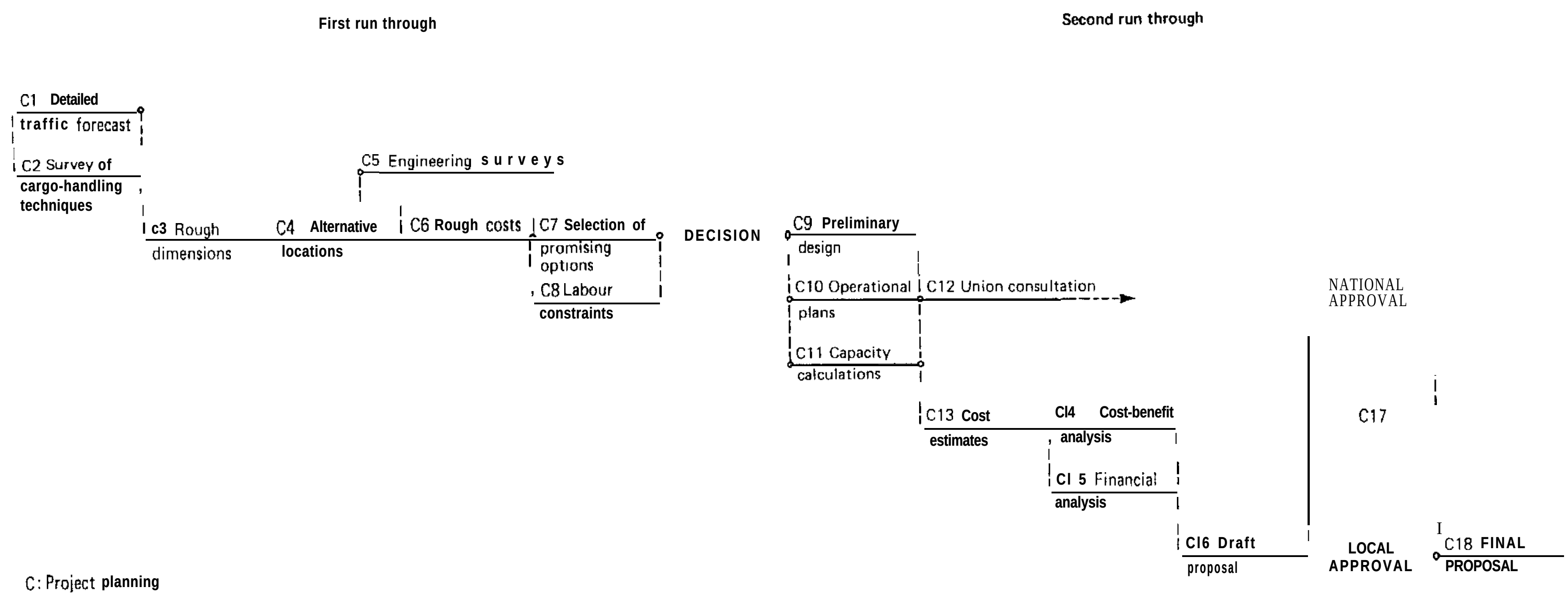
Discuss draft report with local and national authorities and obtain agreement on recommended solution.

Task C18. Final proposal

Formalize the agreed solutions in a report with the supporting analyses.

FIGURE 4

The planning sequence—II



40. The third stage involves the carrying out of the analyses which will show which of the alternatives are the more attractive, and it culminates in a recommendation for a single solution. It is likely to be the longest stage, taking more than 30 per cent of the time. It includes, first, the carrying out of performance calculations to determine what level of service will be given by each combination of traffic and facilities, and then, on the basis of these performance figures, the filtering-out of alternatives, with the use of economic and financial analyses. An 18-step list of the tasks involved in the preparation of a port development plan is given in table 3. The sequence of tasks illustrates the method of gradually narrowing down the alternatives.

H. The **analyses** needed

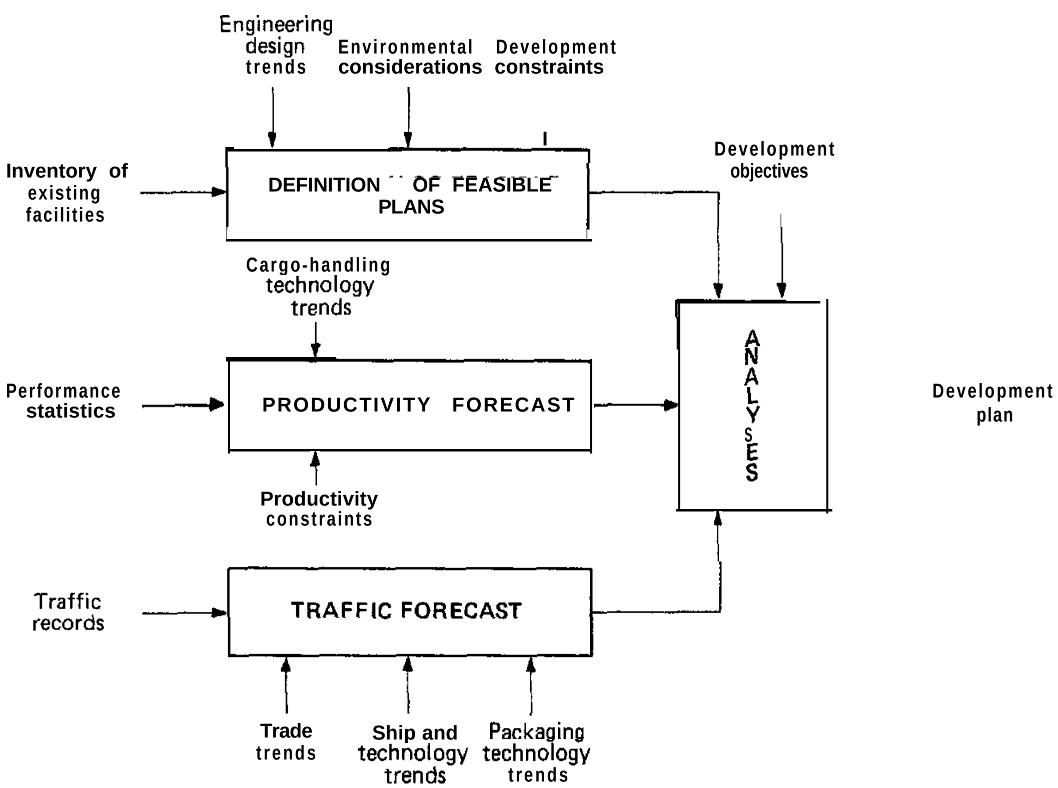
41. In the third stage there is a danger that an inexperienced team will put the emphasis on the wrong task. The economic cost-benefit analysis and the financial analysis, which shows whether a facility will pay for itself, are by far the most important tools to be used in reaching the right investment decision. However, they entail rather laborious and routine calculations which are less interesting to make than the calculation, by novel methods, of the performance of each of the alternatives for the various forecast traffic levels. The appeal of such performance calculation techniques (for example, that of simulation with the use of a computer) can lead to an excessive amount of the valuable project time being spent on them. If a team has a suitable simulation model available, and is experienced in its use, then the work can be done quickly. If, however, the team is new to the method, it should on no account set out to learn the technique during a port investment appraisal. The gain in precision will certainly be at the expense of an excessive amount of time and effort.

42. However, the performance calculations are important and some of the simpler methods which have been used in the past are insufficiently accurate for present needs. For this reason the UNCTAD secretariat has carried out a research programme for the development of a new methodology which will offer a middle course between rules-of-thumb and computer simulation. This methodology is described in part two of this handbook. It consists of sets of general curves which, given a reasonably accurate set of practical input data, give a sufficiently accurate basis for the economic analysis. The performance curves provided have been deliberately designed to have an accuracy matched to the accuracy of the relevant facts and figures known to a typical port planner.

43. To reach a single recommendation on investment, the calculations will need to be done for a number of cases, each concerned with the handling of future traffic by a set of future facilities working at a future productivity. The relationship of these information needs in port development planning is shown schematically in figure 5. Central to this information are the operational statistics necessary for productivity forecasting.

FIGURE 5

Information needed for port development project



44. In summary, the port planning team will need to be provided with the skills and the time needed to carry out each of the following analyses:

(a) A performance analysis to determine the effect of different levels of port capacity on the level of service provided to the port's customers;

(b) Engineering studies to determme the feasibility and approximate cost of each design;

(c) Operational planning to determine how the proposed facilities will be used and what the productivity and the operating costs will be;

(d) An economic analysis to compare the desirability of each alternative in terms of the stream of costs and benefits it generates;

(e) A financial analysis to determine what the revenue will be at different traffic levels and tariffs and whether such revenue will support the costs of the facilities and the servicing of any loans. The effect of the project on existing costs and revenue, and the resulting financial viability of the whole port, must also be studied.

45. Certainly, the whole project involves a considerable amount of work, but in view of the importance to the national economy of finding the right decision, this work is fully justified. It is just possible to bring all these calculations together in one computer model which provides an "optimum" solution. However. this is a very expensive procedure and unsatisfactory as a basis for investment decisions. Planners should rather continue to carry out an individual analysis. with consistent data, for each of the alternatives they wish to study in detail. Where the team has access to computer facilities and skills, these should be applied first to the laborious but straightforward task of carrying out a cost-benefit analysis of a range of alternative proposals, and of their sensitivity to uncertainty in the input data. A well-documented computer programme for this work is available on request from the Central Projects Department of the World Bank.

I. Ancillary services

46. A complete port development plan must include provision for many facilities which are ancillary to the main port operations of trans-shipping and storing cargo. These range from fire-fighting and rescue services to document-handling and data-processing systems. Ancillary services are discussed individually in later chapters and a check-list is given in table 4. They will generally require financial provision, which in total can be a substantial addition to the overall costs of the project. Even if certain ancillary facilities were to be financed separately, provisions should be made for any land required within the framework of the land acquisition plan.

J. Development of the port organization

47. The selection of an appropriate form of port administration is a matter of port policy rather than part of the preparation of a specific port development plan. The basic system of port administration, whether it is to be an autonomous or a centrally directed administration. should be determined by the national ports authority. However, there are certain organizational elements of the administration which are the responsibility of the local port authority. A check-list of these elements is given in table 5.

TABLE 4

Check-list of ancillary port services

1. Pilotage:
2. Tugs;
3. Harbour craft;
4. Navigation aids;
5. Fire-fighting facilities;
6. Rescue service;
7. Medical service;
8. Port security and policing services;
9. Dangerous material area;
10. Equipment maintenance areas;
11. Canteens;
12. Rest-rooms and temporary living quarters;
13 Recreational facilities for ships' crews and port workers:
14. Fuel bunkering facilities;
15. Services (water, electricity, sewerage);
16. Ships' provisions and spare parts;
17. Minor repair facilities;
18. Quarantine facilities;
19. Lighting (for night work);
20. Communications (including ship to shore);
21. Pollution control (huffer zones. facilities for purification of contaminated waters);
22. Waste disposal (dumping areas, incinerators, crushers);
23. Environmental protection (beaches. green areas, open spaces, landscaping)

TABLE 5

Check-list of organizational elements needed in a port administration

1. Organizational structure:
2. Administrative procedures:
3. Cost analysis and control;
4 Tariff structure:
5 Consignment documentation and customs procedures;
6. Electronic data processing and telecommunications systems;
7. Data collection, analysis and dissemination procedures;
8. Staffing and manning policies;
9. Staff selection procedures.
10. Training programmes:
11. Marketing and public relations (including the education of potential users of a proposed new facility).

48. In the case of a new port or of an independent port terminal. planners should take the opportunity to make suggestions for modifying and improving these organizational elements. The possibility of escaping from traditional bad practices can be a powerful argument for developing a new port rather than expanding an existing one. But even in the latter case, where the proposal is for further development of an existing port. the opportunity to introduce modern management techniques in the new facilities should be taken wherever possible. In particular, the introduction of new technologies can spur changes which will improve the operations. For example, the development of a container terminal can be accompanied by the introduction

of modern data-processing methods to improve the quality of the information necessary for managers to control the flow of containers.

49. In any case, whether or not major investments are being made, as the demands on the port change and as the modern business environment changes, there may be a need to adapt the organizational structure of the port and possibly to introduce new functions.

50. It is difficult to generalize as to the best organizational structure for a modern port, but a typical structure is given in figure 6. Attention is drawn to the planning section within the management services department, with responsibility for the following tasks:

(a) The analysis of trends in existing traffic and performance statistics;

(*b*) The analysis and forecasting of future traffic, in terms of shipping and cargo tonnage by types and routes;

(c) The evaluation of information on new technologies in ships and cargo handling as they affect the future port tasks;

(d) The analysis of requirements in water and land areas, equipment and storage;

(*e*) Liaison with all other planning authorities concerned;

(*f*) The preparation and maintenance of the port master plan;

(g) The preparation of specific project proposals.

For major new works, an implementation section may be formed within the engineering department which is given responsibility for the construction of the new works.

51. There may be local reasons why the structure should be substantially different. Further, it should be appreciated that such an organization is more particularly appropriate to a larger port which is to a great extent responsible for its own affairs. For smaller ports, or where it is more appropriate for control to be exercised over several ports together, a number of these responsibilities would naturally be assumed by the appropriate ministry or by the national ports authority. Nevertheless, it would be unwise to transfer any of the functions listed entirely to the central body. However small the port staff may be for the performance of a particular function, a substantial degree of authority and skill should be retained at each port. An exception to this may be the legal affairs function, for which it may be difficult to justify keeping professional staff in each port.

K. Project control

52. It is not necessary, for the supervision of a general port planning project, to use methods of monitoring and control as detailed as those of the engineers who will have to design or construct the facilities. The use of a PERT network is out of place here and critical path methods make little sense in this type of analytical project.

53. A simple method of control is to identify successive goals, or "milestones", along a bar-chart, and to check progress towards each of these goals at regular progress meetings. Satisfactory "milestones" can be simply the completion of the three stages described, each ending with an intermediate decision.

54. Monthly progress meetings would be appropriate in most cases. These meetings should be informal, technical and as extensive as the subjects demand. This will often require at least a half-day of discussion about the work, and this time should be considered well spent.

55. Formal progress reports to management or other authorities can be dispensed with in many such projects. Automatic monthly or three-monthly reports can do more harm than good. A better method is to prepare a report only when there is something of interest to report on, and to provide, on a regular basis. only very brief notes on the subjects discussed at the progress meetings and the actions agreed on. A timetable for producing drafts of reports should be agreed upon in advance.

56. It is inadvisable to delegate responsibility for the whole project to an analyst and let him work in a back room for six months. He must be drawn out of the back room very frequently for discussions with those who know the practical problems. This means that progress meetings should be regularly attended by senior managers responsible for traffic operations and by members of the engineering department. It is more useful to have their views as the work proceeds than to receive their comments after it is finished. However, the project leader must take the initiative in driving on to the end of the project, whatever doubts are expressed (on data accuracy, forecast accuracy, etc.), after he has listened to all comments. Doubts expressed at progress meetings and the need for discussions on technical points should not be allowed to cause delays. The project leader should insist on steady progress on the basis of the best information he has available, with the objective of reaching the scheduled "milestones".

L. Use of consultants

57. In many cases the planning agency concerned with the port development will feel that it lacks certain of the skills needed to complete the work, and, whilst retaining overall control, will wish to hire individual specialists in the missing skills. In other cases, it will be felt preferable to contract out the work in its entirety, Both alternatives are acceptable, but in the hiring of outside assistance certain points should be borne in mind:

(a) Past work, and previous planning studies, even if shelved and not acted upon, should be made available to the new team. Furthermore, even if there are points to criticize in such past work, it will often be more valuable to engage the same team again to carry out a revision or *to* study a new requirement, than to make a fresh start with a new team.

(*b*) It can cost more to ask for urgent early answers than to give the consultants more time to carry out the work at its natural pace.

FIGURE 6

Typical port organizational structure

BOARD OF DIRECTORS

DIRECTOR GENERAL

PORT USERS ADVISORY COMMITTEE

MARINE	TRAFFIC	MANAGEMENT SERVICES	SECRETARIAT	FINANCE	ENGINEERING
Assistant Director-General for Marine	Assistant Director-General for Traffic	Assistant Director-General for Planning	Assistant Director-General for Administration	Assistant Director-General for Finance	Assistant Director-General for Engineering
Director of marine Harbour master Pilots Port craft operators Signal tower staff	Director of traffic Wharf superintendent Wharf inspectors Shed foremen Pier superintendent Port labour	Economist Systems analyst Engineer Cargo-handling expert	Secretary Legal adviser Director of establishment Port police	Director of finance Chief cashier Statistics officer	Civil engineers Electrical engineers Marine engineers Mechanical engineers Draughtsmen
Channel maintenance Navigational aids Movement of vessels Use of port craft Control of pilots Control of marine staff Registration of vessels Survey of vessels Control of signal tower Marine statistics	Cargo handling Allocation of berths Commercial correspondence and claims Operation of sheds Submission of out-turn report Supervision of vessels work Operational control of mobile equipment Operation of barges Control of gates and cargo deliveries Operational statistics	Management information system Planning Port promotion Market research Organization and methods study Preparation of quarterly reports for Director-General	General and despatch section Port security Staff cars Public correspondence Accidents Archives Preparation of agenda and minutes of meetings Liaison with heads of departments Keeping of confidential papers Preparation of annual reports Maintain files for leases, contracts and other legal matters	Collection of revenues Calling of tenders Control, supply and purchase of stores Control and preparation of budget Preparation of salary and bills Payments to staff Payments of public bills Preparation of monthly and annual financial statistics Electronic data processing	All civil engineering works Maintenance of mechanical, electrical, marine and civil engineering works Assistance in port planning Supervision of contractors' work Supervision of slipway and marine workshop

Personnel

(c) The outside team should be contracted to spend a substantial part of the study period at the port location. In return they should be provided with a high standard of office accommodation conducive to intensive work during this period.

(d) Consultancy contracts should name the individuals to be employed on the contract and care should be taken to check the capability of the individuals named. It cannot be assumed that a high-grade corporate capability will be reflected in high-grade individual performance if this is not done.

(e) A liaison officer should be named by the authority to provide a single point of contact with the team, and this officer should be given a satisfactory level of authority in technical and administrative decisions.

M. UNCTAD assistance

58. Assistance in any of the matters discussed in this handbook can be provided by UNCTAD. Informal requests for minor points of advice may be directed to the UNCTAD secretariat in Geneva. More substantial assistance can be the subject of a technical assistance project within the United Nations Development Programme, formulated in consultation with the resident representative in the country concerned.

N. Port development finance

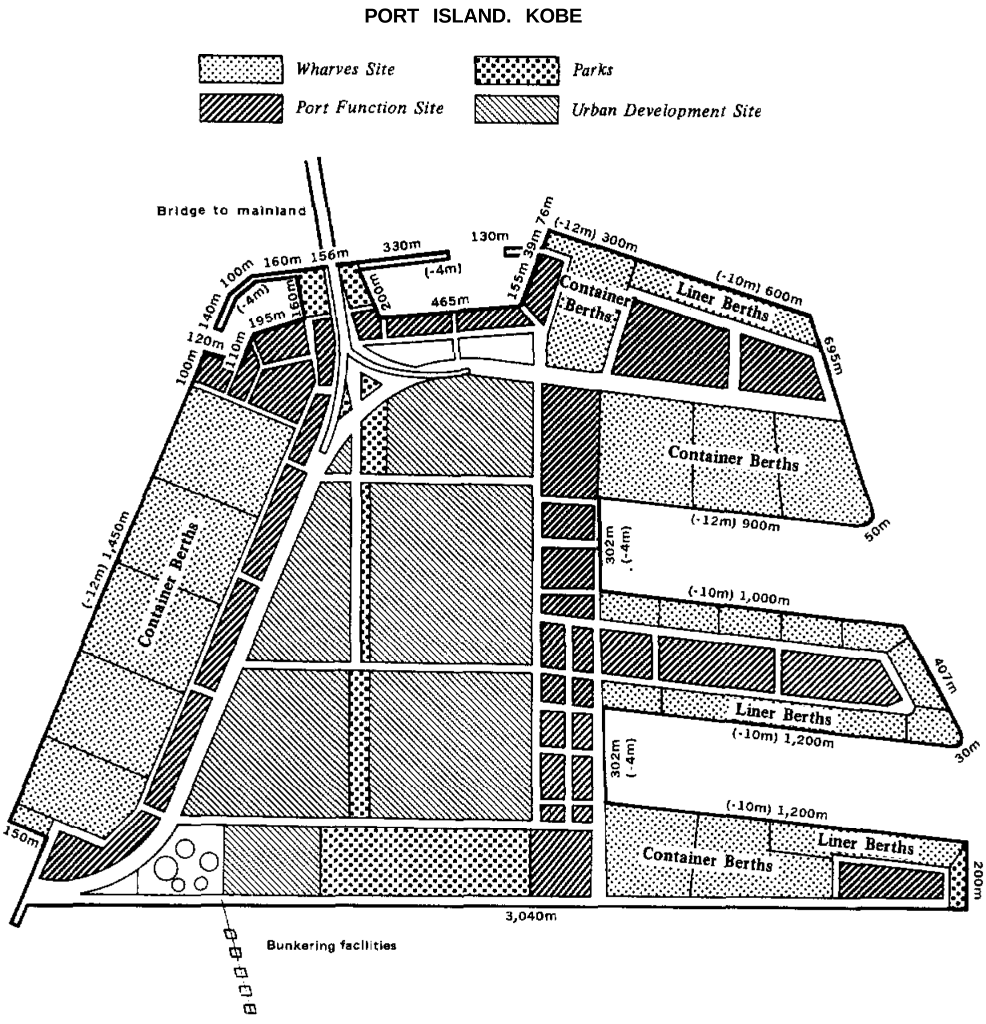
59. The scale of port development can be very large, and in the case of an expanding economy the funds needed will usually require joint action by central government, local municipality and, where appropriate, with international financing organizations.

60. Development projects of as little as one million dollars may be of value, but the more usual port project is more likely to be measured in several tens of millions. At the upper end, it is interesting to examine the financing of a major, self-contained development nearing completion at the port of Kobe, Japan. This takes the form of an artificial port island of reclaimed land, as illustrated in figure 7.

61. The development of Port Island, Kobe, is part of the Osaka Bay Port Development Authority's master plan agreed on in 1968, and in fact reclamation has been in progress since 1966. The work, which is designed to provide 11 container berths and 18 general cargo liner berths, together with full operational and

FIGURE 7

Port Island, Kobe, Japan



commercial facilities, will be completed in 1980-a total development period of 14 years. The first berth was brought into operation in 1969, three years after the start of work on the project.

62. The total budget for the Port Island development was $466 million. This figure includes the cost of transferring 80 million cubic metres of soil by belt conveyor from a nearby mountain site to the shore and then by barge to the reclamation site. The financing of the project was arranged as follows:

	Percentage
Grants from the central government .... ,,, ...	10
Grants from the municipality concerned	10
Long-term financial loans from the central government	40
Long-term financial loans from the private sector (shipping companies and terminal operators with exclusive use of facilities)	40

The 80 per cent long-term loan funds are in the form of the issue of Port Development Authority bonds.

0. Contents of an investment proposal

63. The proposal for a major port investment prepared for submission to an investing authority should be set out in a manner similar to the following:

(a) Rationale for the proposal;

(b) Status of the proposal (will the project proposed compete for capital with other projects, or is it an alternative to another proposal?);

(c) Traffic forecast, giving background assumptions, expected future developments, and margin of uncertainty;

(d) Productivity forecast, giving reasons for any estimate which differs from the current productivity, and any training needs associated with this;

(e) Operating plan for the new facilities, including traffic allocation policy and contingency plan for periods of peak demand;

(f) Performance analysis, indicating expected turn-round times and berth-day requirements for each class of traffic;

(g) Tariff proposal;

(h) Cost-benefit statement;

(i) Financial statement, including cash-flow forecast and statement of risks and uncertainties.

P. Procedure for implementation of port projects

1. THE IMPLEMENTATION SEQUENCE

64. The last phase of preparatory work for a port development project consists in making arrangements for construction. The best plans can be seriously harmed by unsatisfactory construction work or by neglect in selecting the correct building materials. The span of useful life of newly built facilities may be shortened, and consequently the amortization of the invested capital made more difficult. Moreover, urgently needed works may be delayed unless the actual implementation of a major port project is carefully prepared.

FIGURE 8
The overall procedure for port development

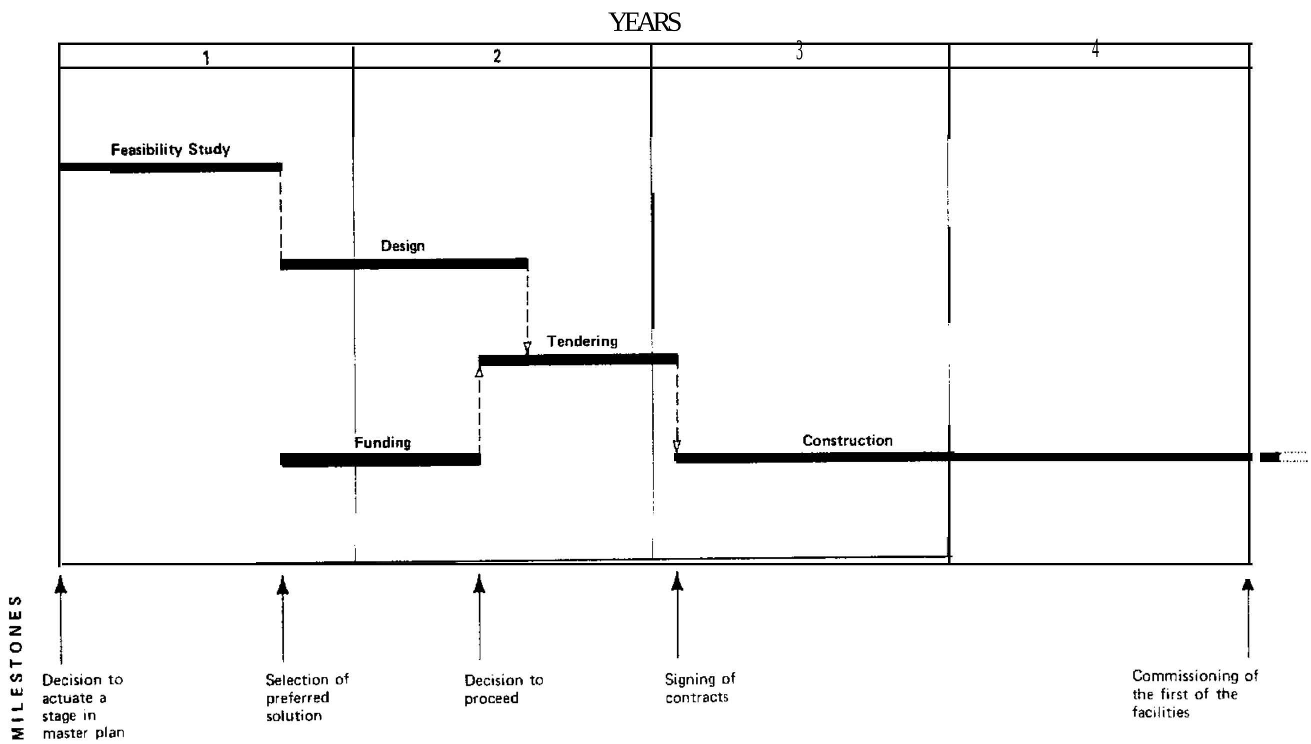
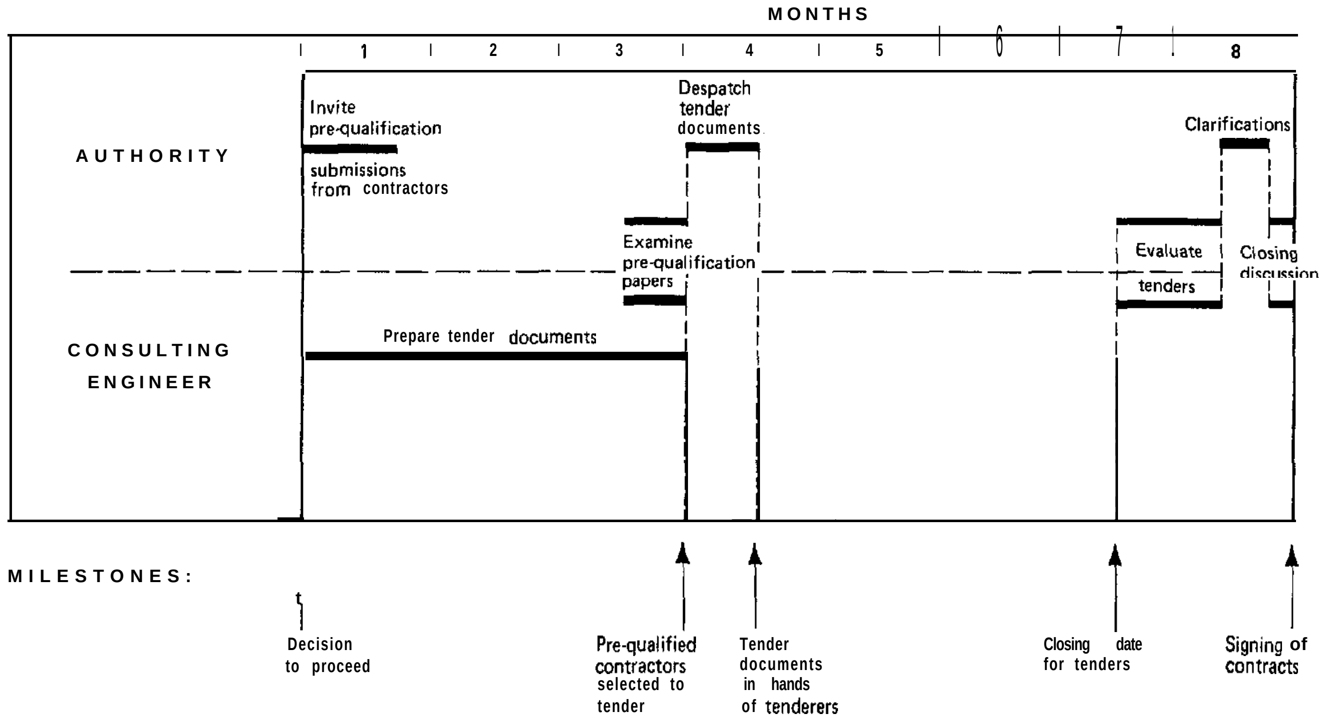


FIGURE 9

A typical tendering sequence



65. The feasibility study shown in the central portion of figure 3 is followed by a design phase of the selected alternative and is normally carried out by consulting engineers. The field investigations discussed in chapter VII; "Civil engineering aspects", are carried out, and detailed layout and design of all facilities is completed, together with cost estimates. It may be necessary to carry part-way through this design phase a choice of two major alternatives, postponing the final decision until sufficient engineering and cost implications of each allow a single design to be chosen.

66. The overall procedure of planning, design and construction is illustrated in figure 8, where it can be seen that even with no delay for decision-making, and with the procurement of funds starting as early as possible in the design phase, the first works are unlikely to be complete in less than 4 years. Therefore, as soon as the decision to proceed with the chosen project design has been taken, time can be saved by setting out a systematic programme of dates for the often protracted tendering sequence. Figure 9 shows a typical sequence in which 8 months elapse between the decision to proceed and the point at which the main contract can be signed. A fuller set of guidelines for procurement is given in a brochure issued by the World Bank.[3]

2. TENDERING POLICY

67. Particularly for major port projects, it is advisable to seek offers from several contractors in order to be able to select the most advantageous one. Care should be taken to deal only with firms of high professional standard and ample experience in marine construction work. Low-priced offers that may be submitted by less competent and experienced contractors can be very costly in the final analysis, as difficulties and delays may arise and claims may be made for additional compensation.

68. In general, it is desirable that one general contractor should be made responsible for all civil engineering works and for medium-sized specialized installations such as generating plants, lighting equipment and not overly complicated mechanical equipment. Confusion can arise at the site if two or three contractors are carrying out their respective tasks simultaneously, especially if the tasks are of a similar nature. Specialized installations, such as a grain silo or facilities for a major bulk cargo terminal, require contractors specialized in the fields in question. Such services could be provided by a subcontractor nominated in the prime contract. Civil engineering works connected with some special installations, such as foundations, may be left in the hands of the general contractor. For large dredging works, a separate tender is almost unavoidable. Civil engineering contractors cannot be expected to have the necessary costly and diversified equipment.

69. In some developing countries there are capable local contractors of international standing who would normally be pre-qualified. But it would be unwise to restrict tenders for large projects to local contractors, since the benefits of international competition and of an access to a wide range of technical expertise would be lost. The employment of local firms may be obtained by encouraging foreign contractors to subcontract as

[3] *World Bank, Guidelines for Procurement under World Bank Loans and IDA Credits* (Washington, D.C., 1977).

widely as possible to local organizations for less complicated works. Only for minor projects would it be appropriate to restrict tenders to local contractors. In many countries foreign bidders are required to enter into a partnership with a reliable local firm.

70. For the construction of large port complexes, even the basic civil engineering works can be divided into a small number of separate contracts. The breakwaters may well be built independently from works within the port area as there would be no danger of mutual interference, and since the construction of large breakwaters can be a difficult task requiring the full attention of a contractor. Separate tenders will also normally be arranged for dredging and reclamation, which are usually very extensive in such big schemes. Nevertheless, for the sake of administrative convenience and simplicity a main general contractor may be entrusted with all or most of the construction work with the understanding that, by agreement with the Government, he will enter into partnership with other firms or employ subcontractors.

71. At an early stage, well-known international contractors should be asked whether they are interested in the project and willing to submit offers at a fixed date. If so, they should send pre-qualification papers listing their relevant experience and achievements. Advertisements in professional publications or leading daily newspapers can supplement individual letters in order to reach a wider range of firms. The character and scope of the project need be only very briefly indicated in the letters and advertisements.

72. Upon receipt of pre-qualification papers, a list can be prepared of firms qualified to submit tenders. At this point the temptation to pre-qualify too many contractors should be resisted. However, a proportion of those invited will normally not tender. The objective is to have sufficient tenders to obtain a broadly based comparison. Tender documents are then sent to the selected firms with a request to submit offers by a certain fixed date. The tender documents will be the basis of the future contract. It is generally preferable to inform each firm invited to tender of the names of the others. Little purpose is served by secrecy in these matters and there can often be a definite advantage in speeding up the possible process of the formation of partnerships or consortia.

3. TENDER DOCUMENTS

73. A clear and full description of the project should be given, in addition to the technical. financial and legal conditions of contract. Only with sufficient understanding of the required port facilities, and reliable information on local natural and labour conditions, can a contractor submit a realistic offer. Three months should be allowed to all bidders for preparing and submitting their bids, and each bidder must be required to visit the site of the future work in order to become acquainted with local conditions.

74. Detailed conditions of tender, including conditions of contract, technical specifications of all works, bills of quantities, etc., usually form a volume of some 200 pages. They must be prepared by a team of engineers well acquainted with the drafting of such documents. The International Federation of Consulting Engineers (FIDIC) and similar approved associations have standardized conditions of contract which will be of assistance in this task. This task is normally beyond the capacity of an average port administration. and it is appropriate to retain a firm of consulting engineers for the preparation of tender documents. This is a natural continuation of the previous task of consultants who have assisted in the planning of the proposed port facilities.

75. Typical tender documents consist of two parts: general information for the bidders, and detailed specifications of all works. The general information includes the following:

(a) Practical data about the submission of bids, the closing date, and so on;

(h) A full description of the project;

(c) Basic information about local conditions;

(d) A statement of the guarantees required (a small bid guarantee (2-3 per cent of the contract value) and a more substantial performance bond or bank guarantee by the successful bidder (10-15 per cent of the full price of works));

(e) The conditions of contract (standard form plus variations);

(*f*) A bill of quantities in which the bidder has to insert unit prices for each category of work;

(g) Questions concerning legal provisions, arbitration procedure. the problems of contractor's responsibility and modalities of payment are usually dealt with in the conditions of contract. Price escalation clauses noting adjustment provisions and ceilings should be clearly defined. It is very helpful to the bidder if a standard form of contract is used.

76. Arrangements may be included in the conditions of contract for advance payments of the contractor for his mobilization expenses, which can be substantial. Heavy cranes, pile-drivers, bulldozers, graders, trucks, trailers and passenger cars, and possibly a dredger with auxiliary equipment, may have to be brought from abroad at a high cost. Housing, storage sheds for building materials and canteens have to be provided, which often require a special water supply and a small power plant: bidders should be asked for a separate quotation for such items. An alternative method, which is not recommended, particularly for a large project, consists in requiring the bidders to include prorated costs of initial expenses in their quotations of unit prices for the various works. The unit prices become artificially inflated by this procedure and excessive payments will have to be made if additional work not foreseen in original plans is to be performed, or if the quantity of work is at all higher than indicated in the bill of quantities.

77. The second part of tender documents includes:

(a) A list of the equipment that the contractor has to bring to the building site and of temporary facilities to be provided for his staff, the workmen and the supervising team.

(b) Specifications proper, that is, detailed descriptions of all things to be done by the contractor, the materials to be used, their storage, handling, sampling and measuring, and the way in which various construction activities should be organized. The written specifications are supplemented by a set of basic drawings as an integral part of contract conditions.

78. It is a good practice to authorize the bidders to make their own proposals for modifying some technical conditions of tenders and to submit an alternative offer with full design data, in addition to the mandatory offer in compliance with the tender documents. The more experienced contractors may be able to make useful suggestions for slight modifications of the designs or for the use of different materials that may result in lower prices without affecting the quality or character of the works.

79. Price quotations must be made by the bidders in unit prices. For each item listed in the bill of quantities, the bidder must enter two separate figures, one for the claimed unit price (per cubic metre, square metre, kilogram, tonne, etc.) and another for the entire item in accordance with the quantity indicated. However, payment is made in accordance with the quantity of work actually performed as measured by the supervising engineer and not according to the quantity originally estimated, as shown in the bill of quantities. A different method of pricing is often used for items where the quantity of materials and the amount of work can be estimated accurately in advance, for instance, an office building. In this case a lump sum price for each of such items should be entered in the bid, so that no measurements will be necessary after completion of the work but only the usual control of quality of work and materials. A similar procedure is used for prime cost items, for example, equipment specified in the contract.

4. BID EVALUATION AND AWARD OF CONTRACT

80. Bid evaluation has the purpose of determining the value to the authority of each bid and the determination of the lowest evaluated bid (which may not be the bid offering the lowest price). In addition to the bid price, adjusted to correct arithmetical errors, other factors such as the time of completion of construction or the efficiency and compatibility of the equipment, the availability of services and spare parts and the reliability of the construction methods proposed, should be taken into consideration. To the extent practicable these factors should be expressed in monetary terms according to criteria specified in the bidding documents.

81. A report on the evaluation and comparison of bids setting forth the specific reasons on which the determination of the lowest evaluated bid is based should be prepared by the authority or by its consultant. The award of a contract should be made to the bidder whose bid has been determined to be the lowest evaluated bid and who at the same time meets the appropriate standards of capability and financial resources. After final clarifications and discussions, the contract can be signed and unsuccessful contractors notified and bid guarantees returned.

5. SUPERVISION OF WORK

82. The work even of a qualified and reliable contractor must be properly supervised to satisfy the interested government or port administration that everything is being done fully in accordance with the approved plans. The first duty of site supervisors is to verify the quality of materials and work. Building materials must be inspected before they are shipped from their place of origin. The method of transporting them, their storage at the building site, and the cleaning and other treatment of materials in preparation for use must be carefully watched. Methods of work and technical operations such as the mixing and placing of concrete should be supervised.

83. A second function of site supervisors is to measure the quantities of work performed and of materials used by the contractor in order to determine the amount of periodical part payments. Usually, such payments are made monthly on the basis of certificates signed by the supervising chief engineer. Payments are calculated on the basis of unit prices quoted in the contract, with the application of the price adjustment coefficient and the quantities measured by the supervisors.

84. The supervisor also has a role in providing guidance and, where appropriate, direction to the contractor and in helping to resolve difficulties. He is required to explain the more complicated parts of designs, to supply additional drawings and to issue instructions in case of doubt. He ought also to appreciate that suggestions made by a contractor with wide experience may be of great value, even though they may be at variance with some provisions of the original specifications. In such cases, provided that the variation is carefully recorded and signed by both parties, noting the implications both as to time and as to cost, the variation may be accepted. Finally, the supervisor may have authority, under the arbitration procedure, to decide on matters in dispute under the contract.

85. To organize such supervision may be a simple task for a relatively minor project but for a large project a strong team of supervisors is needed, since all the above-mentioned tasks cannot be performed by a single person. Civil engineers, mechanical and electrical technicians, surveyors, accountants and office staff are needed for a large project, in addition to an experienced engineer as chief of the supervisory team. These persons must have at their disposal appropriate office facilities, living quarters and transport, all of which may have to be provided by the contractor under the conditions of contract. In addition, the team may have to call on specialized assistance from time to time.

86. It is therefore an appropriate practice to entrust the task of supervision to the firm of consulting engineers which prepared the detailed plans and specifications for the project. The firm's staff are best acquainted with the designs and are thus in a favourable position to offer guidance or direction to the contractor. Few port authorities are able to provide for such supervision from among their own staff, but it would be valuable to attach to the supervising team one or two qualified port staff.

6. Design and construct tenders (turnkey contracts)

87. A different procedure may be used for urgent port projects. Instead of providing prospective bidders with final designs and specifications, a small number of highly experienced firms is invited to propose particulars of construction. prepare specifications themselves and submit them together with price quotations. A general description of port facilities. their character. size and general layout are supplied to the bidders, and it is up to them to select the best structural design and most appropriate building materials. This kind of agreement is also known as a turnkey contract as the builder is expected to design and to construct a complex of facilities in full operational order.

88. Advantages of the turnkey contract are twofold. The first is considerable saving of time, as price calculations are made simultaneously with the preparation of specifications in a single operation. Secondly, the interested port administration may receive a larger variety of ideas and designs from highly experienced sources at a relatively small cost.

89. A well-qualified staff is needed by the port administration for the preparation of basic plans together with other conditions of contract, and later to evaluate the varying technical offers, particularly the different specifications proposed, and to supervise the works. Not many ports have a sufficiently competent staff for this, so that consulting engineers may still be needed. Although a potential saving of consulting engineer time exists, this is unlikely to be great.

90. To prepare such a design and construct offer is a difficult and costly task which can be successfully performed only by firms organized for both port planning and port construction. The number of firms invited to submit offers should be limited to not more than three, since otherwise the incentive for participation would be very small. The high costs of preparing the bid would not be justified by a small chance of obtaining the contract in the face of competition. It is therefore fully appropriate in a design and construct tender to offer a moderate compensation for the preparation of offers, irrespective of the final award of the contract.

91. The design and construct method is more often applied to work requiring very specialized technologies, such as oil refineries, petrochemical plants or even large grain silos. Nevertheless, it can also be used for more general port construction projects if particular circumstances so warrant.

7. Tenders for dredging and reclamation

92. Conditions of contract for a major dredging project are usually standard amendments to the FIDIC forms. It is not easy to determine in advance the quantity of material that is to be dredged or the exact nature of the soil. For purposes of payments, therefore. the formula for measuring the amount actually dredged must be carefully established. Conditions of tide and weather may seriously affect dredging operations and the kind of equipment to be used. Tender documents for a large dredging scheme should be prepared with particular care, and the data gathered during the field investigations discussed in chapter VII, "Civil engineering aspects", should be made fully available to the bidders.

93. The target depth of water to be achieved can never be expected to be reached exactly by the contractor owing to the very nature of dredging. A fair tolerance must be allowed for in tender documents; and in any case the quantity of material moved can be determined only approximately. Descriptions of the kinds of soil which will be found should be as accurate as possible. The nature and the estimated quantity of each kind should be listed in tender documents, together with an indication of the degree of accuracy the estimate is believed to have. The classification of soils should preferably be made in accordance with the 1972 Report of the Permanent International Commission of PIANC;[4] a different nomenclature may be misunderstood by the bidders. The classification of rock materials is less standardized, so that a detailed description in the tender documents is essential.

Q. Participation of project planners

94. Since most of the routine work of implementation is usually entrusted to consulting engineers, the local port planning team has the opportunity to concentrate its attention on the continuing substantive aspects. Team members should follow-the progress of work to ensure that the conceptions and designs are transformed into reality as technical facilities, each of which has a pre-determined function. Small errors and apparent imperfections can usually be corrected during the construction period.

95. When the newly built facilities become operational, it is highly advisable for the port planners, or at least a part of the original local team. to observe carefully current port operations in order to see how various particulars of the design and layout affect the efficiency of the daily work. Observations of that kind, carried out for a certain period of time, will serve as a most valuable guidance for planning future facilities and for possible improvement of those just completed.

R. Project proposals

96. Documents which are thick are difficult to handle and, while they are superficially impressive, they are less likely to achieve their purpose than smaller documents. Many reports are deliberately made bulky by:

Printing on one side of the paper only;
Using double line spacing;
Attaching unnecessary reference material and statistics;
Using heavy paper.

Reports of this type should be suspected since they imply that the authors are relying more on the quantity than the quality of the contents. A good proposal even

[4] The Permanent International Association of Navigation Congresses. 155, rue de la Loi, Brussels. Belgium.

on a major project can be a thin, convenient document, as shown by the World Bank port appraisal reports. These usually do not exceed 25 pages of text and 40 pages of factual annexes and are printed in a format which gives a thickness of about 6 mm. This criterion should be made clear to both internal and external authors as part of their terms of reference.

97. A standard layout for the presentation of port project proposals is given in the annex to this chapter. The layout comprises the full contents for a major proposal. For smaller propsals, only relevant sections need to be completed.

ANNEX

STANDARD LAYOUT OF A PORT PROJECT PROPOSAL

I. SUMMARY

A short presentation of the essential facts from each of the following sections of the proposal, from a few words on the background to the key figures of the analyses. For a major proposal this may be as long as two pages, but for minor projects it should be less than one page.

II. BACKGROUND

This should be a brief recapitulation of the relevant parts of the master plan where this exists. It will normally include the following:

1. National economic setting: national priorities, targets and forecasts of key economic indicators that affect the transport sector.
2. Transport sector perspectives (both national and local): effects of the infrastructure on the port; relevant investment plans; expected transport events.
3. Long-term traffic scenarios.
4. Long-term zoning plan.
5. Review of future projects.

III. EXISTING FACILITIES

This description should be limited to those facilities which play a part in the particular project proposed. It should give key facts, where applicable, on:

Organization and management;
Operations and maintenance;
Physical description of existing facilities;
Users and level of existing traffic;
Tariffs and present financial performance.

IV. DESCRIPTION OF THE PROJECT

This section should be able to stand alone as a clear statement to the reader of why the project is proposed, what it consists of, how it is to be implemented and what impact it will have.

1. Objectives: the project objectives should be stated in terms of the effect it is expected to have, for example, to enable the port to handle containers effectively; to shorten the time for the overland transport of goods; to relieve congestion at the general cargo berths; or to improve the standard of equipment maintenance. Most project proposals will have only one objective.
2. Status: it should be stated whether the project is a part of a wider investment programme or master plan, or is a new requirement.
3. Description of proposed works [or proposed purchase of equipment, etc.): this should be a summary of all aspects of the proposed activity which are described in detail in an annex to the proposal. The headings under which this description should be organized vary widely according to the nature of the investment, but will often include the following: infrastructure works (quays, surfacing, dredging, etc.); equipment procurement (cargo-handling and harbour craft); storage; services associated with the main works (utilities, administrative buildings, workshops, housing); expropriation or purchase of land; technical assistance and training associated with the project.
4. Cost estimates: however tentative the figures, estimates of every item of cost involved in the project should be listed, preferably broken down into local currency and foreign currency components. Today's prices should be used.
5. Financing plan where appropriate, depending on the stage of planning: a statement of sources of finance, loan requirements, rate of disbursement.
6. Implementation: a description of how it is proposed to go about the procedures of design, tendering, project management, procurement and construction, and an outline schedule for all these activities in the form of a bar-chart.
7. Impact analysis: statements on the checks that have been made to ensure that there will be no unacceptable detrimental effects on the environment, from the point of view of: fishing; agriculture; marine life (fauna and flora); local employment; urban development; leisure activities; and historic sites and monuments; and on any protective measures which may be necessary.

V. ECONOMIC EVALUATION

Two subjects may be included here: (a) why the facilities are needed; and *(b)* evidence that the economic evaluation *is* favourable.

In the case of a minor project, only the first item may be needed, since economics may not enter into the decision (the financial evaluation being the sole criterion).

Item (a) may consist of an explanation of such factors as: the pressure of demand on existing facilities; the deterioration of the level of service; the expectation of new demands.

The economic evaluation will be a full analysis of the economic criteria and a demonstration that the project is being proposed at the right time with respect to the rate of growth of traffic.

The traffic forecasts should be summarized in this section, with reference to a detailed annex. The appropriate combination of alternative scenario elements should be used, showing the sensitivity of the analysis to the key factors, which will be different for each project. For example, in addition to analyses for high and low traffic forecasts, analyses may be for two different rates of output, or for different transit storage times, or for different numbers of major equipment items, according to what is the most crucial for this project. It will seldom be possible to analyse the effect of all combinations.

VI. FINANCIAL EVALUATION

This is a standard presentation of the financial viability of the project. For minor projects, a detailed financial evaluation will not normally be appropriate, although a financial evaluation of the investment is still required.

ANNEXES

All extensive tables and statistics should be placed in separate annexes at the end of the report.

Chapter II

PLANNING PRINCIPLES

A. Port planning objectives

98. Many changes have occurred in the technology of ships and cargo handling, and this development is likely to continue. A key principle in planning seaport facilities, therefore. is that development plans should be as flexible as possible to allow a prompt response to changing demand.

99. Ideally, the facilities which a port provides should be designed jointly with the ships which will use them, the land transport and the port facilities at the other end of the route-that is, as part of an integrated transport system. Unfortunately, this ideal can rarely be achieved. It is possible only when the whole transport chain is under a unified management, for example, in the case of a specialized bulk chemical cargo terminal associated with a local chemical plant, where the managing authority also controls the shipping fleet and the land distribution system: or again, in the case of a door-to-door container operation, where the carrier manages the whole system.

100. In such cases, the planner should consider the port problem entirely in the context of the larger transport system of which the port is a part. The planner should not forget that strategic and social considerations play an important role in the location of a new port. Within these considerations he should, however, encourage and assist the industrial planners to search for the overall economic optimum between, for example, ship size, rate of discharge, size of buffer stock and hinterland transport facilities. At this stage the planner should also examine the technical specifications of the ships proposed, to bring to light any technical problems which may arise in the port.

101. More often, such all-embracing plans will be very difficult to draw up and implement since they involve many different interests. Insisting on an integrated transport plan as a preliminary to port development may then cause serious delay. Moreover, in the case of a public berth to handle general cargo there will be so many different users, each with their own physical distribution systems, that there would be little meaning to integrated, transport planning. In that case the port development planning can safely go ahead with the following objective:

To provide port facilities and operating systems in the national interest at the lowest combined cost to the port and port users

102. To plan for such an objective demands a good knowledge of the future customers and their probable cargoes, and is the traditional form of port planning. It aims to produce the best plan for whatever traffic demand is placed on it without trying directly to influence the form of that demand. Naturally any promotion activity in favour of the port, and efforts to attract traffic and increase its volume, should be taken into consideration.

B. The investment plan

103. Ports in developing countries should normally plan on the basis of a continuing climate of growth for the next few decades. The continuing expansion of overseas trade in the majority of developing countries implies a continuing expansion of maritime trade, and in order to serve a fully developed hinterland the extent of port facilities required may be several times greater than those existing at present. Clearly, in spite of the offsetting effect of the introduction of the use of containers and of import substitution policies, there are grounds for believing that developing countries will in general see a strong continuing growth of demand for new or improved port facilities.

104. There will be technological and social developments that necessitate the use of new types of facilities or different locations, for example, sites nearer deeper water or at a newly planned industrial centre. There will thus be a break with the past and the need for a new development policy, independent of previous plans. But in many cases the build-up of demand will be continuous. and the adoption of the new technology will be gradual during a sequence of investments. For example, as described in part two, chapter IV, a multipurpose genera1 cargo terminal may be implemented in stages, each of which takes account of existing general cargo facilities. In such cases it is advisable, both from the engineering and from the economic points of view, to ensure that the investments are in fact treated as a sequence.

105. The master plan for each port should set the long-term development strategy, and this in itself should indicate likely investment sequences. Before taking a decision on any one development project within the master plan, the investing authority should call for comparative economic analyses of several variations in the sequence of which it forms part. The major variations which should be studied should include:

(a) Delaying capital investments by investing instead in improved productivity (equipment, special installations and associated training programmes);

(b) Improving existing facilities instead of building new ones;

(c) Combining the first and second stages of a development programme into a single large project in order to economize in construction costs and to avoid the interference in port operations which would result from a second period of construction activity;

(d) The simple economic policy of investing in facilities one by one as the demand for them builds up.

The first two methods should be employed to the extent possible, before investment is made in the expansion of facilities.

106. The most appropriate plan will usually comprise a mixture of all four of these possibilities, and therefore mathematical methods of optimizing the development policy are not often likely to be of assistance. There is no satisfactory alternative to calculating the economic and financial results of each of the development sequences and comparing them in detail. This work of searching for the best sequence of developments through which the port should pass on its way towards a growth target, rather than merely finding the best configuration to handle a given traffic forecast, can be readily carried out in the form of a discounted cost and revenue analysis.

107. A major advantage of having studied an alternative investment sequence is that at any time during the period after the initial investment has been committed, it will be relatively easy to change the plan as circumstances change, the requisite information being available. This adaptability is an important feature of the continuing development plan, calling for the regular updating of systematic traffic forecasts and the ability to recognize and take quick account of sudden changes in shipping services or traffic demands. Traffic forecasting is discussed in chapter III below. The principle to be established is that the port management should maintain a permanent ability to recognize changes in demand and to re-assess the development programme. Steps which could be considered are:

(a) The setting up of small permanent planning and market research sections;

(b) The institution of periodical (e.g. quarterly or semi-annual) planning meetings at which any new developments are reported and possible action is discussed;

(c) The incorporation in each development project, whether supported by national resources or by external funds, of the possibility of modifying it, if necessary, at any suitable stage of its progress;

(d) Ensuring that the economic, operational and financial calculations of each of the alternative proposals are properly documented and stored for easy reference.

C. Terminal design principles

108. Part two of this handbook gives methods of calculating the required capacity of a terminal to handle a given traffic demand. For these calculations, different principles have been applied, depending on the nature of the different classes of ship traffic:

(a) For conventional break-bulk cargo, it is necessary first to ascertain the number of berthing-points needed in order to keep ship waiting time down to an economic level;

(b) For container cargo, it is necessary first to determine the area needed to handle the annual throughput without impeding the operation;

(c) For specialized bulk cargo, it is necessary first to find the hourly rate of discharge or loading that is needed in order to handle the ships in an acceptable period of time.

109. Although the starting point for each calculation is different, the full method requires the joint study of productivity, the number and size of facilities needed and the level of service to be provided. The relationship between terminal capacity and level of service provided is a basic feature of all development plans, and is discussed in the following paragraphs.

D. The problem of planning berthing capacity

110. If ships arrived in port with complete regularity, and if the time taken to discharge and load ships were constant, it would be a simple matter to determine the berthing capacity that would guarantee both the full utilization of berths and the avoidance of "queueing" by ships. Unfortunately, such an ideal situation can never exist. Liners, and more particularly tramp vessels, arrive in port as if at random. In addition, the time taken to discharge and load ships varies considerably owing to variations in the quantities and types of cargo handled, the way cargo is stowed and the cargo-handling rate.

111. This combination of a variable ship arrival rate and a variable ship working time means that a 100 per cent berth occupancy could be guaranteed only at the expense of a continuous queue of ships. Similarly, the guarantee that ships would never have to wait before being able to berth could be given only at the cost of extremely low average berth occupancies. Neither of these two alternatives is acceptable. What is required is a compromise between these two extremes.

E. Cost considerations

112. Port costs are made up of two parts:

(a) A fixed component which is independent of the tonnage throughput (including the capital costs of quays, sheds, cranes, etc.);

(b) A variable component which depends on tonnage throughput (including labour and staff costs, fuel, maintenance costs, etc.).

As the tonnage handled at a berth increases, so the fixed component, when expressed as a cost per ton, decreases. The variable component, when expressed as a cost per ton, will probably remain fairly stable until the berth comes under pressure to achieve high tonnage throughputs, at which point the variable cost per ton will tend to rise owing to the need to use more costly methods of cargo handling. Figure 10 illustrates the relationship between the port cost per ton and the throughput. It can be seen that the port cost curve (which is the sum of the fixed and the variable components) reaches a minimum value when the rate of reduction in the fixed cost per ton equals the rate of increase in the variable cost per ton (point A on the graph).

113. Then there is the cost of ship's time in port. This time is also made up of two parts:

(a) The time the ship spends at the berth;

(b) The time the ship spends waiting for a berth to become vacant.

FIGURE 10

Variation of port costs with increasing traffic

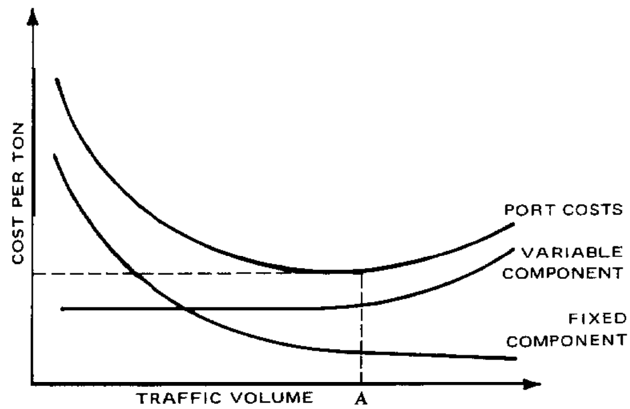


FIGURE 11

Variation of the cost of ship's time in port with increasing traffic

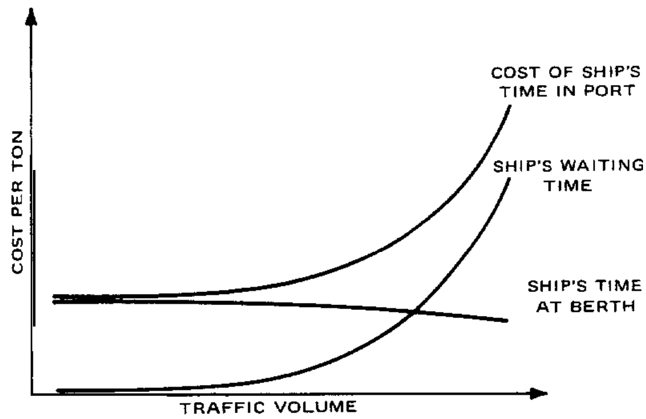
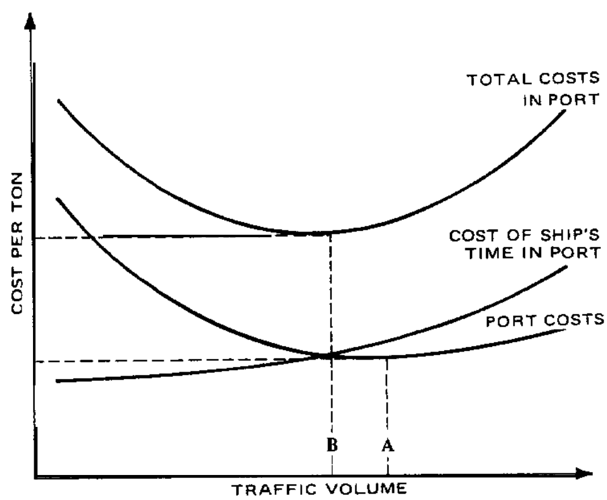


FIGURE 12

Variation of total costs in port with increasing traffic



As traffic increases, the time ships spend waiting to obtain a berth increases. At high berth occupancies, this increase in ship waiting time is quite dramatic. as is shown in figure 1 1.

114. The total costs incurred by ships in port is found by adding together actual port costs and the cost of ship's time in port, as illustrated in figure 12. The total cost per ton curve also has a minimum point (point B on the graph), but this minimum is achieved at a lower throughput than that at which the lowest port cost occurs (point A). Port planners need to be aware of this most important point. Planning to minimize port costs alone will generally result in an unsatisfactory level of service to shipowners which can lead to congestion surcharges and will not be economically acceptable.

115. The minimum total cost depends on the size of the various cost elements. The location of this minimum is dependent on the relative capital costs of ships and of berths. Thus, in respect of break-bulk general cargo ships, higher berth occupancies are economically justified than is the case in respect of the much more expensive specialized vessels such as container ships, tankers and liquefied natural gas carriers. For this reason figures 10, 11 and 12 do not have quantified scales. Furthermore, the shape of the curves and hence the position of the minimum depends on the relationship between berth occupancy and ship waiting time, which is complex. Queueing theory. a mathematical technique, can be used, but there are dangers in using the published tables based on this theory without an understanding of the assumptions involved.

116. To assist the planner in choosing terminal capacity. part two of the handbook provides planning charts which bring into play all the important practical factors. They include a sufficiently accurate relationship between waiting time and berth occupancy to enable planners to find the optimum economic capacity needed to meet a given traffic demand. The relationships are based on a distribution of arrival and service times which corresponds most closely to typical conditions.

F. Berth occupancy

117. Care is needed in interpreting records on berth occupancy, if this is to be used as a yardstick for future plans, or for comparing the relationship between berth occupancy and throughput at different terminals. Berth occupancy is a measure of facility utilization and should not be used as a measure of traffic demand unless the other main factors-resources used, productivity, berthing policy-remain constant, which is rarely the case.

118. For example, a certain container terminal was keeping monthly statistics both of berth occupancy and of the quantity of cargo handled. Examination of a nine-month period showed an apparently inverse relation between the two sets of statistics: as the figure for tonnage handled went down, the figure for berth occupancy went up. This seemed contrary to common sense, and on further examination it was found that the

higher berth occupancy figure was the result of congestion at the terminal, which slowed down ship turn-round and so caused the berth to be occupied for longer periods, while tonnage throughput dropped. In this case urgent steps taken by the management to relieve the terminal congestion brought a reverse in the trend, with throughput rising again and berth occupancy failing.

119. Although recorded data on berth occupancy may be misleading, berth occupancy rules-of-thumb can be used in planning calculations where the productivity target is clearly defined. A better procedure is, as in the planning charts given in part two of the handbook, to obtain the figure for berth occupancy as an output statistic from calculations based on the other factors. Comparison with recorded figures can then be used as a check.

G. Waiting-time/service-time ratio

120. This ratio is widely used as a measure of the level of service provided by a terminal, as would seem logical, for ships that have less cargo to discharge cannot afford to wait as long as ships that have more. It is usually considered that waiting time should be not more than 10-50 per cent of working time. But this ratio is also misleading since it can improve (i.e. decrease) as service time deteriorates (i.e. increases). As with berth occupancy, the ratio should be used only when the other factors are constant. Better still, as shown in the planning charts in part two of the handbook, the ratio should be set aside and only the total turn-round time used as a measure of the port's performance. When the plan has been based on investing for the economic optimum, the waiting-time/service-time ratio is bound to be an acceptable figure, generally less than 30 per cent.

H. Planning for variations in traffic

121. It is not necessary to use complicated mathematics to demonstrate that a tardy port response to an increase in traffic will lead to congestion which can be serious and long lasting. Supposing for example that a terminal can handle 60 ships a month, a 10 per cent increase in traffic, meaning a mere six additional ships a month, is likely to go unnoticed for some months if arrival rates are not carefully monitored. Unless action is taken to increase the rate of working, there will be an extra 18 ships in the queue after three months. If the port management then responds to the situation by increasing the rate of handling ships at the port by 10 per cent, and maintains this increased rate continuously, it will merely stop congestion getting worse. There will still be a permanent queue of more than 18 ships, and long waiting times. In order to relieve congestion, much more must be done: if the rate of working were increased by 15 per cent over the original rate so that the port could handle 69 ships a month, it would still take a further six months to clear the congestion. Furthermore, under congested conditions improvements in handling rates are extremely difficult to introduce and maintain.

122. While emergency action can be taken in such circumstances, the possibility of emergency action is not an acceptable reason for restricting investment at the planning stage. There has been too little appreciation in the past that many ports have been working with far too small a margin of safety in their capacity.

123. Working with too small a margin of spare capacity can have serious consequences not only when traffic gradually increases, but also when there are short-term surges in traffic, particularly as a port has a tendency to be inefficient when it is congested. The port may thus reach a position from which it cannot recover without emergency action. For example, a group of chartered bulk cargo vessels arriving all together can prevent general cargo vessels from using the berths, and their cargo can congest the port land area. Consequently the facilities are unable to recover to handle the average traffic after the peak has subsided. When the increased demand congests a port, work slows down and throughput drops. This is a strong argument for bringing into play more capacity when the demand is high and less when it is low, i.e. having a reserve of port capacity which is used only during peaks. Is there therefore a case for investing in some spare capacity and keeping it for emergencies? To examine this problem the planner must ask what will be the form of a traffic increase when it comes, how the management will find out about it, and what control the port management will have over the port's reaction to it.

124. The traffic increase is most likely to take one of the following forms:

(a) The introduction of a new shipping service or of additional chartered vessels;

(b) A gradual trend towards larger shiploads in an existing service;

(c) More frequent calls by an existing service (through the placing of additional ships in the service—normally announced in advance);

(d) Exceptional calls, for example, ships diverted from a neighbouring congested port.

125. Another change which can have a major effect on the port without being recorded as a change in the level of traffic is a change in the manner of carrying the cargo. For example, a decision to transport grain in bulk can cause serious problems for a port accustomed to and proficient in discharging grain transported in bags.

126. The increase will be sudden when, for example, a new service forms a sizeable part of the total traffic of a port, when a major national planning decision is taken-for example, to increase a building programme, with the resulting arrival of a series of cement charter ships at a port, or when a large neighbouring port becomes congested and diverted traffic swamps a smaller port. Responding to a sudden increase only after it has happened will usually be too late, because of the time needed for adjustment. When the change is gradual (either because it is a matter of a progressive increase in the size of shiploads or because an additional ship placed in a service accounts for only a small proportion of the total arrivals), it may escape

notice unless traffic figures are being very closely watched. Although accurate current statistics in fact reflect the changes that are taking place. since the traffic level fluctuates about its average value all the time, an important trend can be concealed by the normal traffic variation. Consultations with shippers can be of help in discovering these trends or even in predicting them.

127. There can be problems of short duration. For example. when the arrival of a priority passenger vessel prevents work on a ship-loader for one shift, the effect is not likely to be serious. The volume of export cargo piling up is not likely to occupy a large part of the storage space available. With situations of slightly longer duration. congestion problems may arise. For example, when importers take advantage of a low commodity price, a large number of containers may arrive together but several weeks will probably be required to arrange onward transport. The containers must stay in the port area tor that period. and unless an overflow park is available, there will be congestion in the container park.

128. Longer-term traffic changes raise the question of the proper level of port investment. Here, choosing the amount of spare capacity which is available for use hut which is kept in reserve is a very serious decision. The balance between, on the one hand. investing in reserve capacity and thus keeping expensive facilities idle and, on the other hand. the prohability of facilities becoming congested. will need to be argued out on standard economic grounds. However. it must be recognized that the uncertainty in forecasting is such that merely finding the economic optimum solution in relation to the best forecast, and investing for that situation, does not in itself constitute a satisfactory port plan

I. Co-ordinated contingency planning

129. In addition. an investment plan should make provision for flexibility in the port's response to abnormal increases in traffic demand. It is strongly recommended that each port should have at its disposal a contingency plan for bringing additional reserve capacity of various kinds into use in a systematic. co-ordinated fashion. The major facility needed to provide reserve capacity is additional berthing space. Investing in excess modern berths and then delaying their commissioning is one option, but it will normally be too expensive to tie up capital-intensive berths in this way. Arrangements for overflow traffic should be cheap and simple, for example, working to lighters and then to lighterage berths. This will result in higher cargo-handling costs. but the total economic cost per ton of cargo will be less than if ships are made to wait for regular working.

130. The characteristics of such overflow, arrangements-low capital cost and high operating cost-are precisely those of the older berths in the port, or of moorings. An effective policy can be to use regular new berths during normal conditions, keeping the old berths and moorings in reserve for peak periods. This is advantageous also from the productivity standpoint, as concentrating the traffic as much as possible on the new berths will result in lower operating costs. It is true that the approach causes certain management problems in the commissioning and decommissioning of the overflow berths. since the switching of labour and facilities may not he easy, hut the effort involved should he worthwhile.

131. There are several other forms of reserve capacity. Each of the factors that are involved in the measurement of capacity (as shown in the planning charts in part two of the handbook) could have some spare capacity in them. In the matter of ship working these factors are:

(a) The productivity in tons per gang-hour:

(h) The number of gangs allocated per ship;

(c) The number of days the berth is in commission;

(d) The number of hours worked per day.

132. In order to hold down unit costs, productivity should always be as high as possible. Since there is usually a labour pool which is a cost to the port even when idle. and cargo distribution in holds often limits the effectiveness of extra gangs. it will normally be wrong to keep any spare gangs in reserve. Days allocated to maintenance and dredging work should not be considered as a reserve since these activities are essential to the long-term capacity of the berth, although some flexibility in scheduling the work during periods of peak traffic can he useful. Thus the main room for manoeuvre will be in the number of hours worked. A port which is congested should work the maximum possible number of hours within the limits of the available storage area and trained labour. The aim should be to revert to less than this maximum as soon as the congestion is cleared.

133. It is not a good policy for planners to base investment analyses on the assumption that new facilities can be brought into operation and more intensive working methods introduced at one and the same time, Continual planning on the basis of maximum working possibilities and minimum economic investment will leave the port vulnerable to normal variations in traffic, The provision of reserve capacity should he given the same systematic attention by port planners as is given both to the port development plan and to the programme of practical improvements in the use of existing facilities.

134. Preparation of the co-ordinated port contingency plan consists of three main actions:

(*a*) Providing equivalent reserve capacities in all parts of the port system;

(*b*) Obtaining prior approval for the use of these capacities when certain situations occur or are about to occur;

(*c*) Setting up an information system to report automatically when such situations arise or are about to arise.

The basis of any contingency action will be top management approval. although this approval will normally be given only when the agreed indicators of demand have passed the planned threshold.

135. In addition to the use of additional mooring berths, increased overtime working and working during normal holidays, typical contingency plans may include:

(a) Increasing handling facilities by hiring mobile cranes from outside the port;

(b) Increasing the average number of gangs per ship by hiring additional contract labour;

(c) Speeding up the repair of equipment by buying spare parts manufactured locally;

(d) Hiring additional lighters and working overside both at moorings and on the outer ship's side at berth;

(e) Opening up additional storage areas under customs bond either within or outside the port;

(*f*) Hiring additional trucks and trailers for transport to storage areas;

(g) Giving priority berthing to high throughput ship types or ships with perishable goods.

J. The economic optimum

136. The main economic benefit of port investment is the ability to reduce ship turn-round time. Consequently this is often the determining factor in setting the economic optimum. There are two aspects which managements should be aware of in making an investment decision on this basis.

137. First, the immediate benefit from port investment may accrue, not to the investing authority but to the users of the port, many of whom will be foreign, However, in the long run, the port and the country as a whole will derive considerable benefit from the extension and modernization of port facilities, It is also quite in order for the authority to invest in more capacity than the economic optimum when it has good reasons for doing so, for example, in order to provide a deliberately higher level of service to the user as a promotional policy to encourage the use of the port or to foster local industry as part of a regional development policy. There is not likely to be any good case for investing in less than the economic optimum except where the relevant analysis was made on too narrow a base or where the decision authorities know that in a wider context the growth of the port should be restricted (for example, when traffic is to be diverted to other ports or other transport modes).

138. The second aspect is the practical implications of the average ship waiting time. This measure of service to ships is not as simple as it may appear. A typical cost-benefit calculation may show that the best compromise between the cost of keeping ships waiting and the cost of providing extra capacity is arrived at with a berth occupancy of 75 per cent for a group of five general cargo berths, and that this gives an average waiting time of one day, compared with an average service time of 3% days.

139. An average waiting time of one day has a specific mathematical meaning, however. Taken over the long term, this one day average waiting time for a five-berth group should mean that:

(a) Some 55 per cent of the ships arrived to find a vacant berth and did not have to wait at all;

(b) About 10 per cent had to wait more than four days;

(c) About 5 percent had to wait more than 10 days;

(d) For about 2 per cent of the time all berths were vacant.

140. Thus, for this economic optimum berth group, for the greater part of the time there is no queue of ships waiting for a vacant berth, and for about one week in the year all five berths may be vacant. But in spite of this there will be times when the queue builds up to cause ship waiting times substantially longer than the service time.

141. There are three lessons to be learnt from this:

(a) A group of berths which rarely or never runs its queue of ships down to zero is loaded above the economic optimum.

(b) The normal situation at a group of berths should be that immediate berthing is possible for a majority of the vessels arriving, but the fact that this is the case at a given port does not mean that further investment cannot be justified.

(c) Shipowners are not entitled to use the excessive waiting time of a few ships as an argument that the port is congested. Only the average of the waiting times of a sufficiently large number of ships can be used in such discussions.

142. The planner should also be aware of the fact that, even with the same rate of working and the same long-term average traffic demand, there may be substantial deviations from the average waiting time. There is always the chance of a higher than average level of traffic persisting for a month or more, with a slow upward drift of waiting time and queue length which will be equally slow to clear. These upward drifts in waiting time can be counteracted by means of an operational policy that reacts to pressure. For example, provision should be made for more intensive working when required. Planning on the basis of the long-term economic optimum without allowing for contingencies is bound to lead to short-term congestion.

K. Scheduled traffic

143. Where there are expensive facilities for handling expensive ships, ensuring that the ship will not be made to wait will result in a low berth occupancy which will not be acceptable to the port. The only way in which the berth occupancy can be increased without giving an unacceptably high probability that the ship will have to wait for a berth is to persuade ship operators to schedule their arrivals more regularly. Specific days can then be allocated to particular services, so that each ship can be guaranteed immediate berthing if it arrives on time. Such arrangements generally allow a certain amount of latitude as regards arrival times, but with an agreement that a vessel arriving outside these limits loses its priority.

144. If several services can be persuaded to enter

into such agreements. berth occupancy can be quite high. In such cases service-time and waiting-time relationships cease to apply and the berth requirements can be calculated directly from the programme of scheduled arrivals. When some days are allocated to scheduled services and other to general traffic, the calculation of requirements for the general traffic must be made after subtracting from the total available berth commission days those taken up with scheduled arrivals. This calculation can be carried out directly with the planning charts given in part two of the handbook.

L. Seasonal variations

145. When traffic studies show that there is a large seasonal variation, the first action of the port planner should be to persuade shippers' organizations or industry sector planners to investigate the possibility of taking steps to even out the demand. Ordering and stockholding policies may be changed to smooth out the demand fluctuations. New industries such as the processing of agricultural products into non-perishable forms may be introduced in order to reduce the peak demand at harvest time. Another form of smoothing which can always be used is to seek complementary traffic for the terminal concerned during the off-peak season.

146. Such means of smoothing out demand may be less costly in economic terms than the provision of the requisite port infrastructure, the associated physical distribution facilities and a reserve of labour at a level sufficient to meet the peak demand but which remain under-utilized for much of the year. The economic penalty of this under-utilization will be partially offset by the low unit costs resulting from the efficient handling of large quantities during peak periods. In each case the advantages and disadvantages involved must be calculated.

147. Unavoidable seasonal variation is bound to cause a substantial economic penalty which will be related to the level of service the port gives to its customers during the peak period. At one extreme. the port can be designed for the average monthly traffic, which will result in long waits for ships and cargo during the peak periods. Alternatively, facilities capable of handling the peak demand can be provided, and their underutilization during slack periods accepted. Neither of these courses will normally be acceptable.

148. The port management must first decide on an acceptable level of delays during the peak periods. Then steps can be taken to provide the necessary facilities. Care should be taken when calculating the costs and benefits in each season, and then combining them, not to overlook important operational considerations. In order to reduce investment, the provision of makeshift or secondary facilities for use during the peak periods can also be considered. Although these secondary facilities will be less efficient and will give rise to higher unit operating costs, they will reduce capital costs. In the development of an existing port there is a case for using the modern facilities throughout the year and using the less efficient facilities only during peak times. Possibly such older facilities may be switched to coastal or river traffic when not required for peak working.

149. Seasonal fluctuations are often due to the occurrence of seasonal peaks with respect to a small group of bulk or semi-bulk commodities and it will be advantageous to use specialized handling equipment for these commodities. If the level of such seasonal commodities justifies the installation of fixed equipment which prevents the berth being used at other times. the specialized berth may have to be taken out of commission during the off-season. Normally, it will be preferable to find a type of specialized equipment which can be moved or dismantled during the off-season. This will ensure that the modern berths can be used throughout the year, while the older berths are brought into action for handling genera1 cargo only when the specialized handling installations for bulk cargoes are in use at the newer berths.

M. Capacity and traffic specialization

150. When determining the capacity needed to handle the demand forecast, it makes little sense to treat the port as a single entity, however small the total volume of traffic. Each class of traffic must be examined separately, and separate forecasts of annual tonnage. ship size, productivity and acceptable level of service must be made for each. The traffic must be assigned, either individually or in combinations of types, to the berth groups; then the appropriate capacity for each berth group must be designed. This principle of dealing separately with different types of traffic runs throughout the methods given in part two of the handbook, where separate planning curves are given for each main class of traffic.

151. Serious errors can be made by grouping into one traffic analysis cargoes or ships with widely different characteristics. For example, in a given port it may happen that a number of roll-on/roll-off ships are using a break-bulk group of berths for which the demand is fairly light. The overall cargo handling demand (measured in berth-days required) will fail to justify additional investment because the present average waiting time is, say, only one-tenth of the average service time. However, these averages conceal the fact that the ro/ro ships, with a quicker service time, are receiving an unsatisfactory level of service, a situation which cannot be fully rectified by giving them priority berthing. There may be a good case for investing in a special purpose ro/ro berth, a matter which should be separately studied. The special berth may bring added advantages such as the possibility of scheduling the ro/ro services, introducing special tariffs. etc.

152. At the planning stage, it should be considered, on balance, that the handling of dissimilar traffic at the same berth group causes lower throughput than when they are kept separate. This question is complicated, for, on the one hand. specialization causes a loss of flexibility, as follows:

(a) A loss of berthing capacity through dividing the port and the traffic into two before allocating berths, i.e. a loss of berthing flexibility;

(b) A loss of the transit areas' capacity achieved by mixing complementary traffic, for example, by alternating ships discharging shed cargo with ships discharging bulk cargo for direct delivery while the shed clears.

On the other hand, specialization gives the following gains in consistency:

(a) A gain in service capacity in each facility when the segregation of the different classes of traffic means also a separation of high and low average service times and of long and short ships, i.e. there is a gain through greater consistency of demand;

(b) A gain in average productivity since specialized facilities can be made more efficient than general-purpose facilities;

(c) A gain through making fuller user of expensive water areas, dredging costs, for example, being less for berths allocated to smaller vessels.

153. The balance between these advantages and disadvantages of specialization will need separate judgement in each case, but there is one general rule. Wherever a specific traffic on its own would provide sufficient throughput for a separate specialized terminal, this should be the preferred basis for investment. The planner should thus concentrate on identifying and separating traffic which will justify developing specialized facilities. Where a certain traffic taken alone cannot justify a specialized berth, the planner must revert to a multi-purpose solution. Certain traffic combinations for which efficient multi-purpose terminals can be designed are discussed in part two, chapter IV.

154. It is difficult to quantify generally the extent to which working mixed traffic reduces berthing capacity. The effect is greatest when the occasional large bulk ship is worked at a berth normally handling smaller general cargo ships. In that case the disturbance to a smooth berthing sequence will be substantial. The planning charts in part two of the handbook can be used by planners to compare the effect on ship time of building two separate specialized berths or a two-berth multi-purpose terminal.

N. Flexibility and technical change

155. The flexibility which the contingency plan gives in the handling of a fluctuating traffic demand should be matched by flexibility in accommodating technical change. The choice for a port strategy is clear in this respect. It is either to develop separate specialized facilities for each major handling technique, or to develop multi-purpose facilities capable of coping with any handling technique. Specialist facilities are the most efficient and economical when intensively used, but are uneconomical during the transitional build-up period. Multi-purpose facilities are more expensive to install and operate, but are likely to be fully used for the whole period and so may be cheaper overall. Complete failure to plan for the new techniques will lead to the most expensive result-new traffic being handled inefficiently in old ways at very high cost.

156. A specialized terminal will normally be justified whenever a traffic forecast shows that there is sufficient demand, even if the remaining traffic leaves another facility less than fully utilized. This principle will apply to specialized terminals for cargoes such as containers, timber products, iron and steel and dry bulk commodities. For example, a port currently having six break-bulk berths each handling 150,000 tons per annum may be faced with a general cargo traffic forecast of 1,200,000 tons, of which 50 per cent will be containerized. If one specialized container berth is built, its throughput of 600,000 tons will load it to a reasonable level and justify the terminal. However, this will leave only 600,000 tons to be spread over the existing berths, which are currently able to handle 900,000. Nevertheless, the best policy would be to build the specialized berth and either to de-commission two break-bulk berths or, alternatively, to retain them as occasionally used overflow berths.

157. The alternative policy in this example would be to continue working mixed traffic at break-bulk berths and to build two more conventional berths. The cost of the two conventional berths might well be less than the cost of a specialized container terminal. However, this policy should be clearly ruled out on grounds of cost per ton and unsatisfactory service to the container operators.

158. A far more difficult policy decision faces the port where the traffic forecast for a specialized technology cannot justify investment in a separate terminal. In the above example, if the forecast containerized fraction were only 20 per cent (240,000 tons), then the total container demand would not normally justify investment in a specialized container terminal. Nevertheless, both container-handling facilities and additional break-bulk capacity are needed. The solution in this case could be to build one extra multi-purpose terminal equipped with a combination of handling facilities as recommended in part two of the handbook. The main advantage of this solution is that the multi-purpose terminal can be converted stage by stage from predominantly break-bulk cargo to predominantly unitized cargo of various kinds, to conform with the changing traffic.

159. Even where, owing to local circumstances, it is forecast that a port will continue to receive mainly conventional break-bulk traffic, the principle of flexibility in design is still advisable. Where possible, operating areas should be larger, depths of water greater, quay foundations stronger and quay superstructures less permanent than has been traditional. All these features will make it easier to adapt berths to accommodate ships exemplifying the newer technologies, when they eventually arrive.

160. It is not necessary to complete all construction features with an eye to the possibility of ships of larger tonnage in the future, but only to build those elements which would be difficult to modify later. For example, at the time of construction the quay wall could be built to a greater depth than would be necessary for ships currently expected, but the dredging programme for larger future ships need not be carried out until their arrival is more definite.

0. Principles of investment appraisal

161. This section summarizes the main principles of investment appraisal as they affect ports. Both a financial and an economic evaluation are generally required before a loan for a port investment project is approved. The former is essentially a computation of commercial profitability and is not in itself sufficient; it is the economic evaluation-the comparison of the social costs and benefits to the country-which determines whether or not a loan is granted.

162. The two evaluations are identical in several respects:

(a) They require an evaluation of a succession of costs and benefits over the whole useful life of the project;

(b) They take into account the time-value of money-whereby, because this year's money can earn interest, it is of more value than next year's money, which must therefore be discounted back to its present-day value in order to bring both on to an equivalent basis;

(c) They use common criteria to evaluate investments, namely one or more of the following:

(i) Average rate of return;
(ii) Pay-back period;
(iii) Net present value;
(iv) Internal rate of return;
(v) Benefit/cost ratio.

However, the two evaluations differ with respect to the costs and benefits included, since the port account is concerned with direct costs and benefits while the national government is concerned also with social costs and benefits deriving from trade promotion and similar effects.

P. Financial analysis

163. The financial analysis must evaluate the financial viability of the investment and the impact of the investment on the financial health of the port authority as a whole. The financial health of a port authority is usually evaluated by means of the following indicators:

(a) Forecasts (usually for a five-year period) of balance sheet, revenue account and cash flow figures;

(b) Financial ratios of past and future accounting reports, the most commonly used ratios being as follows:

(i) Capital structure ratio (also named debt equity ratio) shows capital and fixed liabilities as complementary percentages;
(ii) Liquidity ratio (or current ratio), i.e. current assets divided by current liabilities;
(iii) Rate of return on average net fixed assets in use, i.e. net operational income divided by average net fixed assets;
(iv) Operating ratio, i.e. operational expenditure divided by operational revenue x 100.

164. In general, port authorities are required to generate and retain sufficient income to:

(a) Carry out efficient operations;

(b) Maintain their assets in good working condition;

(c) Make a contribution to future investments for the proper functioning and development of the port.

165. The data required for the financial analysis come from:

(u) Estimates of the costs of the projected facilities;

(b) Previous financial statements of the port authority;

(c) Data recorded by the accounting systems;

(d) Past traffic statistics and estimated traffic forecasts;

(e) Present tariffs of services from the port authority.

166. From this information, the following values can be calculated:

(a) Expected revenue from future traffic and tariffs;

(h) Expected operating costs;

(c) Investment costs and repayments;

(d) Cash flows;

(e) Financial ratios.

Further information on financial analysis is given in the report of the UNCTAD secretariat entitled "Financial management of ports"[5].

167. The financial costs associated with a proposal are straightforward; they are the actual disbursements which the port authority will be required to make in connection with the investment. They include the cost of all preliminary studies and plan preparation, of land. construction and the purchase of equipment, and of operating the installation, including wages, fuel, spare parts, etc. The financial benefits are the additional revenue which will result from operating the extra facilities, as compared with the revenue which would have been received without them. The main sources of such additional revenue will be the port charges on ships and cargo.

168. Clearly, the results of the financial analysis will be heavily dependent on the assumed throughput. Normally. therefore, evaluation should be done for a range of traffic growth forecasts. Moreover, the opportunity should also be taken, while computing the financial results, to calculate the consequences of different tariff levels. This will provide the necessary information for a soundly based discussion of what would be an appropriate scale of charges.

169. The financial criterion for justifying a project is that. with a realistic tariff, and after covering all costs, including that of annual depreciation. the net revenue earned in each year of operation will pay the interest on loan capital and the equivalent of the interest foregone on the port's own capital expenditure. The adoption of this financial criterion will thus lead to the accumulation of the reserves that would be necessary for building facilities of equivalent value upon expiration of the amortization period.

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[5] UNCTAD/SHIP/138

170. **A** purely commercial development by a port authority that does not have national responsibilities can be justified on a financial criterion alone, but normally both economic and financial criteria must be used.

Q. Economic appraisal

171. The economic evaluation is generally known as the cost-benefit analysis, although strictly this term could also be applied to the financial evaluation. The economic evaluation is based on costs and benefits which differ from the financial transactions in a number of ways. A fundamental characteristic of these costs and benefits is that they accrue mainly to the other participants in the trade rather than to the port authority.[6]

R. Costs

172. The main resources for a port project in a developing country are land, labour and foreign exchange. The economic cost of each of these resources is its "opportunity cost" or "shadow price". This cost is equivalent to the highest-valued benefit which is given up by using the resources for this project rather than for another project. In the case of land, a port may previously have purchased the land needed for expansion at a cost, for example, of $1 million. The value of the land may have appreciated and, if it were released for building offices, might be valued at, say, $5 million. Therefore, in the economic appraisal, $5 million would be entered as the cost of the land. The opportunity cost of labour is very low when there is no alternative useful employment. In areas of high unemployment, irrespective of the wages which will be paid, the labour costs used in the economic appraisal will be very small and may often be set at zero.

173. Foreign exchange rates in developing countries are often fixed at arbitrary levels and consequently the demand exceeds the supply. In that case, the economic cost of the foreign exchange component of the project will be higher than the quoted exchange rate. It is this higher rate, normally determined by a central bank or ministry of finance, which must be used in the economic appraisal to bring the foreign exchange component on to a common base with other costs. Customs duties and other taxes on elements of a port development are not included in the economic costs since they are purely a transfer payment from the port to the government

S. Benefits

174. The major economic benefits of port investment are:

(a) The transport cost savings made possible by the use of ships which can carry the goods at lower cost per ton of cargo (e.g. larger or more modern ships);

(b) The reduced turn-round time of ships in port. This is often the largest single benefit and it is essential to estimate both the waiting time and the time at berth. Irrespective of the fact that this benefit often accrues in the first place to foreign shipowners, it is now standard practice to include it in the appraisal on the understanding that in the long run this benefit will filter through to the national economy, for example, through lower freight rates;

(c) The reduced period goods spend in port and on ships. This will free capital tied up in goods and thus give indirect financial benefits to the country as a whole.

(*d*) The transport cost saving from the new routes for goods to and from inland locations. This may, for example, be due to the new port facility cutting out an overland transport leg;

(*e*) The benefit derived from stimulating or making possible increased national economic activity. This benefit is often difficult to measure and should only be included when the activity could not take place if the port project were not undertaken. The benefit must be offset against the opportunity cost of the resources used in the increased activity;

(*f*) The benefit from making possible an increase in exports through, for example, providing facilities for larger bulk carriers which will result in lower transportation costs and allow the overseas price of the export commodity to be more competitive. For instance, new facilities could permit an increase in exports of a given commodity from one million to two million tons per year, and at the same time reduce the price of transport. The savings on transport for the first million and the benefit from the sale of the additional million are both to be included.

T. Discounting

175. The first step involves the calculation, year by year, of the net monetary flow expected from the project over its life. The net monetary flow in any year is the difference between the benefits expressed in monetary terms and the costs also expressed in monetary terms. The net flow is then discounted to obtain the present value. Discount tables such as that given in annex I (table II) can be reused. For example, with a discount rate of 10 per cent, a net flow of $100,000 in the fifth year of a project has a present value of $62,100 since the discount factor is 0.621. This is equivalent to saying that $62,100 would be worth $100,000 at the end of five years if invested at 10 per cent interest.

176. For commercial profitability, the correct discount rate is the market rate of interest. However, for national economic profitability the appropriate discount rate is more difficult to define because of social factors. The choice of the appropriate rate of discount is a matter of national policy, on which the port planner needs guidance.

[6] A more detailed discussion of economic cost-benefit analysis is given in the report by the UNCTAD secretariat entitled "Appraisal of port investments" (TD/B/C.4/174).

U. The congestion cost pitfall

177. There is a pitfall to avoid when appraising a port investment which is planned to relieve or prevent congestion. With such an investment, the first additional facility will yield greater benefits than the second and subsequent additional facilities. This is due to the very large reduction in congestion costs which is brought about by the construction of the first facility and which subsequent capacity increases cannot possibly match. This should not be used as an argument that this first, limited, investment is the most economic, since in the long run this would amount to planning for a permanent and substantial level of congestion. To minimize the overall costs of maritime transport, the correct level of investment is that which provides the maximum possible capacity while meeting the investment criterion which has been adopted.

V. Summary methods of evaluation

178. There are several methods of evaluation which could be used depending on the nature and magnitude of the investment. A detailed discussion of these methods with worked examples is given in the report on port investments already referred to.[7] The more common methods used are:

(*a*) Average rate of return;

(b) Pay-back period;

(c) Net present value;

(d) Internal rate of return;

(e) Benefit/cost ratio.

The port's evaluation of a project could take the form of any one of the above methods. For economic cost-benefit analyses, however, the more relevant techniques are the last three.

179. The average rate of return is an accounting device and represents the ratio of the average annual profits after taxes and depreciation to the average net investment in the project (the original investment divided by two) or, sometimes, the original investment itself. Since depreciation will gradually reduce the value of the investment during the life of the project to zero, the average investment is approximated by dividing the total investment by two.

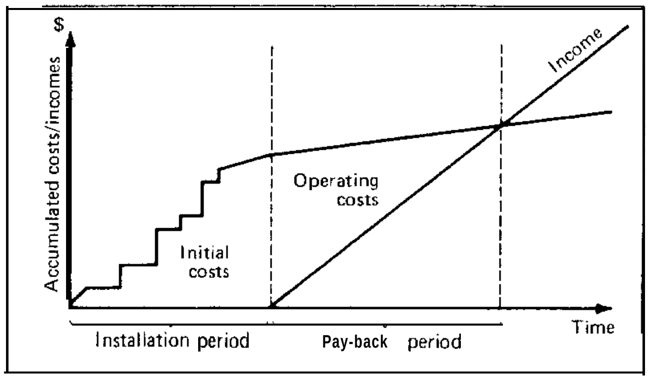
180. The pay-back method literally means the number of years required to recover or "pay back" the initial cash investment. The basis of the pay-back calculation is shown in figure 13, which is self-explanatory.

181. The net present value or NPV method takes into account the time value of money. The discount rate specified must be used to discount all future cash flows to their present value. Summing these flows gives the net present value of the investment. The criterion used in the NPV method is to accept the project if the NPV is greater than zero and otherwise to reject it.

[7] "Appraisal of port investments" (TD/B/C.4/174).

FIGURE 13

The pay-back period approach



182. The internal rate of return or IRR method is another method which takes account of the time value of money. The IRR is the discount rate that gives a zero NPV, that is, the rate at which the present value of benefits equals the present value of costs. If the IRR of a project exceeds the required rate of return, or cut-off rate, the project is acceptable; otherwise it is not. The IRR method and the NPV method will give similar answers with respect to the acceptance and rejection of an investment proposal.

183. The benefit/cost rate uses the present value of benefits and the present value of costs and is obtained by dividing the benefits by the costs. A ratio greater than 1 implies that the project is acceptable, while a ratio less than 1 implies that the project is unacceptable.

W. The four investment decisions

184. There are four distinct questions that must be answered about a port investment proposal:

(a) Is the proposal in isolation economically and financially justified?

(b) Does it represent the best use of the available funds?

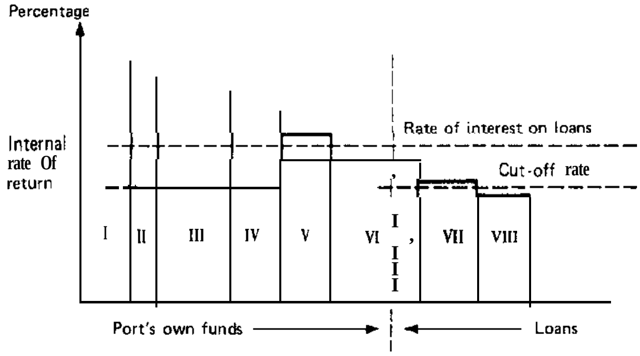
(c) Is the proposed level of investment in additional facilities the right level?

(d) What is the best point in time to make the investment?

185. To answer the first question, the method chosen depends upon whether agreement can be reached on what is the appropriate discount rate to be used. When all concerned are able to agree on a minimum acceptable return on capital. then the cash flows can be discounted at this rate and the justification for the project in isolation will best be on the basis of the benefit/cost ratio or net present value. When it is difficult to reach agreement on the proper discount rate, then it will be necessary to calculate the IRR. In some cases it may be advisable to decide to use the IRR method from the start simply to avoid introducing doubt and delay into the project appraisal work programme.

FIGURE 14

Application of funds to a number of competing projects



186. In answering the second question, and in order to find how to apply a certain quantity of funds to several projects, the most straightforward approach is to rank the projects in order of their NPV, and to stop investing at the project that is only just above the investment criterion used or when funds are exhausted, whichever is the sooner. Unfortunately, there is a complication since there will usually be at least two different types of funds, port reserves and borrowings, and different criteria may apply to each. However, a single method can be used for both, as is shown in figure 14. Here, projects which are competing for the funds are ranked according to their IRR, and on the horizontal scale the point at which the port's own funds are exhausted and a loan will be required is also shown. In the case shown, the IRR of the first five projects is above the required rate of return on the port's own capital, or cut-off rate, while the IRR of the sixth is above this level but is not up to the higher level of interest required to be paid on loan capital, even though it would require a loan. An alternative would be to carry out project VII before project VI, which should either be deferred or, if this is technically acceptable, cut by one third. Ranking by IRR will not be the only criterion, however; whether a project is socially useful, generates employment, or causes direct rather than indirect benefits, will all be part of the decision.

187. The third question is to choose the right level of investment in facilities; for example, what is the right number of berths to invest in at any time? The correct level of investment is found by progressively increasing the number of berths until the NPV (or IRR) falls **just** above the required value.

188. Finally, to find out when to invest in additional facilities, after a decision has been taken on the form of the project, the first year rate of return method may be used. The first year rate of return method involves a comparison of the first full year benefit with the cost of the project discounted up to the year of completion of construction of the project, i.e., up to the year prior to the year in which benefits will begin to accrue. If the ratio so obtained is less than the discount rate, then the project should be delayed by a year.

189. Where both economic **and** financial criteria are satisfied, the following factors may govern the decision between alternative solutions:

(a) Environmental impact: see table 12 entitled "List of site investigations" in chapter VII ("Civil engineering aspects");

(b) Management impact: what new demands does the development place on top management? Is local staff sufficient in number and quality to fill the key positions?

(c) Organizational impact: does the new development demand a greater degree of autonomy or of flexibility which will be difficult to introduce? Does it require changes in the internal structure and allocation of responsibilities?

X. Joint proposals

190. With two proposals, A and B, calculations will have to be made for three cases, A alone, B alone and A and B together. If there is no interaction between the two proposals (with respect, for example, to traffic sharing, space sharing, storage requirements and landward access), A and B together will simply be the sum of A and B alone. When they interact, the joint proposal will need analysis in its own right.

191. Thus, when two interacting proposals are included in an investment appraisal, it will be necessary to calculate costs and benefits both separately and together. Clearly, when three or four interacting proposals are combined in one appraisal, there will be a great deal of work and considerable complications for the decision-maker. However, this will generally be preferable to artificially separating projects which affect each other. For example, the decision to buy fork-lift trucks for old berths will affect the decision to build new berths since the fork-lift trucks are alternative ways of increasing capacity. If these two matters are treated as separate investment projects then not only will the calculation of the benefits of each be false, but the investment authority may not appreciate that there is a real and important choice to be made as to where to put its funds to the best advantage. The authority may then proceed with the new berths and decide that it cannot afford the fork-lift trucks, with the result that the chance of a valuable short-term improvement in capacity is lost.

192. On the other hand, it is equally wrong to present a single analysis for what are in fact two separate proposals. This can obscure the fact that one may be profitable and the other not. The economic justification and financial viability of each type of facility must be investigated separately. Cross-subsidies cannot always be avoided, but before accepting that solution it is important to examine methods of securing the financial reward of the economic benefit, normally by tariff adjustment.

Y. Examination of uncertainty

193. When the full cost-benefit analysis and financial analysis for the central forecast of each parameter have been completed, the effect of uncertainty can be studied by means of a simple sensitivity analysis. This is carried out by repeating the analysis for variation in

each main parameter, taken one at a time, by an amount estimated to be a comparable degree of risk. For each of these values, the economic and financial effects are recalculated. The ship's time costs can be derived simply from the planning charts given in part two of the handbook. For example. for a project which has an IRR of 12 per cent. the sensitivity analyses may show the following:

	Central estimate	*Risk position*	*IRR at risk position (percentage)*
Cost of facilities	$ 10 million	$ 12 million	10
Productivity	500 tons per ship day	20 per cent less	8
Traffic growth rate	5 per cent per annum	2 per cent higher per annum	14
Economic life of facilities	20 years	15 years	10
Cost of ship's time	$ 2,000 per day	$ 2500	15
Number of commission days per year of facilities	300	270	10

194. The percentage change produced in the IRR by each parameter change allows the investing authority to see the effects of changes in its estimates and to take all possibilities into account in its decision procedure. For example, it can be seen that a 20 per cent reduction in productivity gives twice the change in the IRR (-4 per cent) as a 20 per cent rise in the cost of the facilities (-2 per cent). A more rapid change in technology which would make the facilities uncompetitive in 15 rather than 20 years has a 2 per cent effect on the IRR.

195. A useful variation is to invert the calculation and show by how much each of the variables would have to change before the IRR fell to the minimum acceptable level, all other things being equal. For example, if construction costs would have to rise by 40 per cent before the IRR fell below the acceptable (cut-off) rate, then local management might judge this an acceptable risk.

196. The planning charts given in part two of the handbook have been designed with such sensitivity analysis in mind. Since no calculations are required, each alternative value can be tested very quickly so that it is possible to obtain ship's time costs for a sensitivity analysis without too much effort. Four of the six parameters listed above can be used as inputs for the planning tables in order to arrive at the total cost of ship's time. The other two (cost of facilities and economic life of facilities) can be directly inserted in the cost-benefit analysis.

Chapter III

TRAFFIC FORECASTING

A. Forecasting principles

197. The essence of port traffic forecasting is to find out:

(a) What kinds and tonnages of commodities will move through the port?

(b) How will these commodities be packaged and carried as maritime cargo?

(c) What ship types, tonnages and frequency of calls will this result in?

Traffic forecasting requires a combination of commercial and economic knowledge; the mathematical techniques are of minor importance and can often be omitted entirely. Far more important is the need to bear constantly in mind the very high degree of uncertainty in any forecast, and to take steps to minimize the risk which this causes.

198. Any forecast of future trade will be uncertain, and ports are particularly vulnerable in view of their long planning time-scale and limited ability to influence demand. All forecasts should be linked with the overall national development plans. Furthermore, maritime trade is going through a period of rapid change which critically affects the volumes and types of traffic likely to use any port. Errors in forecasting can be serious, and the consequences of overestimating and underestimating are not equal. To over-build may add only a few dollars, at most, per ton to freight costs, but to under-build may cause congestion leading to additional costs of $100 per ton.

199. Even when all precautions have been taken to reach realistic and well-reasoned forecasts, the remaining uncertainty usually produces a wide variation of possible levels of traffic when projected several years in the future to the date of commissioning and beyond, and even greater uncertainty in the long-term master plan. All forecasts are thus to be treated with caution. It is hoped that the actual traffic level will be closer to the central forecast than to the upper or lower forecasts, but the risk that it will not be is normally too great a one for a port management to accept. This applies both to volume and to type of traffic. Thus the range of variation in the traffic forecast will usually be the first concern of an investment sensitivity analysis of the kind discussed in chapter II.

200. The planner can do a great deal to minimize this risk by searching for a design solution which is robust-one that is a good investment under a variety of possible future traffic. To do this he must be able to construct a number of different scenarios describing these alternatives. The port management can reduce the risk further by introducing an operational system which can respond to changes in traffic, together with an information system which gives a clear signal when the response is needed.

B. Scenario writing

201. A traffic scenario is a consistent description of the whole of the future traffic likely to come to the port and the way it will build up. It assumes that the port does nothing to prevent the traffic arriving, but encourages it by providing reasonable facilities. For each cargo category, the probable volumes under different circumstances and the possible alternative types of technology that may be used in carriage and handling are all considered. Several scenarios are then drawn up, each fully self-consistent, resolving any clashes between forecasts for different trades and permitting a reliable estimate to be made of the resources needed.

202. The scenario-writing team should include an operational manager. It is an appropriate task for the traffic manager of the port. The planner must consult the traffic department early in the project and participation of the traffic manager is a useful way of doing that. Representatives of shippers' and shipowners' interests should also be invited to participate, if possible as full members of the team. If the scenario-writing team is formed entirely of local staff who have not recently travelled outside the region, it would be advisable for a small group to visit modern ports at the far end of their main trade routes to become familiar with possible future developments.

203. It will not be possible for the scenario writing to take place until after the routine analysis of traffic data, an examination of numerical trends and the making of simple projections. These are the data on which the scenario is based. But the team should be aware of the danger of reaching conclusions from extrapolation of past figures. For example, a team looking only at past traffic figures may ignore the potential export traffic of mineral products from undeveloped mines whose potential for production and export to overseas markets have been definitely established. The possible high volume of such exports will markedly affect port development.

C. Control statistics

204. It is the task of the traffic forecaster to provide both a central trend forecast and also a system of watching at given intervals to see when the actual traffic

begins to deviate from this forecast. At, say. yearly intervals "signposts" will direct the management either to carry on as planned or to change direction, depending on the degree of deviation from the forecast. This approach can be simple and very powerful. It requires:

(*a*) The regular collection of a small number of essential traffic statistics to serve as a control;

(h) Giving a port manager (e.g. the head of the permanent planning group. where this exists) the responsibility for reactivating the planning process when predetermined deviations from forecast are reached.

205. *Since* any one port investment project may take up to five years to complete, it is possible that within this period the deviation from forecast will exceed the acceptable level. In that case the planning procedure should be repeated, starting from the state which had been reached in the project. Some form of readjustment will usually be possible even at a fairly advanced stage.

206. The most useful control statistics available from the ship and shift records which should be kept are, as appropriate to each terminal:

(a) The total tonnage handled;

(b) The average ship turn-round time;

(c) The average tonnage loaded and discharged per ship;

(d) The volume of special traffic handled at a multipurpose terminal (i.e. the percentages of containers and ro/ro units, of bulk and bagged bulk shipments and of loads on pallets and pre-slung and pre-packaged loads);

(e) The percentage of ships with a specified type of equipment such as shipboard cranes or stern ramps;

(*f*) The average ship length;

(g) The maximum draught on arrival and maximum ship length.

With the exception of the last item, it is preferable to use the three-month moving average for the control statistics.

D. Combining the uncertainty in separate factors

207. Where a traffic forecast is being prepared from a detailed analysis of the factors involved, which are combined (either by addition or by multiplication) to produce the final figure, care has to be taken in dealing with optimistic and pessimistic estimates of each separate factor. Clearly, if there are three independent factors affecting the forecast, then the probability of it turning out that all three have a high value or all three a low value is very small. There are simple statistical methods of calculating this overall probability. These methods are given in annex II. section C, of the handbook, and should be used where appropriate.

E. The forecasting procedure

208. A systematic procedure for carrying out a detailed port traffic forecast is illustrated in figure 15 and the tasks involved are listed in table 6. For minor investments. a review of the traffic forecast is advisable to check on the revenue expected; a simplified procedure as shown in figure 16 is reasonable.

TABLE 6

The forecasting procedure

1. Analyse past traffic
   - I 1 Define routes/conferences, etc
   - 1.2 Choose cargo classification
   - 1.3 Tabulate
   - 1.4 Calculate trends and analyse their causes
   - 1.5 Extract seasonal effects
2 Review market influences on traffic and technological trends
   - 2.1 Survey shippers' opinions, (public and private)
   - 2.2 Survey shipping companies' plans
3. Estimate systematic traffic growth rates
   - 3.1 GNP-linked cargoes
   - 3.2 Special cargoes
   - 3.3 Regional/hinterland trends
4. Investigate expected traffic-influencing events
   - 4.1 Industry plans
   - 4.2 Agricultural plans
   - 4.3 Transport links/transit policies
5. Combine all information into alternative growth and technology scenarios
   - 5.1 Identify principal scenario themes
   - 5.2 Combine all data for each theme
   - S.3 Remove numerical inconsistencies
   - 5.4 Write scenarios
6. For each scenario, tabulate annual forecasts in each traffic class
   - 6.1 Tonnages (weight tons)
   - 6.2 Numbers/sires of ships
   - 6.3 Seasonal effects

Weight/measurement ratio for storage purposes should also be recorded for each traffic class.

209. The first step is to examine the existing traffic in detail, preferably on a year-by-year basis going back for at least three years. If possible, the analysis should be broken down in two ways: by country of loading or discharge, and by major cargo class. This will provide two tabulations such as those shown in tables 7 and 8.

210. The grouping of country flows into regions should be by loading and discharge areas on specific trade routes. This is valuable because in general the same kind of cargo from the same loading area will be carried in a similar way. It is advisable, also, however, to make separate records of the individual country flows because this will make it easier to adjust forecasts to take account of political and other *circumstances.*

211. The grouping of traffic into classes should be done in such a way that it will be possible to estimate, first, the volumes of cargo and secondly, the numbers and types of ship that carry it. There is no very easy way to do this, and it is likely that the classes used will include a mixture of commodities and of ship technologies. One method of classification is as follows:

FIGURE 15

The forecasting procedure

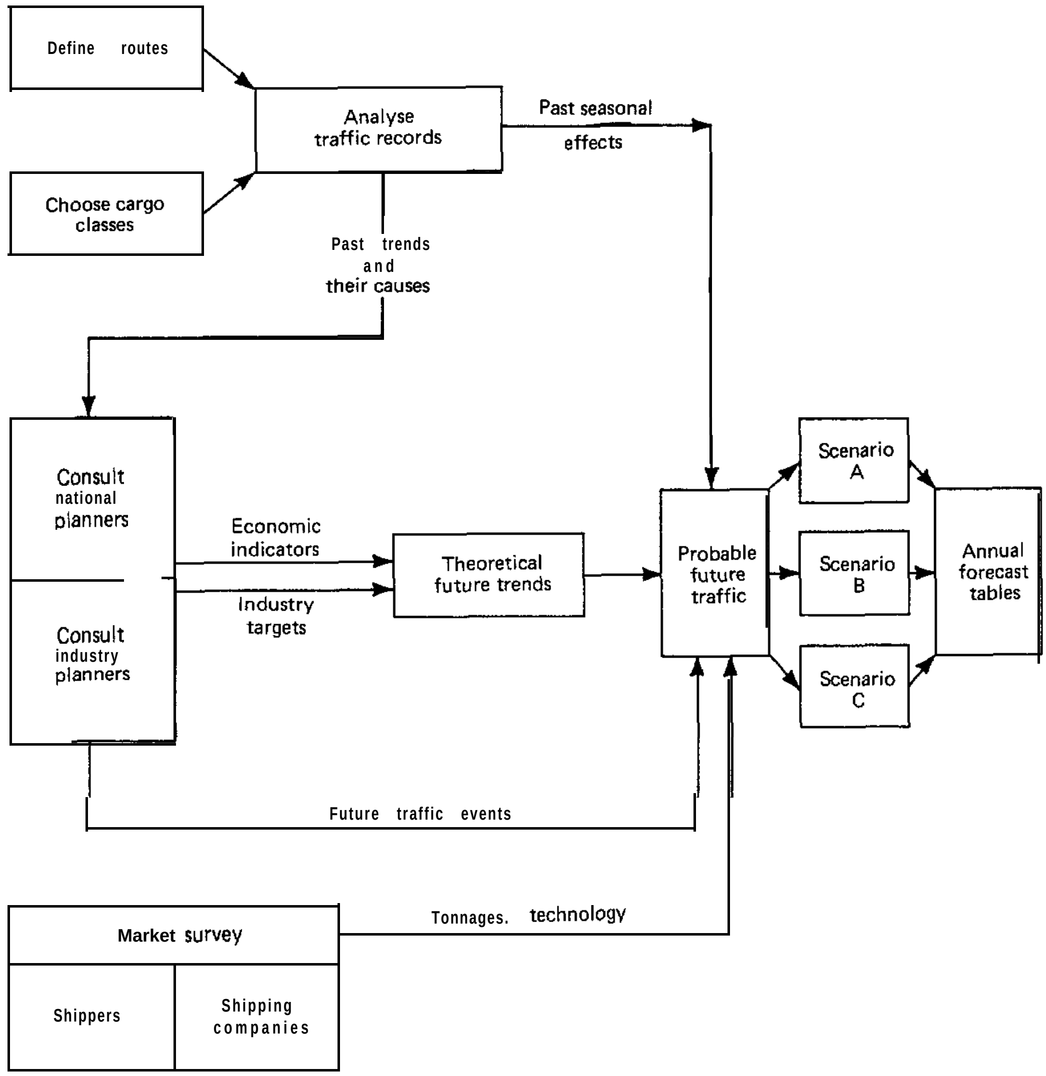
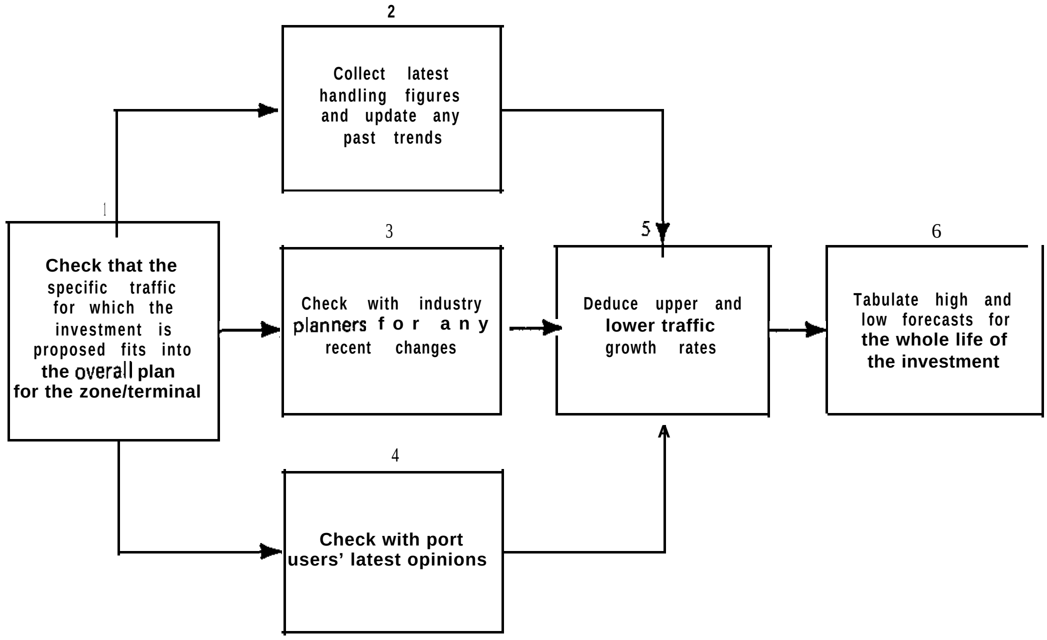


FIGURE 16

Simplified forecasting procedure for minor investments



(a) All bulk traffic should be classified separately by commodity;

(h) Bulk traffic in the same commodity should be subdivided according to mode of carriage and handling where this is significant (e.g. wheat carried and discharged in bulk; wheat carried in bulk and bagged in the hold before discharge);

(c) Non-hulk cargo should be subdivided according to mode of carriage (i.e. type of vessel carrying it). as follows:

(i) Conventional liner;

(ii) Specialized pallet ship (sideloader, etc.);

(iii) Ro/ro ship;

(iv) Cellular container ship;

(v) Specialized semi-bulk carrier (for packaged timber. iron and steel, etc.).

In addition, as an overriding principle. any commodity which is of particular importance locally-a principal commodity-should be recorded separately.

212. Typically, this approach for a port in a developing country will produce a list of, say 10 export and 20 import traffic classes. Care must be taken with regard to the units **used. It** *is unsatisfactory for development purposes to record movement in revenue tons (or freight tons or port tons) which are a mixture of weight and cubic measurement.* All figures should he in tons of gross weight (it is preferable for metric tons of 1,000 kilograms to be used; but if this is not possible then the exact unit must he clearly stated). With regard to containers, both the tonnage of the freight contents and the number of boxes (in TEUs, where a 40-foot unit counts as two TEUs) should **be** recorded.

213. A difficulty arises when vessels load a cargo belonging to a different traffic class from the cargo they discharged, and possibly intended for a different trade route. For example, a liner discharging manufactures from Western Europe could load cotton for the Far East; or, after completing a charter voyage to discharge fertilizer, a vessel might load bulk clinker for a near-sea destination. If these discharging and loading operations are carried out at different terminals, the ship moving from one berth to another, then the solution is simple. Separate terminals or groups of berths must be planned separately. as explained in chapter II above, and their traffic must be considered as independent demands. Hence a ship which discharges at one terminal and loads at a different terminal must he counted as two separate ship visits for planning purposes. This is a point where regular port statistics will not agree with the planners' data.

214. If the discharging and loading of cargo belonging to different traffic classes take place at the same berth, then the solution is not so clear-cut. It will normally be adequate to work with the average performance figures for the mixed traffic, There are two reasons for separating the traffic in the traffic statistics:

(a) To obtain a better estimate of the ship turnround time **and** productivity:

(b) To enable separate forecasts of each kind of traffic to be made and to be revised in accordance with changing conditions.

F. Forecasting cargoes carried by ro/ro ships

215. The variety of cargo classes carried on ro/ro ships makes it particularly difficult to convert commodity tonnage forecasts into shiploads. The majority of ro/ro ships in fact carry a mixture of the following cargo classes:

(a) Rolled on and off:

(i) Containers on semi-trailers/chassis, with or without the prime-mover vehicle;

(ii) Container-like **loads** on road trailers or semi-trailers, with or without the prime-mover vehicle;

(iii) Wheeled cargo (trucks, cars, buses, etc., which are themselves the consignment).

(b) Carried on and off:

(iv) Containers carried on and put down by large fork-lift trucks or straddle-carriers;

(v) Other unit loads such as packaged timber;

(vi) General cargo carried on by fork-lift trucks and stowed in conventional holds, including a high proportion of pallets (general cargo may also be rolled on board on trailers and then stacked);

(c) Lifted on and off:

(vii) Normal container operations on deck or in special compartments.

216. For development purposes, it will be difficult to determine what type of roiro ship will carry the future cargo. and hence the proportions in which these seven classes are mixed will not be known. A simplification for statistical and forecasting purposes will be to group them under four headings only:

(a) Containers: classes (i), (ii), (iv) and (vii) (it may be noted that container-like loads can be measured in TEUs since a road trailer is roughly similar in load capacity to a container of the same length);

(b) Cargo carried by intermediate methods: class (v);

(c) Wheeled cargo: class (iii);

(d) General cargo: class (vi)

217. This grouping then allows the ro/ro cargo forecasting to be part of the overall terminal forecast since all four categories will he forecast in total, irrespective of the ship type that will carry them. Only after preparation of the cargo forecast will it he possible to consider, according to the sea route, roughly how much of each of the four categories may be carried on conventional ships, on cellular container ships or on roiro vessels

218. The final calculation to determine the number of roiro shiploads and thence the probable number of ship calls cannot be accurate. After discussion with the ship operators concerned, a feasible and consistent solution will he to specify one or more "standard roiro ships" with a given part-load-capacity for each of the four categories. The first category will be defined in ship TEU capacity and the remainder in tons deadweight capacity.

TABLE 7

Typical traffic forecast layout for various years

Imports[a] (thousands of tons)	Scenario A						Scenario B					
	1985	1986	1987	1990	1995	2000	1985	1986	1987	1990	1995	2000
Liquid bulk cargoes												
Crude oil												
Oil products												
Sulphur[b]												
Molasses/vegetable oils												
Dry bulk cargoes												
Coal												
Iron ore												
Sulphur[b]												
Cement[b]												
Cereals												
Other												
Containers and ro/ro loads[c]												
On cellular ships												
On conventional ships												
On ro/ro ships												
Cargoes carried by intermediate methods												
Packaged timber												
Iron and steel products												
Other pre-slung and palletized cargoes												
Break-bulk cargoes												
Wheat in bags												
Cement in bags[b]												
Fertilizer in bags												
Refrigerated fruit												
Vehicles												
Machinery												
General												

[a] The principal commodities shown are typical of those that may need separate forecasting at a single port; the list is not intended to be complete

[b] These commodities should be subdivided into different traffic classes according to the mode of carriage.

[c] ISO containers and ro/ro loads should be recorded both in tons and in twenty-foot equivalent units (TEUs).

G. The market forecast

219. An essential part of a realistic port plan is the identification of the potential users and the means of transport being used for the various commodities. This should take the form of a market forecast. In many ports it will be advisable to appoint a commercial manager to carry out a continuous study of the market, and to make sure that this activity is closely co-ordinated with that of planning.

220. The aims of the market forecast should be to describe:

(a) The present users:

(i) Who are they?
(ii) What traffic are they offering?
(iii) Who are the authorities making the decision whether or not to ship via the port?
(iv) What influences their decision?
(v) What berthing, cargo-handling or other services do they require?

(b) The potential users: a similar analysis;

(c) The ability of the port to influence the market:

(i) What users and traffic are likely to be captured by port action?
(ii) What additional facilities would this demand?
(iii) What will be the effect of raising or lowering the port tariff?

221. These questions will be difficult to answer, and normal commercial practice will obscure the truth. Nevertheless, a continuous effort to discuss them with representatives of shipping lines and conferences, and with shippers and inland carriers, will normally pay substantial dividends and ensure that the port plan can be developed to meet the true future demand rather than passively follow past trends. In view of the particularly rapid pace of change in ship and cargo-handling technology, each stage in the analysis should ask specifically:

(a) What types of ship are being constructed for (or transferred to) services which may affect the port?

(b) What methods of cargo handling will they require?

TABLE 8

Typical traffic forecast layout by route (year 1985)

Imports[a] (thousands of tons)	*Origin*													
	North west Europe													
	Norway	*Sweden*	*Netherlands*	*Federal Republic of Germany*	*United Kingdom*	*France*	*Total*	*Malaysia*			*Philippines*	*Total*	*Japan*	*United States of America*
Liquid bulk cargoes														
Crude oil														
Oil products														
Sulphur[b]														
Molasses/vegetable oils														
Dry bulk cargoes														
Coal														
Iron ore														
Sulphur[b]														
Cement[b]														
Cereals														
Other														
Containers and ro/ro loads[c]														
On cellular ships														
On conventional ships														
On ro/ro ships														
Cargoes carried by intermediate methods														
Packaged timber														
Iron and steel products														
Other pre-slung and palletized cargoes														
Break-bulk cargoes														
Wheat in bags														
Cement in bags[b]														
Fertilizer in bags														
Refrigerated fruit														
Vehicles														
Machinery														
General														

[a] The principal commodities shown are typical of those that may need separate forecasting at a single port: the list is not intended to be complete.

[b] These commodities should be subdivided into different traffic classes according to the mode of carriage.

[c] ISO containers and ro/ro loads should be recorded both in tons and in TEUs.

H. Rate of growth

222. In some service industries, such as telecommunications, the demand may be limited only by the facilities provided, so that any forecast may be self-fulfilling. There is an element of such investment influence in ports, as modern facilities often generate commercial and industrial activities related to maritime traffic, and these activities have a multiplier effect on the development of the port. However, such influence is generally considered to be small. A port whose investment lags behind the demand will certainly hold back economic development, at least in the local region; but a port that invests ahead of the demand may only slightly encourage economic development. In a competitive situation, early and substantial port investment can make a very large difference. However, it is not normally appropriate for ports in developing countries to engage in strong competition or in speculative investments.

223. The fact that a congested port can inhibit economic development has an important implication. It is not unknown for port planners to develop their own estimates of future rates of national and regional growth, tempering the central government's growth ambitions with the cold water of past experience. This may be understandable from the narrow point of view of a port's financial interests, since port management normally has to make sure that the future port is financially viable, which it will not be if, for example, investment has taken place on the basis of a government target of 11 per cent annual growth in GNP when over the five years of a development project the actual growth has only been 6 per cent. The demand at the time of commissioning of the new facilities will in that case be only 79 per cent of the forecast demand, an error of over 20 per cent.

224. Nevertheless, this conservative approach by a port authority is not admissible. The past is not always a reliable guide to the future. In the case mentioned above, it would still be possible for a change to take place that might accelerate growth to the target level. The port management must accept that there may be wider issues involved and that its span of responsibility does not include the revision of government targets. Instead, it must take two steps:

(a) Point out to central planners the implications of a high rate of economic growth for port investment at the time the national plan is being formulated, so that this factor can be taken into account;

(b) Introduce review-points into each project plan at which developments in volume and type of demand are taken account of; this will be part of the system of "signposts" mentioned earlier (see paragraph 204 above).

I. Events

225. Important events which may affect the level of a particular traffic should always be looked for, both to explain past changes and to indicate future ones. These may include political events, the bringing into operation of new factories and refineries, the construction of new inland transport connections, changes in the market price of a principal commodity and hinterland agricultural developments.

226. The difficulty of predicting future events should not discourage the forecaster. Very often a re-examination of a forecast made earlier will show that a vital event was not foreseen. This does not destroy the value of forecasting or mean that it was a bad forecast. It is impossible to do more than prepare a forecast that is based on the best information available. Surprise events or circumstances can never be foreseen. The possibility that they will happen is a primary reason for the flexibility in planning recommended in chapter II above.

J. Effect of the port's own policies

227. The policies of the port will influence the future levels of traffic that use it. The users of a port are of two kinds:

(a) Captive users, i.e. the shipping lines, shippers and local industries which ship via the port because there is no economic alternative route;

(b) Non-captive users, i.e. those which, while obliged to move goods in and out of the region, can use another port within the region, or another mode of transport, and secondly, those which could cease trading activity with the region and so inhibit local economic development.

Both types of non-captive user will react to the decision taken by a port planner. Thus a port by its own policies can cause diversion of traffic to other ports or loss of regional traffic. Normally, such questions should be discussed at the regional planning level in terms of a set of objectives for the port.

228. One of the major ill effects which a port can have on the traffic using it is to prevent the introduction of more modern or more economic ship types. For example, the arrival of larger bulk carriers can be prevented by the failure to provide deeper water. It is generally such changes which are in question rather than a gradual falling off in demand as costs rise or the level of service falls.

229. Only rarely, for example when there are competing ports in the same country, will an attempt to evaluate the more sophisticated traffic relationships be justified. Such methods as demand elasticity estimation, analysis of effects of inter-port competition and analysis of traffic creation sensitivity are difficult to apply because knowledge of shipping lines' and shippers' commercial intentions will not be adequate. Moreover, the probability that unforeseen events will seriously affect the forecast is always present. Nevertheless, there may be occasions when the planner considers that the level of use of a certain facility will depend on the charges made for using it, and is at the same time faced with the difficulty that the charges needed to pay for the facility depend on the level of use. In that case it is best to forecast on the basis that charges and unit handling costs will be comparable with those applied at other installations of similar technology in the region and thus neither attract nor dissuade

traffic. Accordingly, the market research which is needed before investment should be based on the assumption of a level of service and price roughly corresponding to those at other installations. If. however, the new port facilities are to be based on improved technology, for instance in handling dry bulk exports. costs may be considerably lower than those for older installations in the region and the above approach cannot be used. The forecaster is then obliged to estimate the relationship between charges and traffic.

K. Trend forecasting

230. The fact that over the last few years a particular class of traffic has been increasing does not in itself mean that the trend will continue. Trends can reverse themselves very quickly. Before projecting any past trend into the future, the planner should determine the reason for this trend, and the likelihood of its persisting. In most cases in developing countries, the reasons will be one of the following:

(*a*) Traffic is directly dependent on the GNP;

(b) Traffic in a specific commodity or product has been deliberately developed or run down (e.g. national self-sufficiency in a major foodstuff; development of a new industry or of mines);

(c) A gradual shift in regional centres of production or consumption is occurring;

(*d*) A gradual shift in transport technology or routeing is occurring (from break-bulk shipment to containers; from maritime to overland transport, etc.).

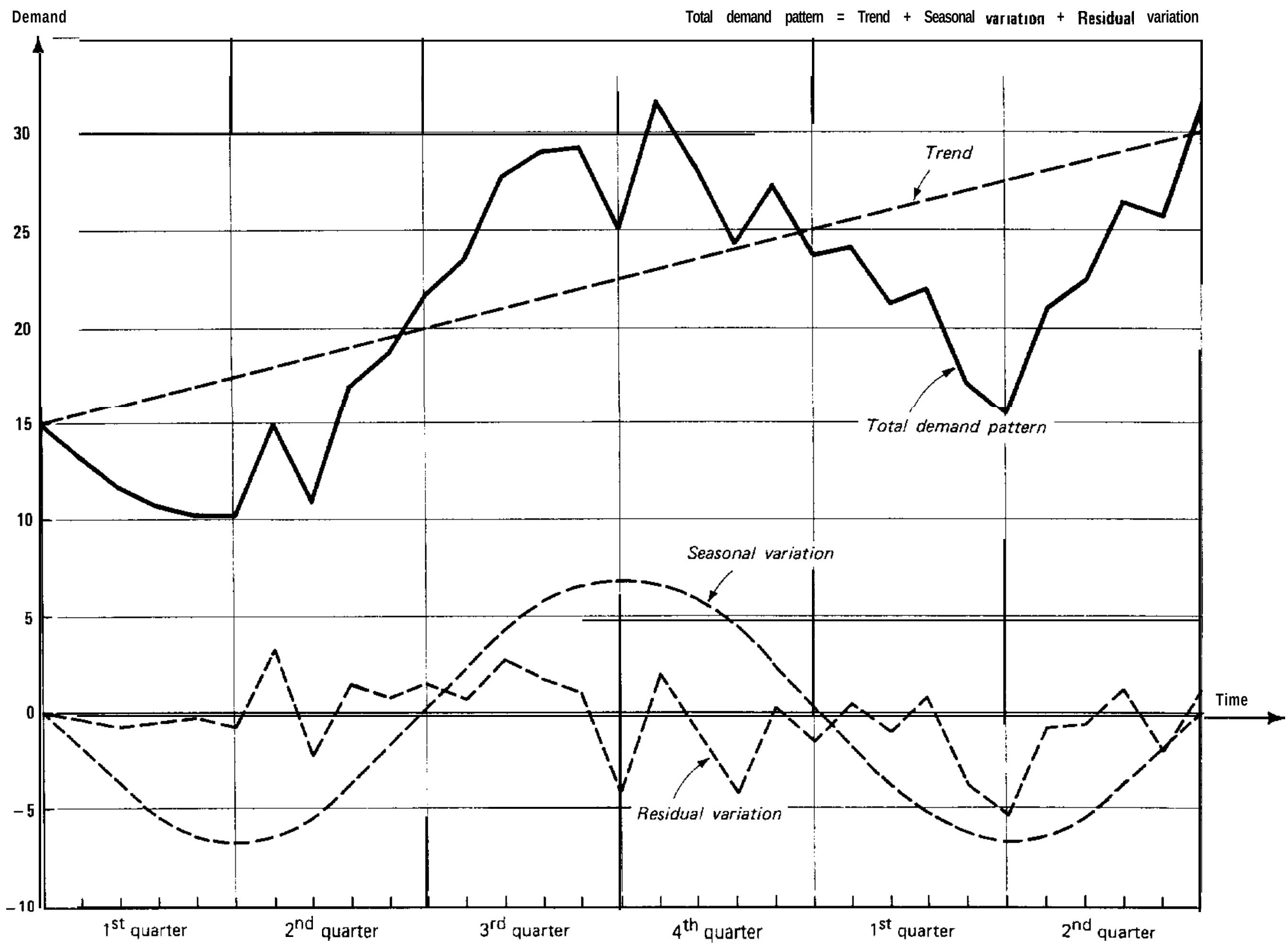
231. If it is desired to find a traffic trend in a series of annual figures, simple methods are the best to use. Usually all that is necessary is to calculate an annual percentage growth rate. or to plot quarterly figures and draw in the trend by eye. When the trend is particularly important and likely to persist. additional accuracy can be obtained by carrying out a "least squares fit" procedure to ascertain the form of the trend. This is a standard method given in text-books on statistics.

L. Seasonal variations

232. When a detailed traffic record-for example, monthly figures maintained for several years-is examined, a regular. cyclic pattern may be noticed. This normally results from a seasonal variation in demand for, or production of, certain commodities. The continuous trend line can be subtracted from the total to obtain the seasonal variation. There will still be superimposed on this seasonal variation a random residual variation, as shown in figure 17. Such analyses are like-

FIGURE 17

Separating a seasonal variation from a trend



ly to be very much simpler and more useful if the traffic is divided into principal commodities, seasonal commodities being kept separate.

M. General cargo traffic and GNP trends

233. Whereas specialized traffic is generally linked to the development of a specific industrial sector, or to individual events and policy decisions, general cargo—which in many developing countries consists predominantly of imports of consumer goods and general manufactures-is far more dependent on the trend in national wealth. An appropriate measure is the gross national product. The figures for the GNP trend and the government target should be taken directly from figures available at the national economic planning unit. Port planners should not normally engage in this form of forecasting. It is, however, necessary to adjust the GNP trend **and** to forecast for the hinterland deviation from the national trend.

234. For example, the hinterland trend may be below the national trend owing to a different rate of growth in various areas or regions of the country. The factors causing this may be expected to continue unless definite government measures are planned for the development period with a view to restoring the balance. Where regional GNP figures are available, useful comparisons can be made between regional growth and general cargo growth which will allow projections to be improved.

235. Apart from deliberate regional development policies, there will be occasions when pressures that build up produce trade shifts of their own accord. One recurring pressure is that caused when a central region or capital city area grows to the point at which land and labour costs become very high and industrial conditions become less attractive. When that situation occurs, a port located in an area of less pressure, with good connections to the major internal markets, can expect a fairly rapid build-up of industry looking for alternative locations where conditions are more favourable.

N. Container traffic forecasts

236. Several principles should be observed when preparing the forecast for container traffic:

(a) The percentage of any trade which may become containerized must be determined on the specific commercial and economic grounds for each case;

(b) There are no fixed lists of commodities which are "containerizable" and commodities which are not, and a wider range of goods is being shipped in containers every year;

(c) Provision must always be made for a substantial proportion of containers moving empty;

(d) The average weight of cargo per 20-foot container can vary from 5 to 18 tons according to the nature of the commodity.

237. There will be a significant trade imbalance, with import containers predominating, during the early years of container operations in developing countries, since few of those countries will be able to provide sufficient containerized export cargo to fill the available import containers. The number of empty containers being loaded in developing countries will therefore be very high. Even so, however, a small number of empty containers will be unloaded there, for example, refrigerated containers intended for perishable exports. Thus, to the number of loaded units exported from and imported to the port, an appropriate number of empties should be added. In the absence of other information, a figure of 60 per cent for export empties and 5 per cent for import empties would be reasonable estimates.

238. Although for rough planning, overall averages of cargo tonnage per container can be used, it is inadvisable to use a single blanket figure, since a tonnage forecast of 500,000 tons, for example, could be carried in anything from 30,000 to 60,000 TEU containers. Wherever possible, the principal type of cargo to be carried (e.g. rice, general manufactures, refrigerated fruit) should be determined and with the appropriate stowage factor, the figure for the average number of tons per TEU can be used, as shown in table 9. In the absence of such information, it would be wise to plan on the basis of a maximum figure of 12 tons per TEU for imported general consumer goods in developing countries.

239. When the class of cargo is known, the procedure for planning more accurately is similar to that of calculating ship loadings. According to the stowage factors of the cargo, the maximum load can be limited either by the weight or by the space occupied. For planning purposes the internal volume of a 20-foot container can be taken as:

29 cubic metres
or 1,024 cubic feet

This volume will be filled at the maximum allowable cargo weight of 18 tons only when the cargo stowage factor is 57 cubic feet per ton (or 1.6 cubic metres per ton). Commodities of this density are, for example, flour, potatoes and palm kernels.

240. Cargoes with stowage factors greater than 60 cubic feet per ton will thus be limited by the physical size of the container, as shown in table 9, and these types of cargo will usually be carried in 40-foot containers.

TABLE 9

Maximum weight per TEU as a function of stowage factor

Stowage factor of cargo		Cargo net weight per TEU (tons)
Cubic feet per ton	*Cubic metres per ton*	
60	1.7	17.1
70	2.0	14.5
80	2.3	12.6
90	2.5	11.6
100	2.8	10.4
110	3.1	9.4
120	3.4	8.5
130	3.1	7.8
140	4.0	7.3

Cargoes with lower stowage factors will be limited by the maximum allowable weight per container (18 tons), and will he packed to a height less than the standard 2.2 metres available in a container. They will all approximate to an 18-ton net weight. For cargoes with a lower stowage factor. the use of half-height containers may be warranted. However, it is not likely that this proportion can be forecast, so that attempts to estimate the effect of half-height containers on stacking and productivity are not likely to be justified. (The principal dimensions of containers are given in annex I).

0. Hinterland changes

241. The port's local and wider hinterland can be examined by studying the inland origins and destinations of a sample of consignments. The hinterland, and hence the port demand, can be affected by changes in the following factors:

(a) Population and GNP;

(*b*) Regional development plans;

(c) Land transport developments;

(*d*) Coastal shipping and inland waterway developments;

(e) Possible re-allocation of traffic to neighbouring ports.

The planner should examine these factors when preparing the traffic forecast.

P. Government traffic

242. It should be possible to obtain information on the traffic demands which central government departments or other authorities have already decided to place upon the port. The only forecasting task with respect to such traffic is to obtain a reasonable estimate of its rate of growth. This traffic will probably consist of large quantities of individual commodities. For example. there may be a central decision to import a predetermined quantity of fertilizer or cement. In this case every opportunity should be taken to convince central planners of the vital necessity of staggering the arrival dates of a series of bulk charters. Very serious congestion can result from failure to appreciate this fact, and the economic consequences of grouping the bulk vessels should be presented to the central planners.

Q. Trans-shipment traffic

243. The trend towards more rational route planning, and the need to reduce the number of port calls made by large, fast and expensive ships on a trunk route, gives increased importance to the trans-shipment function of a port. Not only do such changes introduce a very different class of ship (feeder ships will be smaller and able to work in restricted draught conditions, and will have a high load factor) but there is also a variety of possible effects on the resulting traffic which is often overlooked.

244. For example, figure 18 shows two ports, A and B, each with its own hinterland demand for traffic of 100,000 and 40.000 units per year respectively. When both ports are served by the trunk route ship (case (a)), each has only the standard level of quayside activity associated with its own hinterland traffic. In case ***(b),*** the trunk route ship stops calling at port B and its traffic is carried in a coastal feeder vessel. The level of quayside activity is now:

Ar port A: The port's own traffic plus double the trans-shipment traffic for port B (first discharging the trunk route ship. then loading the feeder ship).

At *port B*: The same level of activity, but with smaller ships.

In case (c) the feeder service to B is via land transport. The level of activity is now:

At *port* ***A:*** The port's own traffic plus the trans-shipment traffic for B.

At *port* ***B:*** Nil.

245. Clearly, the demand for port services varies substantially. After forecasting the traffic demand for the port's hinterland, the forecaster must then consider whether it will be a main port or a feeder port for that traffic, and what proportion of any feeder traffic is likely to go by sea or waterway, as opposed to road or rail. Handling facilities and storage requirements will both be affected. Road or rail feeder traffic will, of course, also place an additional load on the handling and access problems of the land transport vehicles.

R. Technological changes

246. For each class of traffic and principal commodity, the planner must consider the possibility of change in methods of packaging. handling and storage and in types of ship. These possibilities must be discussed with major shippers and shipping lines to determine:

(a) What decisions have already been taken;

(b) What long-term changes are likely:

(i) Assuming that the port plays an active role in providing the necessary modern facilities;

(ii) Assuming that the port relies upon its existing facilities.

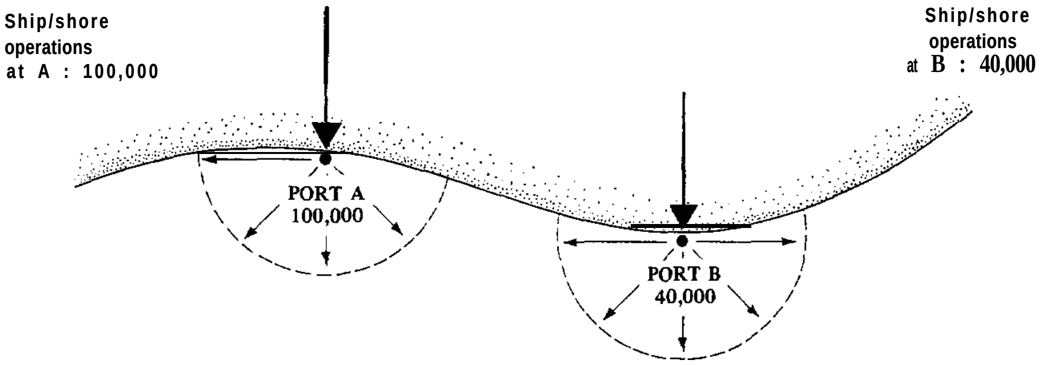
If possible. discussions should also be held with the managers of ports at the other end of major trade routes, since the technological situation at the far end will generally determine the change. This is one of the reasons for maintaining traffic statistics route by route.

247. The decision to introduce new technologies is normally taken by the ship operator. Unfortunately, the time of the port investment decision is usually well before a firm commitment can be expected from the shipping line to bring a specific class of ship to the port. This leads to great uncertainty as to the nature of the future traffic, and often the planner will be able only to suggest that the general trend in technology justifies a particular type of port facility. The port management's decision in such a case-for example; to invest in an expensive container crane-will inevitably carry an element of risk.

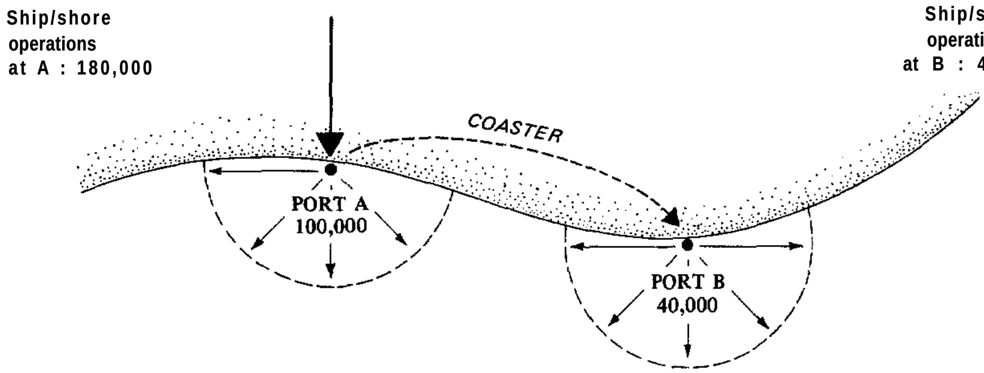
248. The technological changes in shipping which

FIGURE 18

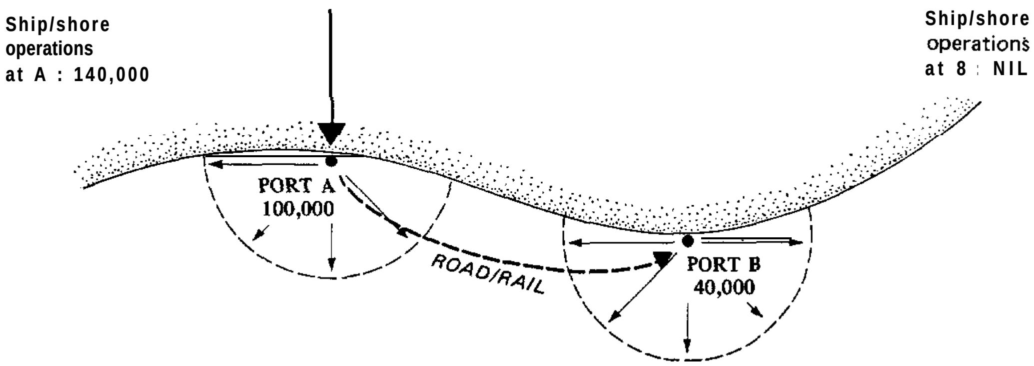
The effect of feeder services on quayside activity



(a) Both ports on trunk route



(b) Port A main port; port B feeder port linked by coaster or barge



(c) Port A main port; port B feeder port linked by road/rail

are taking place are discussed in detail in a series of reports on the subject prepared by the UNCTAD secretariat.[e] These changes take the form of a swing to traffic specialization and economies of scale, both on board ship and in the weight of the indivisible load unit that is lifted, rolled or floated off the ship. The planning implications of container and other unit loads, or roll-on/roll-off methods, and of barge-carrying vessels are examined in part two of the handbook.

S. Shiploads and number of ship calls

249. **A** forecast of the tonnages of each main cargo class on each major route, which is based on the probable trends in modes of carriage and cargo-handling technology, can be converted, by means of the average shipload, into the number of ship calls.

250. The forecast of the number of calls (the ship-traffic forecast), and of the related size of ship is important in planning for the estimation of the following:

(a) Required depth of water;

(6) Required berth lengths;

(c) Future productivity;

(d) Turn-round time for individual ships;

(e) The frequency of ship calls;

(*f*) The back-up areas required to handle the peak shipload.

251. It will be useful to discuss the prospects for the consolidation of shipments with local shippers' organ-

[e] "Technological change in shipping and its effects on ports" (TD/B/C.4/129 and Supp. 1-6).

izations and with the shipping lines. Those bodies should be encouraged to consider what is the required and economic frequency of shipment, the size of shipment and the storage demand. on the expectation that there will be a trend towards economies of transport and distribution.

252. Both the trend analysis and the discussions will produce a picture of the future which should be satisfactory for the purposes of ship traffic forecasting. The forecast of the number of ship calls should be made in the following two ways and if necessary a compromise forecast arrived at between the different results:

(a) By dividing the figure for total cargo by that for the average shipload;

(b) By ascertaining the number of calls directly from present records and the general trend.

253. It should not be assumed that there is a direct relationship between the tonnage loaded or discharged by a ship at a port and the ship's size. In liner services the size of the cargo load taken on or discharged at a given port is virtually independent of the ship's carrying capacity, except for home ports or terminal ports, where loads tend to be a larger fraction of the capacity. For regular short-sea feeder services or ferries, on the other hand, it is reasonable to assume full shiploads (allowance having been made for a minimum of 10 per cent unused capacity in addition to the stowage factor limitation). For bulk carriers it is not normally likely that calls will be made for loads of less than 25 per cent of the ship's capacity, but it should not be assumed that bulk tramp ships will have a regularly high percentage utilization at a single port. Loads varying between 25 per cent and 75 per cent of the ship's capacity are to be expected, except with respect to major high-capacity terminals for the export, for example, of mineral ores, where the bulk carriers may be fully loaded.

254. The portion of the carrying capacity of a ship that is loaded at a particular port is determined by whichever is the smaller of the cargo available and the shipping space available. In addition, for a given amount of space, there will be a minimum load which will economically jusify the call. This load will also depend on the pattern of calls made at neighbouring ports as part of a sharing of carrying capacity. In the case of container ships, port loadings have already settled down to typical figures on economic grounds. The average numbers of TEUs loaded or discharged per port of call are 400-500 on deep-sea routes and 100–150 on short-sea routes. These averages are relatively independent of ship size in both cases. The pattern of sharing out of carrying capacity is, of course, seriously changed on the introduction of feeder services.

T. Ship size

255. It is likely to be fruitless to try to find the future ship size on a route by looking for the relationship between size of ship and route length in existing services all over the world. Such relations exist, but they are so imprecise as to be of less value than a practical operator's opinion. For example. although there is a clear relationship between the grt of a given class of ro/ro vessels and service distance. as would be expected on economic grounds, there is a wide range of variation within this trend. On 1,500-mile short-sea services, ships vary from 2.000 to 8,000 grt and on 4,000-mile services, they vary from 7,000 to 14.000 grt. Planning cannot be based on such broad trends. The planner should study the existing port traffic and attempt to forecast future trends in order to determine this essential factor.

256. An element to be borne in mind in long-term planning for handling bulk cargoes is the tendency to use larger and larger ships for this purpose because of the economies of scale they afford. Consequently. sufficient water depth as well as width of turning basins and channels must be ensured for the long-term development of bulk-cargo terminals. The relations between dwt and the principal ship dimensions are reasonably systematic and thus can be used in planning. They may be found in the various chapters of part two of the handbook dealing with the different ship types.

U. Evaluation of forecasts

257. Traffic forecasting is an art which places heavy demands on the planner. Outside consultants will often be required to prepare the forecast: in this case. it is advisable to check the forecast carefully to be sure that the consultants have fully understood the local needs. Apart from being mathematically correct and showing how all the figures have been derived, the forecast should pass the following tests:

(a) Has what is desirable to achieve been considered, as well as what is likely to happen? What is desirable can best be found from national economic targets.

(b) For each projection of a past trend, have the reasons for the trend been explained and has the future continuation of each of these reasons been questioned?

(c) Have past records been analysed for seasonal variations, and their causes identified?

(d) In each industry, and for each principal cargo. has a search been made for possible future events which will affect the traffic? Traffic-influencing events are:

- (i) The opening, or major expansion, of mines, steel and cement works, refineries and other processing plants;
- (ii) The introduction of a new crop or of a new fertilizer policy;
- (iii) The building of a new port;
- (iv) The opening or closing of roads. railways, canals and bridges;
- (v) The loss of an export market;
- (vi) Changes in import licensing policy;
- (vii) Changes in the pattern of feeder and trunk shipping routes;
- (viii) Changes of frontiers and other political events.

(e) If any forecast trends are linked to national economic indicators, have these been adjusted for local deviation from the national average?

(*f*) For each future trend. have possible constraints on growth been considered? Growth-limiting constraints could be due to:

(i) Lack of transport capacity;
(ii) Lack of storage outside the port;
(iii) Lack of manpower;
(iv) Competition for the same traffic;
(v) Environmental impact.

(g) Have alternative scenarios (future histories) of how the port may develop in the long term been written, and each converted into broad forecasts for each class of traffic?

(h) Has an attempt been made to gather, and then to reconcile, the views of shippers, shipping companies, and industrial planners? A valuable forum for reconciliation of views are commodity associations, chambers of commerce, etc.

(i) Has a check been made of whether any of the traffic in the forecast is also claimed by another port? If there is no national ports plan, there should at least be a reconciliation of the forecasts of neighbouring ports, and of their traffic shares.

(j) Have annual forecasts (both optimistic and pessimistic) for the whole life of the investment been tabulated for each class of cargo, showing:

(i) Weight tons of cargo;
(ii) Numbers and sizes (dwt) of ships;

and recording seasonal variations and weight/measurement ratios for each cargo class?

(k) Are there any broad options or views of the future which the authors take for granted but which could be wrong and should be questioned? What are they?

258. For planners who carry out their own forecasting, the following dos and don'ts may be of help:

Do talk to port users about their future plans, including changes in technology and in cargo consolidation.

Don't forget that underestimates of traffic can result in far more costly mistakes than overestimates.

Do listen to the views of the port traffic manager.

Don't believe that a past trend will continue in the future without good reasons.

Do spend more time looking for likely future events than examining past trends.

Don't eliminate traffic from the forecast merely because its arrival is not definite. Present all the possibilities to the investing authority; it is up to them how much risk they want to take.

Do prepare separate forecasts for transit traffic to neighbouring countries. This traffic will have different procedures, charges and storage needs, and may develop differently from national traffic.

Don't use advanced mathematical techniques to deduce accurate trends from traffic records. The data is most unlikely to be consistent enough or persistent enough to justify the effort.

Do keep separate tabulations of transshipment traffic. It will be subject to different development from normal traffic and can rapidly change.

Don't waste effort trying to estimate the elasticity of demand for port services.

Do classify the cargo in enough detail to leave only a small percentage under the final heading "other" or "miscellaneous".

Don't multiply together two uncertainties to produce a bigger uncertainty. If you have to combine several traffic components, each with high and low estimates, use the method given in annex II.

Do periodically revise your ideas of what cargo is containerizable, as this changes year by year.

Don't guess at the average weight of cargo per container. Estimate this from your knowledge of the type of commodity to be carried (see table 9 above).

Do maintain complete traffic records and introduce a system of regularly checking key statistics for deviation from forecast.

Chapter IV

PRODUCTIVITY AND OPERATIONAL PLANNING

A. Pitfalls in estimating productivity

259. Estimating the cargo-handling productivity which will be achieved is a vital part of the plan for a future port development. A mistake here can lead to serious investment errors. In considering the extension of existing facilities, the planner must find out:

(a) What is the real productivity at present? Recorded data are often inaccurate or misleading;

(b) How will this change with the new development? In theory, new methods should improve productivity, but in practice this is not necessarily the case.

260. There have been many cases of very poor estimates of future productivity, almost all being unduly high. This has probably been due mainly to two basic errors:

(a) Contrary to a widespread misconception, an increase in cargo-handling productivity will not automatically give higher berth throughput. For example, a change from conventional break-bulk cargo handling to the use of pallets should give, say, a 50 per cent increase in discharging rate, from 10 tons per gang-hour to 15 tons per gang-hour. But unless this is followed by a similar gearing-up of all subsequent activities (putting into storage, passing through customs, etc.), there will be no increase in berth throughput and probably very little increase in ship handling rate.

(b) Productivity can go down as well as up. It is a common experience in developing countries that at certain stages of development there is a transitional period during which productivity falls.

261. For example, a port which has perfected methods of manual handling over many decades is likely to see a drop in productivity for a considerable period after a change to less labour-intensive mechanical methods. Discharge of wheat in bags by a large, skilled workforce can achieve tonnages per shift which may be difficult to match during the first year of operation of bulk discharge equipment.

262. With respect to a new terminal, where there are no local data to serve as a basis for estimating productivity, planners are forced to rely on performance figures taken from elsewhere. Great caution is needed before adopting these. Often the figures are taken from installations with quite different conditions. New methods have generally been first introduced in countries with a temperate climate, whereas the performance which can be achieved in a tropical climate may be far lower. This is due not only to the human problem of keeping up continuous activity under difficult climatic conditions, but also to the direct effects of humidity and heat on equipment, which can seriously reduce both performance ratings and reliability.

263. These local effects are sometimes compounded by the optimistic sales information provided by manufacturers of cargo-handling equipment. There is a tendency to quote performance figures on a short-run basis and to imply that long-run performance is merely a question of multiplication. This is seldom true of any machinery, for:

(a) There may be other parts of the installation which cannot keep up with the main equipment;

(b) There will be faults and breakdowns;

(c) There will be periods when the equipment is out of commission for routine maintenance.

264. These questions are discussed further in later chapters where the main classes of equipment are reviewed and some guiding figures are given. Nevertheless, wherever possible, the planner should search for proven experience with the equipment in question from ports with similar conditions to his own. Assistance can also be given by the UNCTAD secretariat and by organizations such as the International Cargo Handling Co-ordination Association (ICHCA) and the International Association of Ports and Harbours (IAPH).

B. Rated and effective productivity

265. There are three basic elements in cargo-handling performance. The first is the rated productivity, defined as the number of tons each gang. crane, shiploader, pump, etc., handles when it works for one hour without interruption. The second element is the interruptions which tend to happen during any shift and the consequent idle time that reduces the shift output. As a result of this idle time, the average hourly performance is reduced to what may be termed the effective productivity. The third element is the manner in which gangs and appliances are used, for example, how many are used per hatch and per ship, how many shifts there are, how much overtime working there is. This last element is termed the working intensity. It determines how much total effort is used and this, combined with the effective productivity. produces the long-term performance.

266. A major preoccupation of the planner will be to make a realistic assessment of the effective productivitv from all the optimistic and arbitrarily chosen productivity figures which will be given to him. For example, many container terminal operators quote productivities of 700 TEUs per day, but a rigorous

UNCTAD analysis[9] showed that, of 21 major container terminals, only one, working so-called second- and third-generation container ships, was able to maintain a productivity of this order (749 TEUs per day) over several months, whereas at the great majority of the terminals, working with two gantry-cranes, productivity fell within the range of 300-500 TEUs per day.

C. Matching of operations

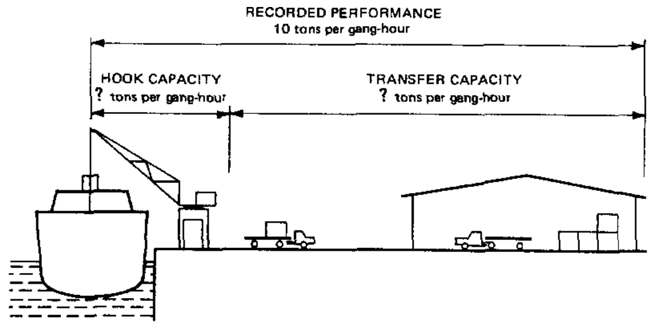
267. Some parts of the berth system are linked in that every ton of cargo which passes through one of them has to pass through others. The most important links are between the ship cargo-handling system and storage, and, later, between storage and onward transport. The first pair of linked operations, unloading from the ship and placing in storage, must be matched on an hourly basis; otherwise one operation will have to wait for the other, or goods will pile up in the operational area and cause congestion. To find out if they are matched. it is necessary to know the hourly capabilities of each operation separately. But here lies the problem: it is difficult to measure the one independently of the other, as any recorded performance will be that of the combined operation. For example, with regard to figure 19, where it is known that for a break-bulk operation the performance being achieved is 10 tons per gang-hour, it will be very difficult to find out whether this figure is limited by the gang in the hold which is feeding the hook, or by the tractor which is transferring cargo to the shed.

268. Retrieving cargo from storage for onward transport cannot be matched with the placing of cargo in storage either on an hourly basis or even on a daily basis so far as general cargo is concerned. Customs clearance and delivery formalities take time, and their duration may vary considerably. But the capacity to despatch cargo from the transit storage areas must match the flow of cargo from quay to storage on, say, a weekly basis; otherwise, transit sheds and open storage areas will become over-filled, and serious congestion will result.

269. Such methods as those described in the UNCTAD report on berth throughput[10] if applied with respect to break-bulk cargo early enough during the project planning period, can serve as the basis both for achieving improvements in current productivity at the port and for giving planners a better idea as to what the future productivity is likely to be. It is advisable to be very cautious-indeed, pessimistic-at the planning stage. Planning figures should be lower than the targets the operating staff set themselves and intend to achieve under a new set of operating methods or with new equipment.

FIGURE 19

Combined capacity of ship cargo-handling system and transfer system



270. The methods proposed in the berth throughput report can be used to check that the development proposal for a terminal gives a balanced throughput capability. In the operations of a port, the various sub-systems function together so that the effectiveness of one sub-system affects the operations of others. The various sub-systems can be thought of as a series of highway sections of different widths, as illustrated in figure 20. The maximum throughput through this traffic system is determined by the capacity of the narrowest section, B, which forms a bottle-neck. It is obviously not possible to increase the overall capacity by widening any other section before making improvements to section B. The only way to increase the overall capacity is to increase the capacity of section B to that of the next largest capacity section, D. Then, if justified, further improvements in the total capacity will require an equal increase in the capacities of both sections B and D.

271. The two major capital costs in many terminals will be the berthing points, with their associated discharge equipment, on the one hand, and the storage areas on the other. Planning charts for both of these are given in part two of the handbook, but it is important to appreciate that the planning of these major elements is based on the assumption that an equal level of capacity is provided also in the other stages of the operation, in order to allow full exploitation of the two major investments. For the import operation this will require particularly:

(a) A design for the capacity of the system for the transfer of cargo from discharge point to storage point;

(b) A design for the capacity of the system for the clearance of goods from storage;

(c) A check with sector planners as regards the capacity of the onward distribution system.

D. Appropriate technology

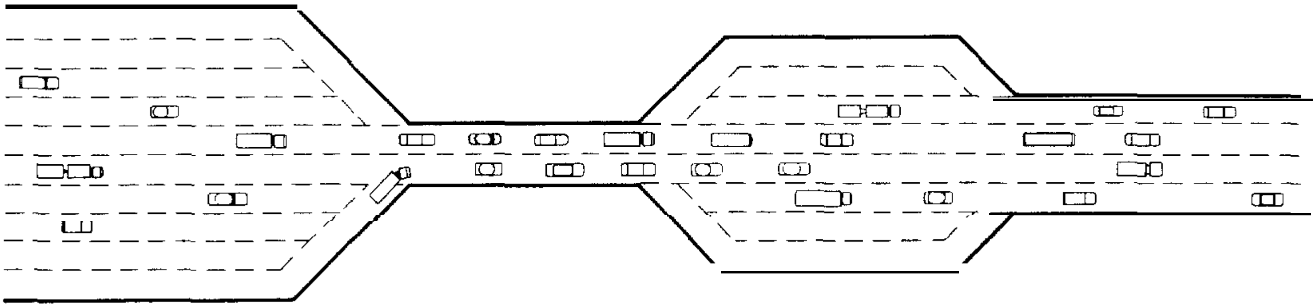
272. The high cost of labour in many of the industrialized countries has justified the use of more advanced techniques of mechanization and automation. In developing countries, different social factors usually apply. Moreover, the shortage of skilled operators and, even more important, of technicians to maintain ad-

[9] "Technological change in shipping and its effects on ports: the impact of unitization on port operations" (TD/B/C.4/129/Supp.1), table 10.

[10] Berth throughput: Systematic Methods for Improving General Cargo Operations (United Nations Publication, Sales No.E.74.II.D.1).

FIGURE 20

Diagrammatic representation of a highway of varying widths



vanced equipment, means that special care is needed before introducing such equipment. Simplicity and sturdiness are more important considerations than high handling speeds, since the overall cost per ton with slower and simpler equipment can sometimes be lower than with advanced equipment that is out of service and requires more costly support.

273. Some handling equipment demands an operator workload and tempo which are excessive in a hot climate and for the local labour physique. This will hold the output down below what can be achieved in a temperate climate. In some cases the controls, for example foot pedals, are designed for persons of different physique. a fact which makes the tasks very difficult and lowers output further. This can apply to fork-lift trucks as well as to more advanced equipment.

274. It is thus vital not only to make sure that productivity targets are realistic for the local conditions, but also that the suppliers of equipment can refer to its successful introduction in similar port conditions elsewhere. Unless there is definite experience to go on, ports are advised to reject offers of untried equipment and go for proven equipment only.

E. Productivity increases

275. Although the emphasis throughout this chapter has been on the danger of planning on the basis of too optimistic a forecast of future productivity, it would be wrong to ignore the real increases in productivity which can gradually be achieved when specific changes are made, Measures for the improvement of productivity that can be incorporated into a proposed project can be divided into three main categories: those concerned with human relations (labour and personnel), those concerned with technical factors and those concerned with administrative and procedural matters.

276. The first category will include all means for improving the performance of each individual manager and labourer irrespective of existing technical conditions. Experience in many ports has shown that the productivity of labour and of clerical personnel depends not only on their professional skill but to a great extent on how far they are satisfied with the conditions of their work, and whether they are really Interested in that work. Specific measures may include:

(a) An adequate level of wages. commensurate with the arduousness of dockers' work, including premiums for performance above predetermined norms;

(b) Possibilities for promotion to more skilled jobs;

(c) Accident prevention measures, first aid stations and well-organized health care;

(d) Canteens and rest-rooms near working areas;

(e) Adequate housing and recreation facilities;

(*f*) Training in technical skills and general education, and greater delegation of responsibility resulting in greater opportunities for initiative.

277. In the category of technical improvements the following steps can be taken:

(u) The introduction of preventive maintenance programmes, with properly equipped and staffed workshops and an adequate supply of spares;

(b) The purchase of a set of pallets to be used for general cargo;

(c) The purchase of additional tractor-trailer combines or fork-lift trucks for increasing capacity for the horizontal movement of cargo;

(d) Technical training programmes for superintendents, the labour force and union officials, including visits to ports in developed countries.

278. The third category of measures, those for the improvement of procedures and organization, includes some that are likely to bring about a considerable increase in throughput at a general cargo berth. Specific measures will include:

(a) Strict enforcement of the rule that individual consignments must be removed from transit sheds within a limited period, normally seven or ten days;

(b) Simplification of old regulations and cumbersome procedures which can delay the smooth transit of cargo through the port.

279. A forecast percentage increase in productivity should not be taken as meaning that there will be an equivalent percentage cut in service time. The two are not proportional. for

$$\text{Service time} = \frac{\text{Total number of tons worked}}{\text{Effective ship productivity}}$$

where the effective ship productivity is the number of tons worked per day at berth. At the maximum, a 100 per cent increase in productivity would result in only a 50 per cent decrease in berth time. The planning charts in part two of the handbook can be used to determine the effects of various changes in productivity.

F. Offsetting effects

280. Productivity improvements are often associated with social and commercial factors which offset them. The gradual trend to shorter working hours, and the resistance to working at night or at weekends in industry in general, may become important factors in ports of the future. Again, theoretical reductions in ship service time due to increased productivity may be offset by increased idle time as the ship operators may have a tendency to keep to a traditional fixed time in port.

G. Productivity targets

281. It can be misleading to give standard or even average figures for hourly or daily productivity. There are many valid local reasons why one port, or one berth group within a port, may be able to achieve a figure much higher than another, and inter-port comparisons of this sort are of no great value. Each port should compare its current performance with its performance of previous years and try to improve on that rather than attempting to achieve apparently higher figures derived from elsewhere, which may have been calculated on a different basis.

282. When the planning charts given in part two of the handbook are used, the figures entered for the tons per gang-hour, the fraction of time worked and the number of gangs employed should all be taken from figures actually recorded. Where these are not available, and particularly where a port has little experience of the type of operation proposed, it is strongly recommended that operational staff pay a visit to a port experienced in that operation, preferably in similar local conditions. The information they gather on such a visit, suitably adjusted to take account of local conditions, should be used as the basis for planning.

283. Nevertheless, in order that such productivity estimates remain realistic, the planner will want to check that the figure proposed is within the right range. Table 10 gives values which can be used for this purpose. The figures given are for a well-trained and motivated team working the average number of hatches for each class of ship, and for a shift pattern which gives a fraction of time worked (standard shift-hours per week divided by 168) of 0.6. The figures can thus be considered in the nature of long-term operational targets. Their main purpose, however, is to act as a check-list to prevent over-optimistic productivity estimates. Higher figures should not be used unless strong evidence exists to the contrary, and planners may prefer rather to adopt lower figures according to local circumstances.

TABLE 10

Productivity check-list[a]

Cargo class	*Tons per ship-day*
Conventional general cargo:	
On deep-sea routes	700
On short-sea and coastal routes	500
Fully palletized general cargo	900
Packaged forest products	1 500
Bundled iron and steel products ..	2 000
Pre-slung cargoes	900
Ro/ro units ..	2 500
Containers:	
On deep-sea routes	450 TEUs[b]
On short-sea and feeder routes	275 TEUs[b]
Dry bulk:	
Loading ..	70 per cent of shiploader rated capacity[c]
Discharging	50 per cent of unloader rated capacity[c]
Liquid bulk	Ship's pumping capacity (approximately 5-10 per cent of dwt capacity per hour)

[a] Before these figures are used, reference should be made to paras. 281-283.

[b] See para. 266.

[c] See definitions of capacity in part two, chapter VII, "Dry bulk cargo terminals".

H. Operational planning

284. The preparation of an operational plan for any new facilities is a key step in project planning. The layout, equipping and method of operation of cargo-handling areas must be known before either productivity or cost estimates can be made. Particularly for new technologies or operating systems, it may be necessary to visit other installations or to engage a specialist.

285. To encourage detailed operational planning, the planning charts in part two of the handbook call for inputs at a detailed level-number of gangs, tons per gang-hour, etc.-rather than at the overall performance level, such as tons per day. The operational plan for a new development should give a reasoned figure for each parameter needed in the capacity calculations concerned.

286. However, it will not normally be acceptable merely to state the expected value for each parameter without considering two supplementary pieces of information: how is the present performance and why will the future performance be different? These points could be tested where applicable by the following questions:

(a) Has the impact of the traffic demand on operations been considered?

(i) Ship call frequency and ship load;
(ii) Seasonal variations;
(iii) Consignment size;
(iv) Routeing (direct/indirect);
(v) Storage characteristics;

(b) Has the full sequence of movement of the cargo in the port been specified?

(i) Mode of transport for receipt/delivery;
(ii) Facilities for loading/discharge of this transport;
(iii) Type and volume of space needed for operations and storage;
(iv) Procedure and facilities needed for customs and other inspections;
(v) Method of tallying, sorting and weighing;
(vi) Mode of transport for each movement in the port area;

(c) Is the sequence of operations matched to the ship discharge/loading rate?

(i) Work in the hold;
(ii) Quay apron work;
(iii) Transfer to and from the quay;
(iv) Stacking and retrieval;
(v) Receipt and delivery;

(d) Are steps proposed to make sure that enough trained manpower will be available?

(e) Have the operational requirements for each of the following been considered:

(i) Pilotage;
(ii) Tugs;
(iii) Harbour craft;
(iv) Navigation aids;
(v) Fire-fighting;
(vi) Port security and policing;
(vii) Dangerous material area;
(viii) Equipment maintenance areas;
(ix) Canteens;
(x) Rest-rooms and temporary living quarters;
(xi) Minor repair facilities;
(xii) Lighting (for night work);
(xiii) Communications (including ship to shore);
(xiv) Pollution control;
(xv) Waste disposal.

Chapter V

MASTER PLANNING AND PORT ZONING

A. Port location

287. The early traditional ports were generally located close to or were part of a coastal city. Their function was to serve that city and, secondarily, inland areas and towns. The traffic they handled was predominantly general cargo. Even where there were principal export commodities, the quantities involved were small enough also to be handled in break-bulk fashion (for example, in bags). The commercial activities associated with the port, apart from warehousing, did not call for much land area, and there was little industrial activity. Thus the city centre waterfront was an acceptable location for the old general cargo piers.

288. In the last few decades, many factors have influenced the location of the port, changing the above picture almost completely:

(a) Commercial, warehousing and light manufacturing activities have been forced to move out of the main urban area, both because of their increasing scale and resulting land needs, and because other demands for city centre land have become too great;

(b) Industries have grown up which require extensive land area and easy access either to the port or to the inland distribution system, or both;

(c) The tonnage of principal commodities has increased to the point where the whole scale of the old operation has been outgrown;

(d) This increase has made possible the introduction of bulk transport, which utilizes larger ships needing deeper water and large transit storage areas, and also requires unencumbered landward traffic routes;

(e) The economies of scale have induced port planning authorities to concentrate development at a single port which services a considerably larger area than before;

(*f*) The old concept of mixing port activity with the normal life of a city population has been generally abandoned on environmental grounds.

289. As a result, the preferred location of a modern port is no longer on a city waterfront. Existing city ports may continue to operate, but they serve only a fraction of the total traffic, mainly the residual break-bulk cargo traffic for the local hinterland, together with coastal trade and lighterage operations. The principal traffic and the major proportion of the general cargo traffic, especially when unitized, must move to more suitable locations. In developing countries, where unitization is developing slowly, there may be the possibility of continuing for a certain time to handle all the general cargo in the old location, but if there is a considerable volume of general cargo traffic, even if it is not unitized it may need a new, more convenient location. In the great majority of cases, the industrial port activities must be moved out of the urban area, even if only on environmental grounds. In fact, the new port may function as a focal point for regional development and thus its location can be used to stimulate national economic growth.

290. A point to consider for ports contemplating the transfer of some activities to new areas is the possibility of offsetting the cost of new developments by selling or leasing the valuable city centre waterfront land.

B. The master planning approach

291. The search for suitable locations for new port developments and for extensions to existing ports will be governed by the need for the following:

(a) Deep safe water at berthing points, and satisfactory approach channels;

(b) Sufficient land area;

(c) A labour force;

(d) Good access to road, rail or waterway routes.

This chapter considers the way in which the first two requirements may be harmonized. The availability of a labour force to operate the port is a very important aspect, as the economic and social costs of resettling workers is considerable. Engineering aspects of the water area requirements are discussed in chapters VI and VII below. The inland transport connections are discussed in chapter IX below.

292. These requirements form an early part of the work of master planning. The relationship between the master plan and other, shorter-term port development projects was described in chapter I, where it was pointed out that the master plan is concerned with preparation for the long-term future. The emphasis is on setting a rational development framework into which successive construction projects can be fitted as the traffic increases.

293. Master planners must look into the distant future and search for the most economic configurations, but the usual financial project appraisal techniques are not appropriate at this stage of planning. The major criteria are industrial, social and environmental, with enough practical engineering study to ensure that the long-term path chosen does not lead in a direction of excessive civil engineering cost. A principal consideration of the master plan will be to keep the port's options

open as long as possible. For this purpose the planner should give his main attention to preparing an overall programme of land use and preventing the authorization of the use of land for other purposes which would hamper the future development of the port.

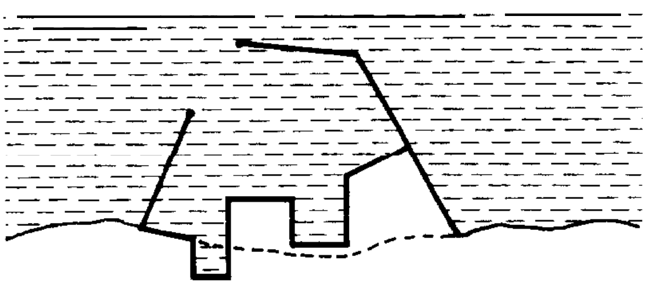
294. When the port authority has responsibility for ship repair facilities within the port area, these will form a special zone. Dry docks, slipways, etc., have their own land and water area requirements and will have an important effect on the overall zoning plan. For assistance on this subject, reference should be made to UNIDO.

C. Classes of port

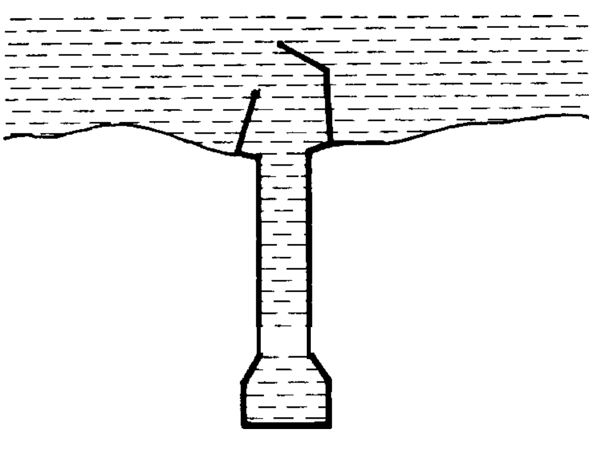
295. It is important to consider a wide range of alternatives before selecting one concept. A common mistake is to become preoccupied with one proposal too early in the work. Nowhere is this more important than at the broad master planning stage. since there are opportunities here for influencing the whole course of a country's regional development. The conceptual stage starts with the co-ordinated national port strategy, and here the options open for a country with a long coastline or many rivers are numerous.

FIGURE 21

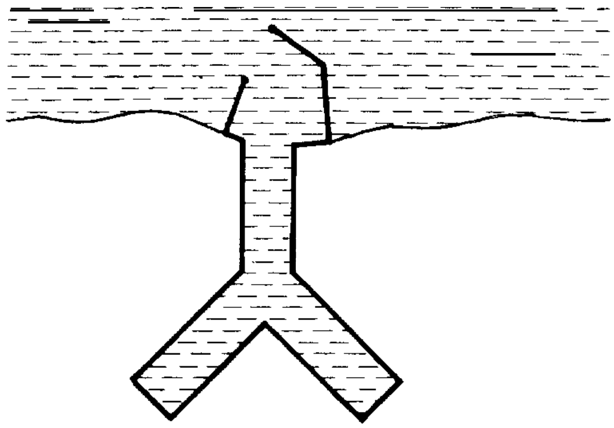
Artificial harbour configurations



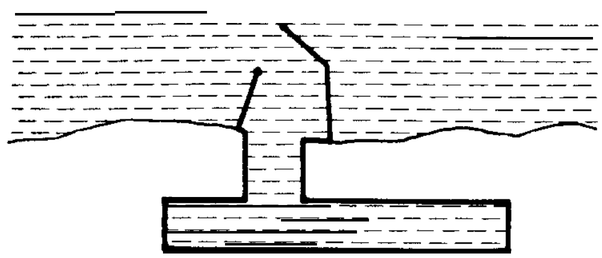
A. Projecting (dotted line shows original coastline)



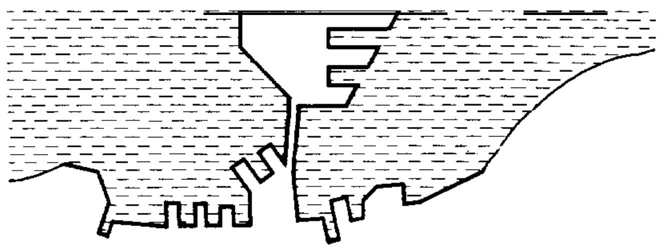
B. Cut channel and turning basin



C. Y-cut channel



D. Parallel-cut channel



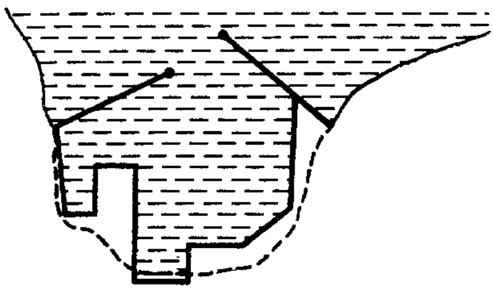
E. Addition of artificial port island to an existing port

296. The main classes of port which may be considered before deciding on a short list of site alternatives are shown in simplified form in figures 21 and 22. In every case the aim of the development is to provide sheltered water with access to substantial areas of land. In that respect the artificial harbour formed by cutting a channel in land is particularly useful, and the Y-cut version (figure 21, C) may be considered to give the possibility of an optimum land-use policy. Such a Y-cut can also be a useful elementary dock shape in more complex ports. In certain cases, however, such channels have been found to amplify the wave pattern and therefore careful model studies should be carried out. Where the facilities needed require more space than would be provided by any possible extension of the berthing length of a fully developed port waterfront, and water conditions permit, the formation of an extensive artificial island linked by a bridge, as shown in figure 21, E, offers a solution.

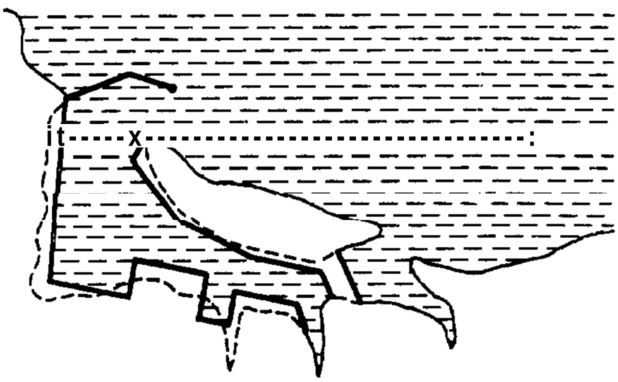
297. In the case of natural harbours, the estuarial port, such as that in figure 22, C, is likely to be the most productive of harbour facilities per unit of construction cost, provided that dredging costs are not too high. To avoid excessive maintenance dredging, this type of de-

FIGURE 22

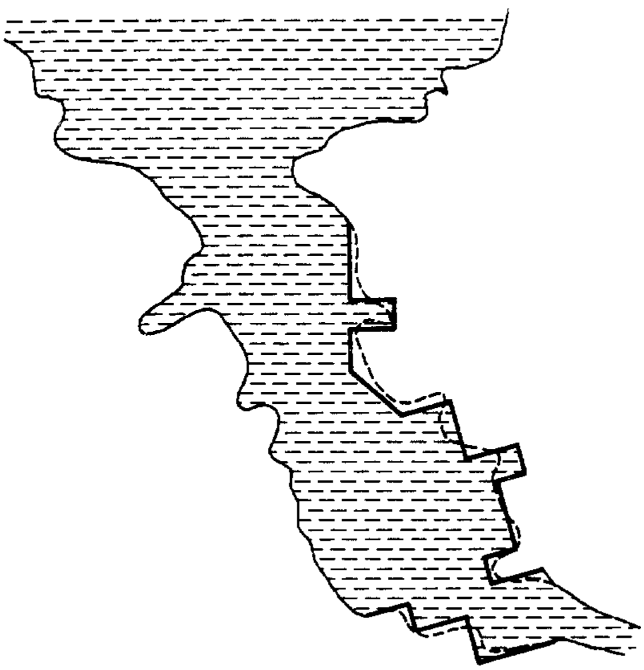
Natural harbour configurations



A. Development of a natural harbour



B. Development of a natural offshore island



C. Development of a natural estuarial harbour

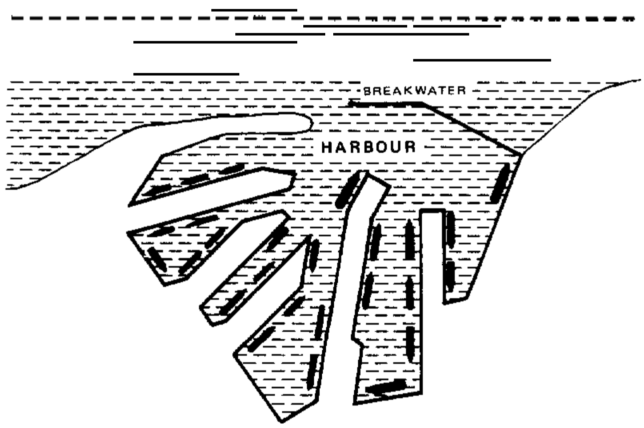
velopment requires particularly careful analysis of the hydraulic conditions, and the configuration chosen will normally be most satisfactory when it reinforces the natural regime rather than disturbing it.

D. Harbour configuration

298. A useful indicator of area requirements in port layout design is the number of square metres of operational land needed per metre of quay. For a linear quay, this can be simplified to the depth of operational land needed behind the quay wall. In earlier days, with small ships and low handling rates, the figure was small-often around 50 (50 square metres per metre of quay), which included the areas required for the quay apron, sheds and rail track. This enabled long narrow piers to be built inside a harbour to maximize quay wall length, as in figure 23.

FIGURE 23

Port layout to maximize quay wall length



299. In this typical old harbour layout, maximum use was made of the sheltered water. When the cargo carried per ship increased and productivity went up, the indicator increased quickly to 100 and then 200, so that it was impossible to find enough operational land with such an internal layout. The reason for this is that a ship of twice the length will carry about eight times the tonnage. It has more recently been fashionable to try to eliminate piers and basins entirely and to use only deep corner areas and long linear quays, as shown in figure 24.

300. Although the layout shown in figure 24 is excellent from an operational standpoint, it clearly uses far more natural coastline and far more sheltered water per berth than the layout shown in figure 23. Therefore this construction is only likely to be economically feasible in rivers and estuaries where ample coastline and sheltered water are available. It would be very costly to build the harbour illustrated in figure 24 on a coastline which needed artificial protection by breakwaters.

301. A simple layout is usually the most flexible for future development. The best way of providing the operational land needed without wasting coastline and sheltered water is to build a pier-type configuration, but where the piers are far wider than is traditional. As a rule of thumb it may be taken that a pier for any form of general cargo should not be less in width than two ship-lengths, as shown in figure 25, A, that is, about 320 metres wide for an average operational cargo pier. For operational reasons it is advisable, where possible, to use the end of the pier only for minor harbour-craft and not as a berth. Prevailing currents and winds plus other navigational considerations will often make it preferable to use a slanted or herringbone pier as in figure 25, B.

FIGURE 24

Port layout to maximize operational land area

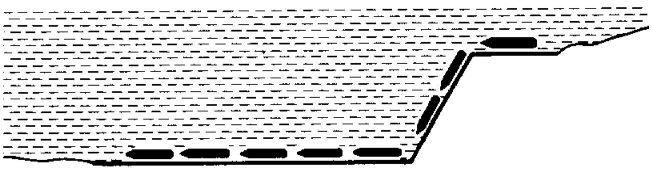
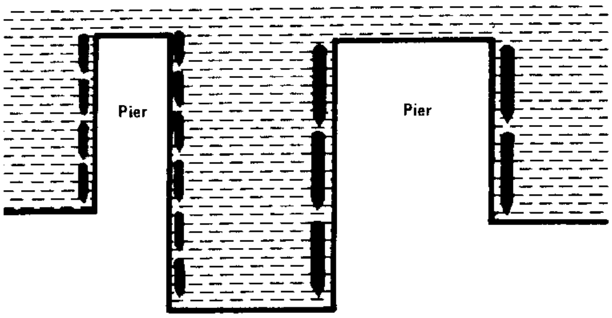
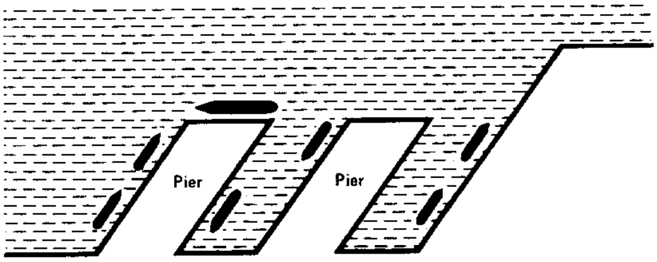


FIGURE 25

Modern **pier layouts**



A Straight piers



B. Slanted or herringbone piers

E. The industrial port

302. Whether the port is to fulfil only its primary function of transferring cargo between land and sea transport or to play a wider and more active role in national development is a primary question for the government. On economic grounds alone, a clear case can often be made for siting certain industries at the point at which different modes of transport meet, since any other intermediate location between the source of raw material and the destination of the product will introduce an extra handling and buffer storage stage.

303. But the question is deeper than this. Port activity constitutes a substantial industry in its own right. The port employs large numbers of workers and trains them in a varietv of skills which are transferable to other industries. It'is therefore a focal point for a complete community and exerts a natural attraction for other industrial activity. Environmentally, it is also likely, prevailing winds permitting. that atmospheric pollution can be minimized when plants are located on the coast. Thus, to plan a port without considering an industrial zone is to lose a valuable opportunity of stimulating regional development. The development of a new port that does not include some industrial activity can normally only be justified when:

(a) Urban pressure and/or environmental aspects are a deterrent to further development;

(b) Geographical or climatic factors limit coastline activity to the bare minimum.

304. Strictly speaking, major industrial developments which, for reasons of economy, are to be sited near a waterfront, should be considered purely as generators of traffic and supplied with port services in the normal way. However, there will be arguments advanced for such industrial areas to have their own port facilities. This gives rise to the concept of a specialized industrial port which is dedicated to that group of industries and separated from the commercial port. Relatively isolated industrial complexes-for example, a mine and an ore-processing plant near a stretch of undeveloped coastline-may justify the building of a special terminal close at hand to reduce land transport costs. Large oil terminals are also often sited away from built-up areas for environmental and safety reasons. However, in both cases, the accessible water depth is likely to be the governing factor, but the possibility of long jetties or off-shore terminals gives considerable freedom in siting.

305. Such freedom to operate independently from an established port can be very attractive to industry planners who may prefer to keep control over all stages of their operation. Two notes of warning must be sounded, however. First, it should be recognized that, in the long term. industrial complexes of any type tend to gather around them associated industries and commerce. with a gradual build-up of local population and all the resulting land-use needs. It would be wise to foresee such developments before deciding on the location of the specialized terminal. Secondly, even though it appears that the terminal will be sited on an undeveloped stretch of coastline, and it may not be possible to imagine any alternative use, the long-term prospects may be very different. Coastline, which is a national resource, should not be given up to a user without a reasonable revenue being collected. In such cases legislation may have to be passed to re-define the boundaries of an existing port area to include the new terminal, so that the port authority can collect revenue as well as providing any miscellaneous services (maintenance of navigation aids. ship repair, tug assistance, fire-fighting) which it would be uneconomical to duplicate.

306. Major industrial development areas, as opposed to isolated industries should, if sited adjacent to a port, be provided with normal common-use port facilities, and the temptation to give up coastline exclusively to special industry needs should be resisted. General cargo needs should be routed through the normal port facilities, and only when specific industrial concentrations require specialized bulk terminals should they be given a separate terminal within the enlarged port area. The cargo-handling needs of the development area will thus be brought fully under the planning and control of the port authority, one of whose main concerns in master planning will be to exclude users of port land who do not need to be located in the port area.

Analyses have shown that the proportion of users who do need to be located in the port area is sometimes surprisingly small. Such considerations can lead to a realignment of the proposed development area inland, rather than parallel to the coast, thus reserving the maritime community's future freedom of action.

307. Since the secondary and tertiary industries add the most value and aid regional development most, while the primary industries tend to contribute most to port revenue, a conflict of interests may arise in the allocation of land by the port authority to the various industries. Where the economic advantage of a particular port land-use overrides the port's financial objective, a land-use subsidy by the government may be appropriate to compensate the port for its loss of revenue.

F. Free zones

308. The setting up of a free port, or a free zone for commercial or industrial purposes, will have a major impact on the port's master plan. This in itself may not always be enough to encourage the extra activity, and a careful and objective market survey should be made before taking a decision on such a venture.

309. Free zones are areas where goods can be handled without passing through the national customs boundary. In the early days, such zones were predominantly for warehousing and trading, while more recently they have emphasized manufacturing, processing and assembly operations. Goods can be imported into a free zone without incurring customs duties or quota restrictions, and can be stored there indefinitely.

310. A UNIDO publication, concerning export-free zones[11] describes the concepts involved and covers the physical planning of such zones. A report by the Economist Intelligence Unit gives additional information on this subject[12]. The following salient points, taken from the UNIDO handbook, are mentioned below to provide guidance for preliminary master planning.

311. With the high cost of land development it is preferable to carry out the project in stages. The initial stage should be small enough to show successful operation, with all necessary services provided, in a period of two or three years.

312. Light industry is less likely to be attracted to a seaport area than medium to heavy industry, because of the advantages of airport zones for light industry. Firms which pollute the atmosphere and are thus restricted from locations near to residential areas may also be more suitable for location in a seaport free zone, provided that environmental effects are carefully considered.

313. Areas involved can be of 200 hectares or upwards when fully developed. Above this level excessive strain may be placed on traffic movement in the area. As a rough guide, the built-over areas of a zone may occupy around one-third of the total area, the remainder being necessary for roads, parking areas, service buildings, recreational areas, etc.

314. Normal principles of industrial zone planning apply, such as a preferred rectangular road layout with well-lit roads for night-shift working. The customs boundary will rarely be smuggler proof, and it is preferable to rely on random examinations at checkpoints rather than high-security fences.

315. The daily power requirements for the average medium industrial development is around 1 kilowatt per 10 square metres of factory space. Water requirements, assuming no special process requirements (such as dyeing), should lie in the range 135-365 litres per worker per day. As a guide to both employment opportunities and water requirements, the approximate number of workers per acre are given in table 11.

TABLE 11

Number of workers per acre by type of industry

Type of industry	*Employment per acre*
Food, drink, tobacco	40
Refineries	1 112
Petrochemicals	4
Other chemical industries	10
Large-scale shipbuilding	4
Steel works	2
Other metal processing	20
Other industries	13

G. Reclamation

316. Parcels of operational land are often gained by pumping or carrying dredged material from the waterside of a quay wall to where land is needed. The combination of both operations can give a lower cost, since the dumping of dredged material at sea is a costly operation. The quality of the dredged material, however, must be suitable for reclamation purposes. This engineering activity can significantly change the master plan possibilities.

317. By this means, an island, a sandbank, marshland or a tongue of land which would otherwise not be usable can be improved and given a berthing face and an operational surface. Small offshore islands can play an important role in a modern port, particularly in the development of bulk handling facilities for commodities which can be transferred to land via pipelines or conveyors without the need for an expensive causeway. A costly alternative, using advanced technology, is to create a complete floating offshore port. This, however, is not likely to be a feasible solution for a developing country.

318. Reclamation on a wider scale, for instance to provide substantial industrial areas on low-lying land, is another possibility. Again dredged materials can be economically used to raise the ground level. In such large programmes the optimum solution will call for a pre-planned, step-by-step approach. Such an area will usually need to be large enough for several industries, and its development as part of a regional policy will

[11] *Handbook on Export Free Zones* (Sales No. UNIDO/100.31).

[12] *Investment: The Growing Role of Export Processing Zones*, Economist Intelligence Unit, Special Report No. 64 (London, 1979).

normally be undertaken by a public authority which, for a port industrial zone. means the port authority. Various sites would then he leased on a long-term basis by the authority to industry. Unfortunately, there can be little guarantee of successful leasing at the time of planning, since tenants will not start inquiries until the area looks less like mere sandbanks or marshland and more like a real industrial site, But once the site is complete, industrial demand is capable of building up very fast and as a general rule such reclamation must be beneficial to regional development.

319. Expensive infrastructure projects of this kind take so long to complete that they have to be started not merely well in advance of any project to build the superstructure which is to use them, but often before the need for the superstructure has even arisen. This is a vital aspect of port development and was probably first appreciated in the Netherlands where action of this kind was a major factor in the success of Rotterdam.

320. When forecasts show that the growth in trade will eventually necessitate very substantial new port facilities, large-scale reclamation schemes deserve serious study as a long-term solution. The reclaimed land can reach out to deep water and so reduce dredging costs. The whole complex can be planned to minimize adverse social and environmental effects. The complex can become a combined residential. commercial and industrial development with properly planned communications, including a commercial airport. Such integrated schemes are likely to become more necessary as development gathers pace.

321. The principle mentioned earlier of selecting a quay configuration in harmony with the existing conformation applies even more strongly to schemes for the recovery of large areas of tidal flats or marshes. In such cases, not only can the major change in land/water interface cause environmental effects which may only partly be foreseen by model studies, but the approach channels and berth faces may be subject to siltation and other adverse effects which can normally be minimized by co-operating with the natural system.

H. Rationalizing port land-use

322. In parallel with the type of development discussed above, where the extra land needed for the modern port is provided by reclamation, extension or developing additional harbours. there is the need to examine the port’s existing use of land and its general waterfront configuration. This examination is an essential part of the master plan. since the rationalization of the configuration and of the zoning of land-use can release land for the increased operational port areas needed in a modern port.

323. In a port which has grown up haphazardly into a complex pattern of piers, basins and railway marshalling areas, a major rationalization needed is the simplification of the layout by closing berths made redundant by modern cargo-handling methods, filling in basins and docks, removing rail tracks and resurfacing. This can transform the port from a configuration which may look rather like that of figure 23 to that of figure 22, A. The process is a gradual one. but such a long-term direction of modernization should be set at the master planning stage.

324. A second possibility is the transfer of nonessential activities of the port area. Strictly speaking. the only essential port activity is the loading and discharge of ships and all else could be done some distance away, either inland or on a less valuable part of the coast. A port of this type is an impractical commercial concept, but the principle of removing activities inland when port land runs out is a valid alternative in master planning. Long-term storage or warehousing with the associated sorting and commercial activities may be strong candidates for removal. The three necessary technical conditions for movement to an inland depot are: first. that the transport operation can be organized economically; secondly, that the consignments are through-consigned on the shipping documents; and thirdly, that customs formalities are transferred to the inland depot. But in addition there can be serious organizational problems, which means that only countries with a strong management base may find this solution feasible.

I. Zoning

325. Zoning is to some extent an art which, like architecture, involves many technical constraints. The planner should at each stage ask the question: “Why here and not there?“.

326. The way in which the different areas are fitted together will be a major factor in preventing future congestion. The most serious mistake to avoid is to allow long-term commitments to be made with respect to a piece of land which may later prevent the expansion of other areas and/or the access to them. A similar mistake is to allow land to be used-even when there is no long-term investment-for purposes which it will later be too difficult to change for social and political reasons; for example, waterfront recreational areas.

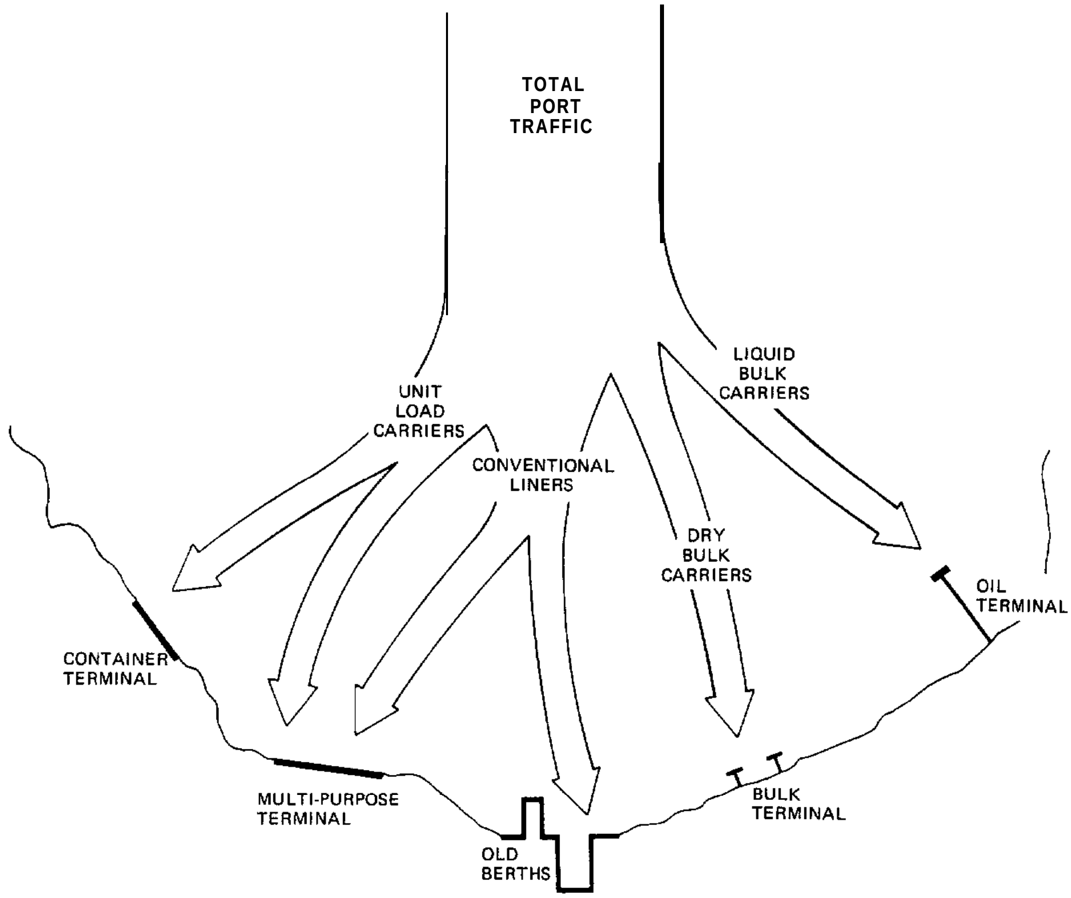
327. All except the smallest or most specialist ports consist of several separate terminals or groups of berths, each handling one kind of traffic. The need to divide the port area into specialized zones has resulted from the demand for increased productivity at each terminal. Where the volume of traffic is too small to justify a separate terminal for each kind. or where uncertainty as to the form of future traffic does not justify a specialized terminal, the answer can be a multipurpose terminal. In general terms the port will consist of the separate zones shown in figure 26.

328. At an early stage in the preparation of the master plan, these zones should be clearly identified. Subsequently, the port authority should recognize the separate nature of these zones and should both delegate specific responsibilities for their control to designated managers and institute separate information systems to collect traffic and performance statistics for each zone.

329. The point at which it becomes economical to provide a specialist terminal for a particular class of traffic depends mainly on the annual throughput of that traffic. The planner must determine the ships‘ turn-

FIGURE 26

Allocation of traffic to port zones



round times for the two alternatives, with and without the specialized terminal. Then, according to the cost estimates of the various terminals, the best development strategy can be selected.

330. Ports will require a number of service craft such as tug boats and pilot launches. Suitable docking facilities for these limited draught vessels should be provided for at the time of master planning.

331. The relative siting of the zones in the port will depend on the following factors:

(a) Water depth requirements for each terminal: the traditional break-bulk depth of 7.5 to 10 metres will not be adequate for deep-sea container vessels or dry-bulk and oil carrier vessels;

(b) Land area requirements for each terminal: for example, the back-up area for a container berth will be greater than that for a break-bulk berth;

(c) The influence of prevailing winds: the siting of the zones should be such that dust and odours from bulk cargoes are not carried towards general cargo berths, passenger facilities or inhabited areas;

(d) Safety considerations: terminals for oil products, which must often be sited within the main port area, should preferably be located near the port entrance at a reasonable distance from general cargo zones. Other dangerous cargoes will need similar special zones separated from other zones by a buffer area (see chapter VIII) ;

(e) Inland transport access: terminals for dry bulk commodities should be sited in such a way that an easy access to the highway or railway network can be arranged, without the necessity of crossing densely inhabited areas;

(*f*) Compatibility of adjoining zones: apart from the consideration of prevailing winds, care should be taken to avoid placing zones together whose cargoes may have adverse influences on each other. For example, a zone for grain and flour can safely be located next to timber or steel terminals, but not in the vicinity of fertilizer facilities;

(g) The traffic flow system: a zoning plan should not be adopted before making sure that the routes for vehicles, rail-tracks, conveyors and pipelines fit harmoniously together. A plan which produces a large number of route crossings, bridges and flyovers must be suspect,

332. In considering whether or not to site individual traffic separately, the possibility of finding compensating import/export traffic should be checked. Examination of origins and destinations of traffic shown in the forecast may suggest a combination of compatible flows which will help fill ships on their return voyages. Such possibilities should be discussed with the shipping authorities. If the different kinds of traffic concerned are sited together, ship movements within the port will be minimized and operational areas may be used more intensively.

333. Land-use management is made easier if land is under the ownership of a single authority. The ownership is secured either hy statute or purchase. Contracts or leases granting the use of port land should be conditional on the agreement to assist in the development of port **trade.** The length of security granted to the occupier of port land should be the minimum period acceptable to him. Port-located industrial activities must be controlled after they become established. to prevent **them** from changing into activities which do not require the use of maritime land.

J. Increasing revenue from large port expansions

334. The development cost of creating either large areas of sheltered water or large areas of reclaimed land will be very high. It will be essential to exploit fully the potential thus created so that the costs can be carried over a wide range of uses. For example. the best place for the breakwaters forming an artifical harbour may be one enclosing a water area that is larger than that needed for mooring and access to berths. It would then **be** advisable to look for ways, such as the construction of berth extensions or jetties. or the **development** of a fishing port or a recreational park. which will permit the sheltered water to be used more fully and allow the costs and benefits of the breakwaters to be shared by a larger number of users. Similarly, on tidal flats it may be necessary to site the port facilities adjacent to a low water line that may be several kilometres from dry land. The sea defence work, necessary to create the port may be more viable if it encloses a large land area rather than merely a narrow access strip. The costs of the works can then be partially supported by revenue from the dry land created by reclamation.

ANNEX

MASTER PLAN CASE STUDY: LOS ANGELES

A. Historical development of the port

1. Figure A. 1 shows the stages of development of the port from 1872 to the time of preparing a new master plan in 1975 The stages through which the port has passed give an interesting example of the way in which a bay with some offshore islands may be developed into a large harbour with substantml waterfront and land areas It will be seen. however, that although the areas developed up to 1975 were **very** substantial, the master plan for 1990 requires a "et increase of 1.000 acres of land to serve the port's needs

2 In the first diagram, relating to 1872. the port was handling 50.000 tons of cargo per year at small Jetties, mainly in the San Pedro area. the approach channel being to the left of Dead Man's Island This channel had been recently dredged to a depth of 10 feet at low tide from its previous depth of 18 inches

3. Between 1872 and 1908 a good deal of development took place. with a breakwater off the southern point and two short breakwaters defining the entrance channel to the inner harbour which was beginning to be used, this channel now being dredged to 15 feet. By 1908 the breakwaters formed an outer harbour in which projecting jetties were built Railways were constructed both to the wharves on Rattlesnake Island and to the jetties in the outer harbour. The build-up of cargo was very rapid, reaching 500,000 tons in 1888 and a million tons by 1908 Successive dredging projects produced a depth of 18 feet at low tide throughout the whole of the main channel.

4. Between 1908 and 1915 Rattlesnake Island was gradually built out to a new harbour line, producing substantial warehousing and market areas. plus wharfage. The southern end of the Island. now renamed Terminal Island, was developing as a substantial fish harbour. Theeastern breakwater was removed to widen the channel. but Dead Man's Island still remained as an obstruction.

5. By 1929. substantial new infilling broadened Terminal Island even further. Dead Man's Island was removed and Reservation Point was reclaimed for federal use (to this day. and even in the 1990 master plan, Reservation Point has been retained for federal purposes which in fact are not connected with the real objectives of the port) The required berthing spaces were achieved in typical fashion for the needs of vessels of that period by cutting slips and piers along the main channel waterfront During this period, access roads were built through to the waterfront and bridges and viaducts were constructed. A very substantial build-up of traffic followed the commercial opening of the Panama Canal. and the traffic doubled. redoubled and doubled again during the ten years from 1920 to 1930, reaching a peak of 26 million tons of which 21 million tons consisted of petroleum imports. The west basin on the land side of the harbour was developed. including substantial dredging, with all channels in the harbour deepened to 35 feet.

6 In 1935, the middle breakwater was built across the bay to provide calm water and warehouses. ferry services and many other facilities were steadily developed.

7 The pattern of development from 1947 was mainly a specific response to the need for specialized facihties for Individual shipping lines, including. for example, a bulk grain terminal, special oil terminals and a scrap metal terminal. together with new storage areas and a new customs building. The development plan in 1960 proposed 15 new berths to be added during the next five years and an early container facility. During this period the final dredging of various sand bars from the interior of the west basin was completed Private boating began to develop with a boat marina, and yacht and small boat anchorages

8. The main developments between 1967 and 1975 were a number of container berths and the improvement of access roads Ro/ro facilities were installed in 1974 and planning began for provision for hquid natural gas tankers.

9. The resulting port zoning which was reached in 1975 *is* shown in figure A.2.

B. Future requirements

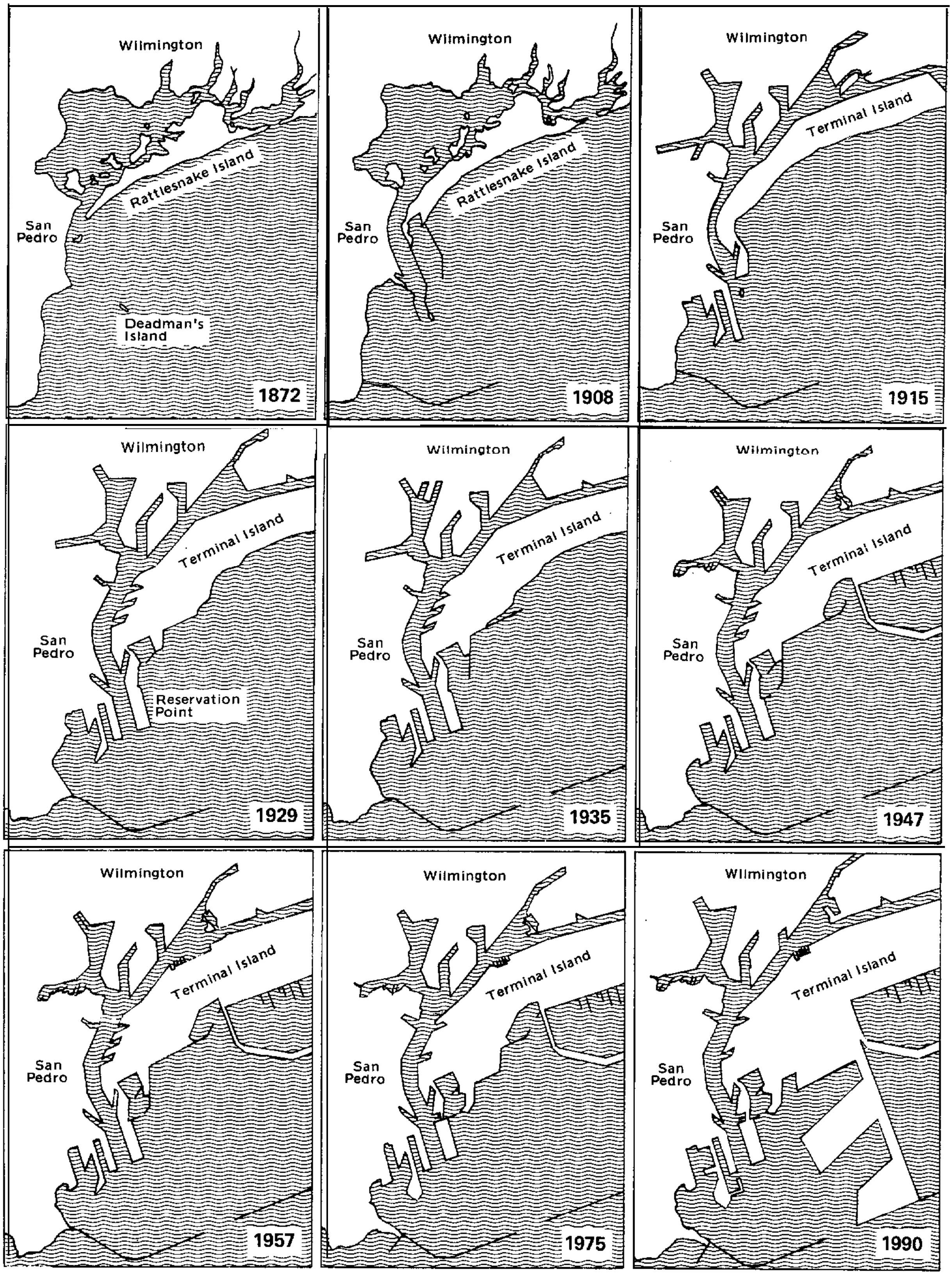
10. At this point, in 1975, a major master planning study was carried out to assess the long-term needs of the port and give a set of guidehnes for the zoning and major port development which could, in the immediate future, be translated into detailed developments.

11. The study found that for the port to remain competitive it must be able to accommodate ships of greater size and draught. Vessels with draught greater than the existing range of 30 ft in the inner harbour and 45 ft in the outer harbour and channel had been visiting the port in increasing numbers. A large number of these had been unable to enter the port at fully loaded draughts and had to be lightened in deep water outside the breakwater before entry. It was anticipated that by the year 1990 the average size of tanker would be 250.000 dwt (draught 70-75 ft) and bulk carriers of 100,000 dwt (draughts at least 45 ft) Moreover, examination of the world container fleet showed that the port would not be able to accommodate container ships larger than those of the so-called second generation. Finally, liquid natural gas (LNG) cryogenic *carriers* were expected, and these also had greater draughts than could be accommodated. Many tenants of inner harbour areas indicated that they would need 45 ft depth in order to remain. Thus there was a definite need for deeper water to accommodate increasing ship sizes

12. Secondly. the study found that there was a need for additional land. Land use analyses and cargo forecasts indicated a requirement for a net additional I ,000 acres of land to serve the port's needs by

FIGURE A.1

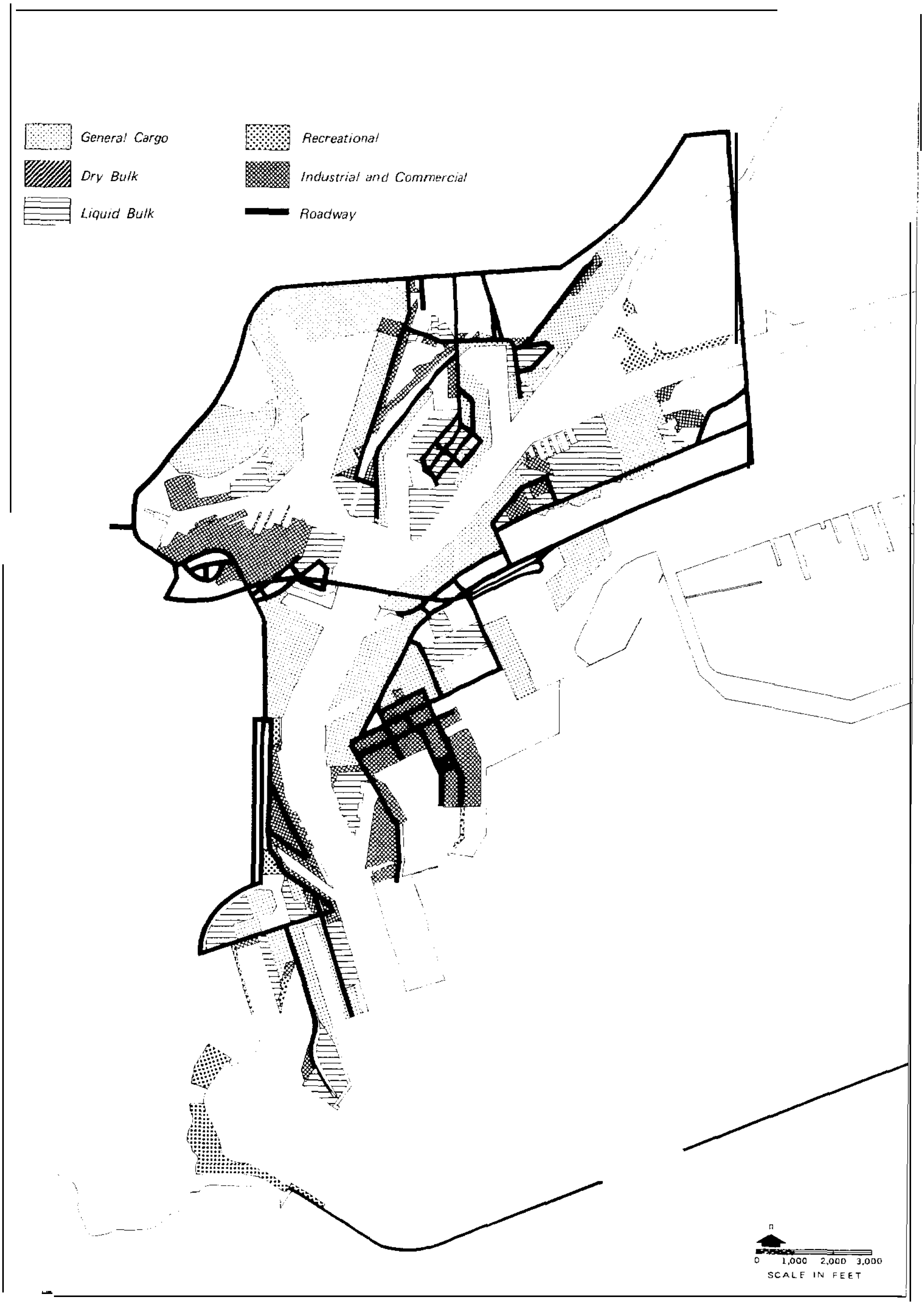
Past and future development of the port of Los Angeles, 1872–1990



Source: This figure and subsequent figures in the annex have been taken from the "Port of Los Angeles Comprehensive Master Plan 1990" prepared for the Port by Voorhees, Trindle and Nelson Consolidated, Inc., in 1975.

FIGURE A.2

Port of Los Angeles, land use 1975



1990. The need existed t" increase the length of straight berths and the area behind them for the space needs of tenants. Sites with these characteristics were not available at the port.

13. Since deepening would naturally require a substantial dredging programme, there was a unique and exceptional opportunity to solve the port's need for deeper water and additional land in an economically, technically and environmentally sound manner. This was to combine the current dredging programme with a landfill programme. This possibility led to the proposal for a large landfill area extending south east from Terminal Island.

14. The estimate of the requisite port capacity from the cargo-handling point of view was concerned rather with area requirements than with the number of berthing points needed. The port planners had found that any reasonable quay wall layouts such as those given earlier in this chapter (see figures 21 and 22 above), must provide sufficient berthing points when the area behind them provided the space needed for typical annual throughputs.

15. The individual zones of the port were examined in detail but the preliminary cargo flow projection looked at the demand on the port considered as a whole. Figure A.3 and table A.1 show the broad long-term forecast to the year 2000 broken down by the major cargo groups. These forcasts were developed using standard techniques as described in chapter III above. Figure A.4 illustrates the magnitude of the increase between the 1973 actual figures and the 1990 projections. The next stage was to convert the commodity flow forecasts into land area requirements; straightforward land use coefficients were used, relating the tons per year throughput figure to the number of acres needed. as is done for the existing situation in table A.2. There was a great uncertainty regarding the intensity of land use in the long term and two alternative assumptions were used in the calculations. Alternative A was based on the assumption that all tenants would continue to operate at their present intensity of tons per acre. This gave very large requirements, as shown in table A.3. Alternative B assumed that with the advance of technology the land utilization would intensify and a figure of 30 per cent higher intensity was used. The reduced requirements given by this alternative assumption are also shown in table A.3 and in fact this was the assumption adopted for the master plan

16. The forecast was checked against a survey of user opinion and the two results are shown in figure A.4.B. It is interesting t" note that port users forecast much lower area requirements than the planning team and it can be expected that the views of users will often be too low because of their conventional approach t" long-term planning, which is likely to be less imaginative.

17. The cargo-handling requirements form only part of the land utilization of the port, and similar forecasts of land requirements were carried out for mdustrial, commercial, recreational, institutional and miscellaneous uses. These are shown in table A.4, where the uses are broken down by planning areas—i.e., port zones Again substantial increases, particularly in mdustrial use, are forecast and land has t" be provided for these.

C. Master plan decisions

18. As suggested above, the major decision was to carry out substantial dredging, linked to the landfill of a new port area of 1,034 acres. This landfill is expected to be carried out in co-ordination with the overall dredging programme and the demand for deeper channels. It was also decided that hydraulic analyses would be required and that a hydraulic model would be used. The main alternative which had been discarded in reaching this decision was that of using offshore buoys to provide the deep water facilities. This decision was based mainly on the fact that the San Pedro Bay area is susceptible to earthquakes and underwater pipelines would be liable to rupture, with serious effects. Moreover, operating experience with single buoy moorings had indicated, in the view of the port planners. a high maintenance cost on floating hoses. Expensive dredging for pipeline trench, buoy maintenance. and ship collision possibilities, together with possible ecological effects on marine life, were all contributory reasons for deciding to provide deep water inside the harbour rather than utilizing the deep water outside it.

19. The landfill decision was less difficult since, as shown in figure A.5, the three possible solutions within the port boundaries were based on the same area of landfill but with varying quay wall configurations, all of them adopting a major pier approach as described earlier in this chapter (see figure 25 above). The alternative selected had the simplest shape and the broadest piers and connecting arm.

TABLE A. 1

Total cargo commodity flow projections, 1980-2000

(In thousands of short-ions)

Commodity group	Year 1973	1980	1990	2000
General cargo				
Special general cargo:				
Lumber	355		483	483
Automobiles	235	301	421	538
Iron and steel	410	658	795	960
Bananas	102		124	150
Special **general** cargo subtotal	1 102	1 544	1 823	2 131
Containers	3 224	4 848	7 315	9 363
Break-bulk cargo	1 025	1 025	1 384	1 747
General cargo total	5 351	7 417	10 522	13 231
Liquid bulk cargo*				
Crude petroleum	7 528	26 974	47 402	68 828
Other liquid bulk cargoes	9 040	9 040	9 222	9 408
Liquid bulk cargo total	16 568	36 014	56 624	78 236
Dry bulk cargo	2 397	2 397	3 009	3 814
Total	24 316	45 828	70 155	95 2x1

Source: This table and subsequent tables in the annex have been taken from the "Port of Los Angeles Comprehensive Master Plan 1990" prepared for the Port by Voorhees, Trindle and Nelson Consolidated, Inc., in 1975.

* Excluding LNG, imports of which have been estimated by the Western LNG Terminal as rising to approximately 6 million tons by the year 1990 and to as much as 12 million tons by the year 2000.

TABLE A.2

Intensity of land utilization for cargo handling and storage, 1973

Commodity group	Gross acres	Total tonnage (thousands of short tons)	Tons per year per acre (thousands of short tons)
General cargo			
Special general cargo:			
Lumber	70	355	5.07
Automobiles	197	440	2.23
Iron and steel	a	b	b
Bananas	9	102	11.33
Special general cargo subtotal	276	897	n.a
Containers	187	3 224	17 24
Break-bulk cargo	314	1 230	3.91
General cargo total	777	5 351	n.a.
Liquid bulk cargo	215	16 568	80.42
Dry bulk cargo	97	2 397	24.71
Total	1 089	24 316	n.a.

[a] Land use for iron and steel cargoes is included in acreages for automobile and break-bulk facilities.

[b] Iron and steel tonnage (410 000 short tons (see table A.1)) has been divided equally between automobiles and break-bulk cargo.

20. Once the main lines of development were decided in this way, the allocation of land use between the seven different zones of the port was considered from a fresh point of view given the combination of future possibilities and existing use. In many cases users were invited to move t" more suitable locations. It was decided to eliminate minor irregularities of quay wall in order t" provide better berth-

ings, and to demolish out-of-date superstructures such as warehouses in order to provide larger service areas. The resulting land use changes planned for each of the zones is summarized in table A.5, from which it can be seen that there is no general policy of specializing or of distributing cargoes between zones. Area 7, the new landfill, is allocated a range of cargo types.

21. A communication plan was built up, consisting of a new layout for rail connections and road connections with a major new road link down the connecting arm of the proposed south east landfill area and several simplifications of trunk access to other port areas Figure A.6 illustrates the land use and communication network as provided for the 1990 master plan

22. Before the plan was finalized, a series of impact analyses were carried out to ensure that the master plan proposed did not create problems. These consisted of:

[a) An air resource impact analysis: this concerned mainly air polluting industrial activities in the port;

(b) A biological resource impact analysis: this examined possible effects on marine organisms and displacement of fish and plankton;

(c) A geological resource impact analysis: this consisted of analysing the effect on the geologic environment of the major channel and landfill activities;

(d) A water resource impact analysis: this studied water supply problems and waste water treatment questions together with navigational safety;

(e) A cultural resource impact analysts: this was a check on archaeological and historic sites;

(f) A socioeconomic analysis: this major study consisted of reviewing energy requirements, questions of health and safety, employment and aesthetic questions, in close co-operation with the local planning authorities.

FIGURE A.3

Tonnage projections for port of Las Angeles

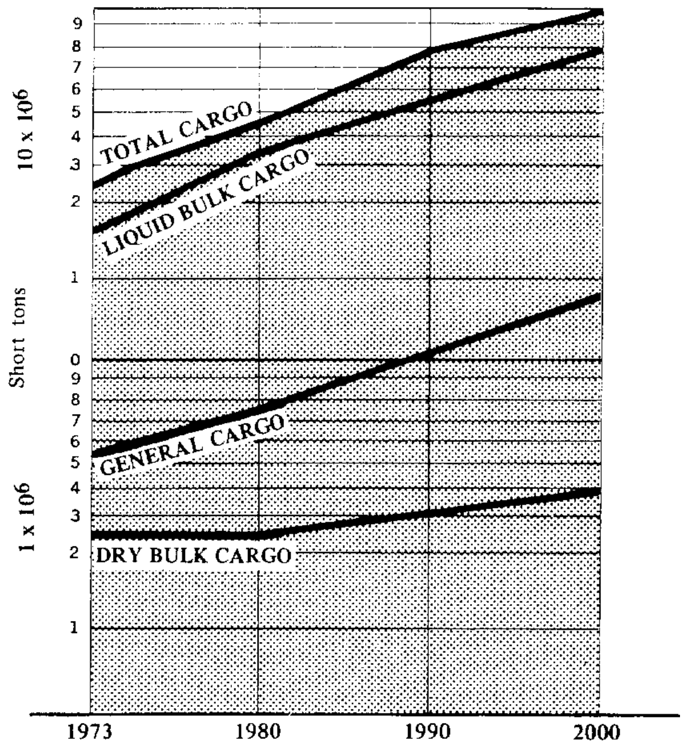


FIGURE A.4

Comparison of commodity flow projections and land acreage needs

A. Cargo commodity flow projections

B. Land acreage needs

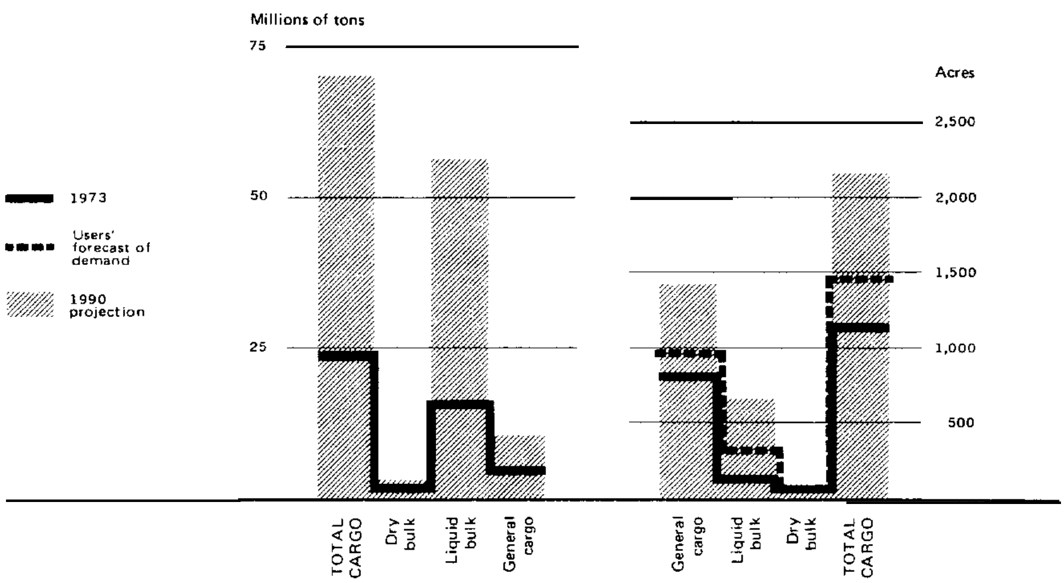


TABLE A.3

Projected land needs, 1980-2000

(In acres)

Commodity group	1973	Alternative A 1980	Alternative A 1990	Alternative A 2000	Alternative B 1980	Alternative B 1990	Alternative B 2000
General cargo							
Special general cargo:							
Lumber ..	70	95	95	95	73	73	73
Automobiles ...	197	282	366	455	216	282	350
Iron and steel[a]							
Bananas	9	9	11	13	7	8	10
Special general cargo subtotal	276	386	472	563	296	363	433
Containers	187	281	424	543	216	326	418
Break-bulk cargo	314	346	455	567	266	350	436
General cargo total	777	1 013	1 351	1 673	778	1 039	1 287
Liquid bulk cargo[b]	215	448	704	973	344	542	784
Dry bulk cargo	97	97	122	154	75	94	118
Total	1 089	1 558	2 177	2 800	1 197	1 675	2 153

[a] Iron and steel land needs are included in acreages for automobile and break-bulk facilities [b] Excluding land requirements estimated for LNG

FIGURE A.5

Alternative landfill proposals

(Alternative C was selected)

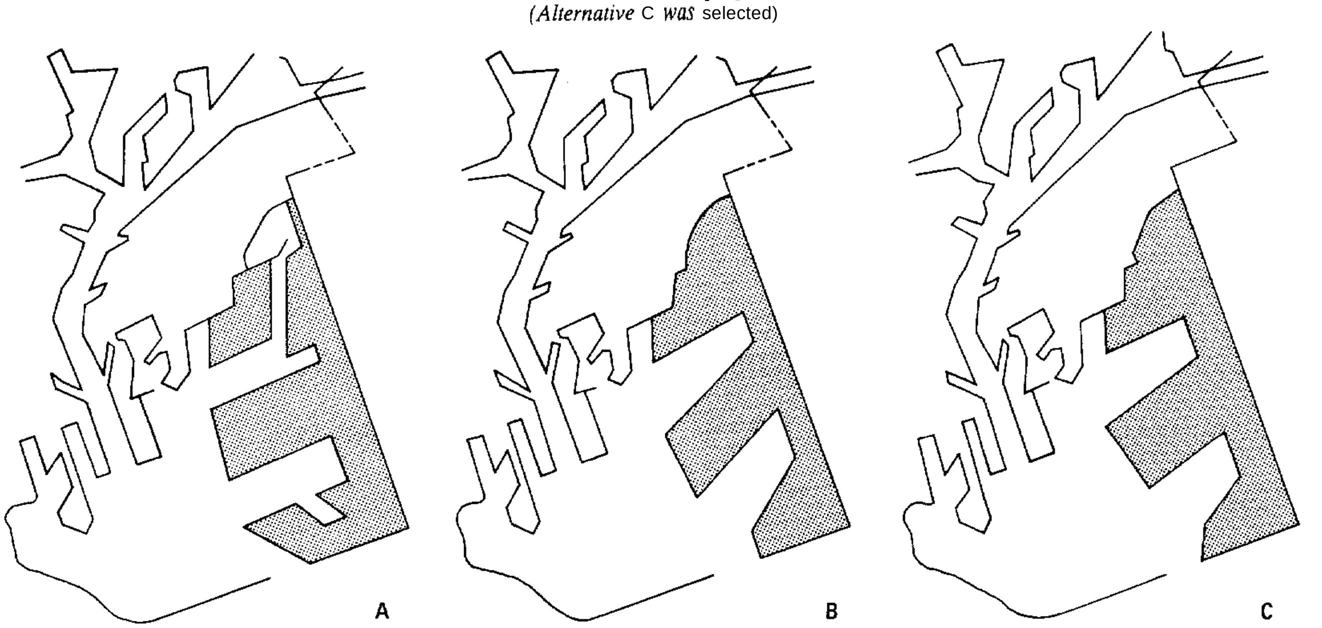


TABLE A.4

Summary of land utilization for purposes other than cargo handling and storage, by planning area, 1973

(In acres)

Use	Planning area[a] 1	2	3	4	5	6	8	Port[b]
Industrial	5	14	78	13	68	221	4	403
Commercial ..	1	42	18	0	0	5	0	66
Recreational	70	2	0	0	19	4	0	95
Institutional	37	0	0	0	23	285	0	345
Other' ..	22	60	51	85	374	285	270	1 147
Total	135	118	147	98	484	800	274	2 056

[a] Area 7 is the proposed Terminal Island landfill that is non-existent today.

[b] Includes land within the port study areas not controlled by the Los Angeles Harbor Department.

[c] Includes vacant land, land in litigation, the Knoll Hill residential area (area 3), right-of-way of roads, rail and utilities. Since 1973, 32 acres in area 8 have been leased for liquid bulk use.

FIGURE A.6

Port of Los Angeles, master plan **1990**

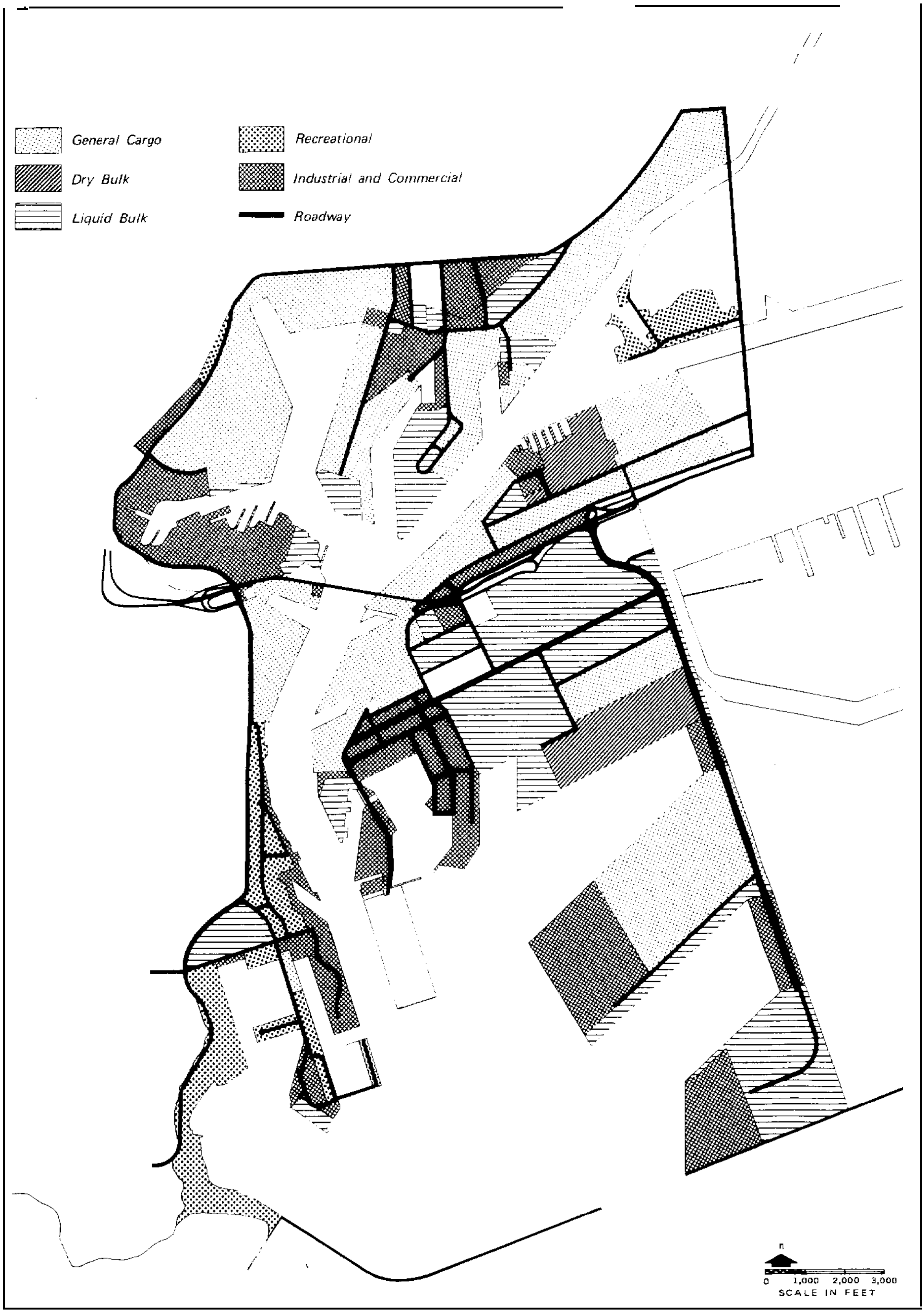


TABLE A.5

Planned changes in areas for handling different types of cargo
(In acres)

Type of cargo	Planning area 1	2	3	4	5	6	7	8
Containers								
1975	—	—	57	33	11	86	—	
1990			63	175		155	100	—
Break-bulk cargo								
1975	14	33			195	42		30
1990	—	11	—	—	250	52	100	
Special cargo								
1975	—	—	—	89	57	100	—	30
1990					136	60	65	30
Dry bulk cargo								
1975	—	21			6	70		
1990					10	70	100	—
Liquid bulk cargo[a]								
1975	—	—			5			
1990	—	—	—	—	5	—	—	

[a] Not including liquid bulk cargoes for energy production

Chapter VI

NAUTICAL ASPECTS OF PORT PLANNING

A. General considerations

335. In the development of a port. nautical aspects play an important role: the movement of vessels in the approach and access areas. manoeuvring within the port area as well as mooring operations at the terminals. Site selection for developments should be based on the most economic and safe location. The purpose of this chapter is to promote the systematic planning, realization and implementation of provisions for a safe and expeditious navigation to. in and from these ports. The chapter will be chiefly oriented towards the reception of large ships, because these have a dominating influence on the form and dimensions of a port's infrastructure.

336. For deep-water ports that have to be suitable for the reception of large ships. the problem arises that the actual sailed track of these ships-as compared to the ideal track-may deviate considerably from those of conventional vessels (as a result of the long reaction times of large ships like VLCCs to. for example, rudder motions or r.p.m. changes). Such different manoeuvring characteristics can lead to new operational criteria for traffic in a port's approaches and other navigation areas. Furthermore. the provisions to be made for safe navigation to and from the ports may be extensive as compared to those for conventional vessels.

337. Important developments in sea transport are not necessarily restricted to past decades, but are continually stimulated by technological improvements and changes in transport demand. If a port and its facilities are not adapted to or do not keep track with these developments, delays, congestion, accidents and collisions will result, in short. in inadequate functioning. The penalty for the regional and national economy is always heavy.

338. Adapting an existing port to new requirements is often a difficult, time-consuming and expensive affair, if originally insufficient flexibility was incorporated in the design. Therefore in the development of new ports, first of all. a thorough evaluation should be made of the type, size and number of vessels that will make use of the port initially and in the future. and whether these vessels will arrive and depart loaded or unloaded. Secondlv. because of the inherent inadequacies and errors'in these evaluations and forecasts. a maximum degree of future adaptability of the port's approaches and manoeuvring areas to new types of ships must be built in. A survey of the approach characteristics will evaluate local traffic movements. effects of weather and time, fishing operations and possible channel characteristics.

339. The transition of a ship sailing in open sea to the mooring at a terminal can generally be divided into three phases. This division reflects the type of manoeuvres to be performed, dependent on the configuration of the specific local coastal area. The first phase is the preparation for the transit movement, the second phase the negotiating of the port approaches Itself. the final slowing down and stopping manoeuvre and the third phase the approach and mooring to the berth. Similar phases apply to vessels leaving a port, but in reverse. The nature of these transit phases is determined by representative maximum and minimum sailing speeds within which these manoeuvres can be performed without breaching acceptable safety criteria. For example. there are maximum and minimum port entrance velocities within which a ship can still stop inside the port boundaries without taking resort to crash stop procedures.

340. The above leads to requirements for the horizontal and vertical dimensions of the port's access and manoeuvring areas. Manoeuvring characteristics of vessels with a big mass inertia lead to large manoeuvring space requirements as compared to conventional vessels. The assistance of tugboats is required at slow sailing speeds and in confined waterways: usually the efficacy of tugboat effort increases with decreasing vessel speed. The possibility of failures in the steering machine or the propulsion unit of vessels during port transits cannot be neglected. These deficiencies already occur more frequently in port transits than in open sea because of the sudden changes in the regime of the engines. The potential effect of such deficiences should be minimized as much as possible, particularly where dangerous cargoes are concerned, by adequate port planning. Deviation from the ideal track in port transits can be caused by many factors. one of them being the human element. Navigators are human beings. and no two react in the same way to a given instruction. The dimensioning of the port transit areas should make allowance for the variations in these human reactions.

341. In a general sense, the tracks actually sailed depend on the manoeuvring characteristics of the ship concerned and on the condition of the waters in which it sails. These in their turn affect the actions taken on the bridge necessary to guide the vessels through the subsequent manoeuvres of the port transit. The control activities on the bridge are dominated by three different types of human actions:

(n) maintaining the required course;

(*b*) countering at an early stage deviations from the intended track; and

(c) avoiding unstable vessel motions which might result in loss of control in steering the vessel.

Unstable vessel motions are associated with resonance conditions, which vary according to different types and sizes of vessels. Some forms of resonance can be mastered by human navigators, while others can only be mastered insufficiently, or not at all. Therefore, in the planning of port approaches, the investigation into the response of design vessels to conditions representative of the coastal area concerned is very important. The purpose should always be to ensure safe navigation to and from the port.

342. Availability of information to the ship's navigators is obviously an essential element: for example, information on the ship's position with respect to the track to be sailed; information of a co-ordinative nature in the context of traffic surveillance and/or guidance in the port's navigation areas; and data on environmental conditions (wind, visibility, waves, currents, tides). The desired and feasible degree of integration of these information systems, the required range, accuracy and reliability, and the peak density of the traffic as well as local atmospheric conditions jointly determine the types and positioning of the equipment to be procured.

343. New research methods permit the systematic investigation of the dynamics of port transits and marine traffic flows. Such investigations provide basic data, ***inter alia,*** for establishing procedures for navigators during port transits. Together with the introduction of advanced electronic navigation systems, they make it possible to allow the safe and efficient navigation of large and vulnerable vessels to and from a port.

B. Ship manoeuvrability

344. Since the late sixties, considerable research and development work has been carried out throughout the world to define the factors and the relationships which determine a ship's manoeuvrability and its response to its own control systems under actual conditions in both open and restricted waters. The advent of the larger tankers and bulk carriers has provided the incentive for such development, the results of which are being applied in the design of ship hulls and ship control systems, in training, in setting navigational requirements and operational limitations, and in the design of channels and other waterways.

345. Considering the factors which influence a ship's manoeuvring behaviour, the basic properties belonging to the vessel itself are called here vessel manoeuvring characteristics. They are determined by the ship's hull, its mass, the rudder system and dimensions, the propulsion system and the power. These characteristics are:

(a) The way the ship reacts on the rudder and on changes in propeller t-evolutions;

(b) Turning ability;

(c) Stopping distance.

346. The L/B (length/beam) ratio and the block coefficient, together with the B/d (beam/draft) ratio and the rudder area, mainly determine the manoeuvring characteristics. A small B/d ratio and a large block coefficient result in a relatively long time to react to an applied rudder angle; but once the ship is rotating, it has a good turning ability. It is clear that these characteristics are important for the manoeuvring ability of a tanker in a channel. However, equally essential is the way the human operator on the bridge uses these manoeuvring characteristics in steering the vessel.

347. In confined water, the time to reach ship's response to an applied rudder angle can be favourably influenced by a simultaneous rudder and propeller action, the latter only during a short time to avoid an increase in ship speed. The effect of this manoeuvre increases at decreasing speed. In general, course stability indicates the extent to which the ship reacts to external disturbances. In shallow water, the course stability tends to be better than in deep water.

348. The turning diameter in deep water at service speed and a rudder angle of 35" varies considerably between types of ships, and even between individual ships of the same category. Many container ships have a poor manoeuvring capability, particularly those built or originally built to operate at high service speeds of 26 or 27 knots. For these ships, turning diameters are in the order of 6 to 8 ship lengths (L). Turning diameters for large oil and dry bulk carriers at service speeds in the range 15-17 knots are in the order of 3 to 4 L, some even less than 3 L. LNG carriers are mostly in the 2-2.5 L range, which would also apply to a great number of conventional general cargo and multi-purpose vessels.

349. Turning capability at low speeds is often improved by the use of a twin propeller arrangement or bow thrusters, or a combination of the two. These measures, however, do not constitute a universal remedy against inadequate manoeuvring capability. Many container ships, for instance, are equipped with twin propellers. However, due to the shape of the hull, the distance between the propellers is so small compared to the length of the vessel that the turning momentum that can be exerted is virtually ineffective. Bow thrusters are useful for berthing and unberthing operations but, particularly at speeds of 4 to 5 knots, they lose much of their effect.

350. The stopping distance of vessels is obviously strongly influenced by the relation of astern power versus mass of the vessel. Also, the astern power as a fraction of the installed power varies from one system to another and may be as low as 50 per cent for a vessel with a steam turbine and fixed blade propeller, or close to 100 per cent for a vessel with diesel engine and controllable pitch propeller. As a result, the distance, S, travelled during a crash stop varies considerably, even when expressed as a function of the vessel's length, L. For deep water conditions and starting from service speed, approximate figures are as follows: large tankers and dry bulk carriers (over, say, 200,000 dwt): S = 15-20 L; container ships: 6-8 L; large LNG carriers: 10–12 L: conventional general cargo ships and multipurpose ships: 4-7 L.

351. A vessel making a crash stop has little or no course control due to the flow pattern near the rudder and will generally deviate dramatically from the desired straight track. The actual track sailed is highly unpredictable. A degree of course control can be maintained by giving periodically brief ahead propeller thrusts with the rudder set to give the desired course correction.

This however. unavoidably leads to greater stopping distances.

C. Effects of environmental conditions

352. The manoeuvring characteristics and manoeuvring behaviour of ships are strongly influenced by environmental conditions, particularly by:

(a) Shallow water effects: increased resistance, squat, bank effects. changed response on rudder;

(*b*) Waves and swell: stable or unstable course deviations, increased resistance. sometimes reduced rudder response;

(c) Currents and winds: drift motions.

Cross-current or cross-wind components induce a sideways drift to vessels. To maintain course. a vessel will have to steer at an angle with its theoretical course. As there are practical limitations to this drift angle. the phenomenon becomes of particular importance in port transit manoeuvres, the more so, because the effect of cross currents increases with decreasing keel clearance. Waves and swell have a considerable effect on course stability and on the required allowances for deviations from the ideal track when navigating in constrained waterways. The effects however, cannot be generalized, but must be investigated for every situation; they will not be further discussed here. The consequences of ship's response to waves and swell for the design depth of dredged channels are mentioned in paragraphs 359 and 360 below.

353. The influence of water depth on a ship in motion becomes noticeable at a depth of less than about 4 times the ship's draught. The influence becomes significant at a depth of approximately 1.5 times the ship's draught. Shallow waters are therefore usually defined as fairways with a depth of 1.5 times a ship's draught or less.

354. An important shallow water effect is the increase of the squat of a vessel, that is, the sinkage resulting from the return currents along the sides and under the keel. Many investigations have been carried out into this phenomenon and many formulae developed. The squat is essentially proportional to the square of the ship's speed.

355. The effects of shallow water on the manoeuvring characteristics are an increased course stability against a decreased rudder efficiency. In other words, there will be a decreased tendency of a vessel to zigzag around its ideal track. On the other hand. turning radii will increase and the response to rudder angles will be slower. Due to increased resistance of the water. stopping distances will relatively decrease in shallow water, although not in a spectacular way.

356. A special aspect of the shallow water effects is the sailing above or through low-density mud (sling mud). For a number of ports. these aspects have direct consequences for their channel maintenance policy or accessibility criteria (Rotterdam, Shanghai. Bangkok, Paramaribo, Cayenne). In general, it can be stated that, because of the higher rudder efficiency due to the higher propeller speed in navigation under silt conditions. dynamic movements such as changes in course will be initiated more directly, while less time and space will be necessary for their execution on account of the damping action of the silt.

357. Attention is drawn to the work of the IMO Sub-Committee on Ship Design and Equipment. which has been considering manoeuvrability characteristics, squat and hydrodynamic forces in shallow water, and which can supply much relevant information.

D. Consequences for port planning

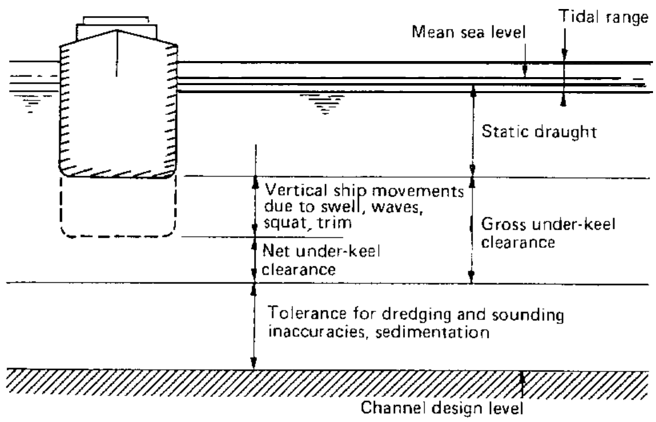
358. In this section, the consequences for port planning are given in an indicative way and to the extent that they can be more or less generalized. It should be appreciated that no two ports are alike and that no standard solutions can be given.

1. Depth of approach channels

359. The required keel clearance and safety margins are schematically shown in figure 27.

FIGURE 27

Definition of under-keel clearances



This figure is a simplification of the actual conditions. The vertical movement of a ship in response to waves and swell is in fact a stochastic parameter. for which the probability of exceeding a given value can be determined, if the local wave conditions as well as the ship's response characteristics are known in sufficient detail. These response characteristics in their turn may vary significantly between vessels of the same size and class. Furthermore, the actual channel bottom level, as a result of dredging inaccuracies and sedimentation, is not a flat plane. nor are there fixed tolerances to determine a nominal level. Lack of detailed information results in a certain degree of simplification, and estimation is usually applied.

360. PIANC suggests. by way of approximation, that the gross under-keel clearance can be taken as follows:

(a) Open sea areas exposed to strong and long stern or quarter swell, high vessel speed: 20 per cent of the maximum draught;

(b) Channel and waiting areas exposed to strong and long swell: 15 per cent of the draught;

(c) Channel less exposed: 10 per cent.

Obviously these percentages may vary appreciably from one location to another, depending on physical conditions. Moreover, it is emphasized that the figures apply strictly to large ships, which for this purpose are defined by PIANC as vessels of 200,000 dwt or over. For conventional vessels, or even for LNG carriers, these percentages would in many instances be grossly insufficient.

361. It is emphasized that for channels subject to tidal motion, not all ships need be able to enter or leave port at all stages of the tide. On the contrary, it will often be more economic to restrict the navigability of the channel, at least for the biggest ships. to a limited period of the tide. The type and number of ships involved and the applicable degree of restriction-i.e. the width of the "tidal window"-must be studied from case to case. It will normally be determined on the basis of a minimization of the sum of channel construction and maintenance cost, and of the ship waiting cost. In practice, there are often considerable hidden waiting costs, because ships tend to reduce speed well in advance of the harbour entry rather than have to wait at an anchorage.

2. CHANNELWIDTH

362. A ship will generally not be able to navigate a channel in a position parallel to the channel axis or leading line. The forces acting on the ship by cross currents and wind necessitate steering under an angle—the drift angle-in order to follow this leading line. In this way a state of equilibrium is reached between external momentum and forces, and those from resistance and rudder. It is possible to determine this drift angle for varying circumstances by means of model tests. In confined water it turns out that under the above-mentioned external conditions, the ship also needs a compensating rudder angle to keep the ship on average on a straight track. Especially for channel-axis navigation in cross currents, relatively large rudder angles are needed for course correction to preclude a further drifting away from the straight track. The drift angle has consequences for the path-width used by the vessel, which at 10" is already approximately twice the beam. The limitation of the drift angle may have consequences for the minimum sailing speed in the channel.

363. The channel width required for a one-way channel consists of the path-width, the compensating width for the motions which a ship makes around the theoretical straight line course, the compensating width for location information inaccuracy, and a safety margin. The translation of the above into actual dimensions is not a straightforward matter. Methods used for this purpose are as follows:

(a) The empiric method: making use of experience with other channels elsewhere and converting qualitative opinions of navigators into quantitative terms;

(6) Physical model investigations;

(c) The maximum deviation method: quantifying the effect of correct and specified pilot response on vessels with specified manoeuvring characteristics after a certain minimum deviation from the ideal course has occurred;

(d) Mathematical navigation simulation models incorporating computerized pilot reactions on computerized ship's performance;

(e) Real-time navigation simulation, using a simulator comparable to the link trainers in aviation training of pilots or navigators.

Methods (d) and (e) belong to the sphere of probabilistic research and design methods and, when used in combination, may be expected to give the most convincing results. Their reliability will increase with the improvement of modelling vessel response to the complex external forces in restraint waterways.

364. Research and experience so far have shown that the required channel width depends particularly on environmental conditions such as cross currents and cross-current gradients (variation of these cross currents per unit length of channel), waves and swell, wind and visibility, as well as on the accuracy of information regarding the ship's position and the easy "readability" of this information by navigators. A minimum value for the width of a one-way channel (width at full depth) would be 5 times the beam width (B) of the biggest vessel in the absence of cross currents, while an average value for average conditions is more likely to be 7-8 B. Actual one-way channel width in existing ports varies between 4 and 10 B.

365. For two-way traffic, a distinction must be made between vessel types for which encounters are allowed. If two-way traffic is required for the biggest vessels, channel width should be increased relative to the one-way channel by 3-5 B plus compensation for a drift angle. In curves, ample and gradual widening should be provided for. The magnitude of this widening is again strongly influenced, apart from the radius of the curve, by currents and, particularly, current changes.

3. CHANNELLAYOUT

366. The layout of an approach channel is often largely dictated by the local sea-bed topography and other local conditions. In so far as alternative layouts are possible, the following aspects should be duly considered in their evaluation:

(a) A channel should show as little curvature as possible. Curves should in particular be avoided near the harbour entrance, as this is nautically already a difficult point;

(6) A single curve is better than a sequence of smaller curves; distance between curves should be at least 10 L;

(c) Curve radius should be greater than or equal to 10 L, or in exceptional cases 5 L;

(d) Cross currents should as much as possible be avoided. This applies even more to high cross-current gradients. for instance near the harbour entrance and in curves;

(e) Anchorages (normal or emergency) should be provided along the length of the channel. of which the last one should be located close to the port entrance.

4. PRINCIPAL MANOEUVRING AREAS WITHIN THE PORT

367. The manoeuvring of small to medium-sized vessels generally poses no special problem in the sense that specific measures have to be taken in the dimensioning of the port infrastructure. The required stopping lengths are limited and can generally be accommodated in traditionally sized inner channels and manoeuvring spaces, Manoeuvring capability of these vessels is generally good, and upon entering port they will often manoeuvre and stop under their own power.

368. For large ships the situation is different. Because of their much longer stopping distance and their lack of course control during the stopping manoeuvre, they will generally not be allowed to stop under their own power. This may already apply to vessels of approximately 50,000 dwt and over. This means that such ships, as long as no effective tugboat control is available, have to maintain a certain minimum speed relative to the water at which there is still sufficient rudder control available. This speed is about 3-4 knots, sometimes slightly less. The above is of particular importance where large ships with dangerous cargoes are concerned, for example, crude and product tankers, liquid gas carriers, etc.

369. The slowing down and stopping length then required within the port boundaries, that is. in relatively sheltered water with little or no currents, is determined by the entrance speed of large ships. the time required to tie up the tugboats and to manoeuvre them into position: and the actual stopping length.

370. Consequently, the length of the inner channel-in terms of aviation, the runway of the port—should generally measure 3-4 km and more, to allow the port to be able to receive large ships under acceptable standards of nautical safety. The slowing-down and stopping length can be decreased to the extent that the ship's entrance speed can be reduced. The latter can be attained by limiting port entrance for large vessels to a certain maximum cross current. Although this has operational consequences. it may nevertheless be economically attractive The concept of introducing planned port transit navigation for large and very large ships (i.e. making entry and departure subject to. *inter alia*, vertical and horizontal tide. as well as sea conditions) will in many Instances be a sound one.

371. Immediately past the port entrance. the navigable width of the channel should be increased. This is necessary as the drift angle of vessels upon entering has an initial tendency to increase: the bow of the vessel is in more or less current-free water. while the stern still experiences the cross currents. The width can gradually be brought back to around 7 B. The boundaries of the channel should preferably consist of flat slopes and should be free of obstacles. Under no circumstances should oil, chemical or gas tankers or ships be moored immediately adjacent to main manoeuvring areas.

372. The inner channel should end in a turning basin or circle. from where vessels, whether small or big, are towed by tugboats to their respective basins. The diameter of this turning basin should be equal to or greater than 2 L of the largest ships. In exceptional cases for small ports where no tugboats are available; the diameter should be equal to or greater than 3 L. In case of currents. for instance in river ports. the turning basin should be lengthened to compensate for vessel drift during manoeuvring.

Chapter VII

CIVIL ENGINEERING ASPECTS

A. Introduction

373. The objective of this chapter is, on the one hand, to outline the role of the civil engineer in port development and, on the other, to summarise the main steps and techniques used. The text is also intended to be readable for someone with a non-engineering background. Engineering cost estimates and subsequent investment decisions must be based on detailed studies by experienced civil engineers.

374. The work of engineers in a port development project extends over a long period. Starting with initial studies of the development potential of alternative sites, the costs of engineering proposals which meet the water and land area needs are broadly estimated to give the basis for the investment appraisal and the project decision. Detailed drawings and specifications are then prepared; contracts are awarded; the construction work is supervised, and, finally, the new facilities are handed over to the operating authority.

375. In this chapter, attention is directed to the part played by the engineer in the studies leading to an investment programme. Technical judgement is important to enable proper estimates of development alternatives to be prepared, but close attention to detail is not necessary at this stage.

376. A most important feature of the engineers' work in the project team is that estimates should be realistic. The starting points for this are a sound knowledge of the physical features of the site and a full appreciation of the requirements of the various types of shipping and port traffic.

B. Field investigations

1. GENERAL

377. Careful investigation of the site is essential to the success of the project. Field investigation means the study of all physical features of the area:

(a) Hydrography and topography;

(b) Meteorological and oceanographic influences;

(c) Coastal hydraulics, which comprise the local influence of the sea on the shoreline processes;

(d) Exploration of the subsoils both on land and under the sea.

Field studies may be supplemented by the use of special hydraulic modelling techniques to forecast changes due to port construction works. A list of the site investigations which may be required, together with their characteristics, is given in table 12.

2. HYDROGRAPHIC AND TOPOGRAPHIC SURVEYS

378. Reliable information on the bathymetry (the depths of water in the sea or river) is essential. The depths of water are represented on charts by figures for individual soundings or by submarine contours.

379. For a new project, the hydrographic charts available may provide sufficient information for preliminary engineering purposes. It may also be possible to obtain copies of the working charts of the hydrographic surveyors who did the original work for the hydrographic charts, and these may show soundings at closer intervals than those given on the published charts.

380. However, hydrographic charts are often out of date or not available and a detailed bathymetric survey must be planned. When the area to be sounded is large, and shore points are insufficient to permit a good location of sounding points, it can be of interest to put into operation-during the whole of the surveying period— one of the radio location systems that are on the market. Such a system requires specialists to assure its maintenance. The area selected for the survey should be large enough to allow for alternative sea approaches and alternative locations for the port installations.

381. Most bathymetric surveys are now carried out by means of a high-resolution echo sounder, which can be mounted in a suitable vessel obtained locally. The older method of taking soundings by lead line is still used, however, particularly in awkward places and near structures.

382. **Some** topographical surveying is required in conjunction with hydrographic surveying to establish shore points. In addition, a survey of the land areas associated with the port works is required.

383. For a new port site, after a first examination of all available plans, an area should be defined for an outline survey, and permanent survey points established. As the project crystallizes, the extent of survey work required is more closely defined and the degree of detail correspondingly increased.

384. For the production of contract drawings, fully detailed survey plans of the port area, with particular attention to road and rail access, should be prepared. A suitable scale for these plans would be 1:1,000.

3. METEOROLOGICALSURVEY

385. Most inhabited regions of the world have weather records, although in some cases they may be insufficient for statistical trends to be fully assessed.

TABLE 12
List of site investigations

Investigation	*Physical features studied*	*Influence on port design*
Bathymetric survey or side-scan sonar survey	Water depth Profile, obstacles, wrecks, etc	Choice of sea approach Location of port installations
Topographic survey	Coastal topography	Type of Port Ease of landward access Extent of land areas available
Meteorological survey	Dominant winds (speed, direction, duration of gusts) Frequency and severity of storms Visibility Rainfall	Orientation of approach channel, harbour entrance and berths Breakwater design Ship manoeuvring requirements Lost capacity due to interrupted working Navigational aids
Oceanographic and hydraulic surveys	*Waves* Offshore wave statistics Local wave patterns *Storm surge* Amplitude Frequency *Currents* Coastal and estuarine currents (intensity, direction, variations) Tidal currents *Tides* Mean water level Tidal fluctuation (range, statistics) *Sedimentation* Littoral drift regime Zones of stability, erosion and sedimentation River siltation	Breakwater design Profile of channel and harbour bed Profile of banks, beaches and quay walls Orientation of channels, piers, etc. Maintenance dredging needs Quay wall design Requirements for locks and basins Ship manoeuvring requirements
Geotechnical survey (subsoil investigation)	Geology Seismic sounding of subsoil strata *Subsoil exploration* Identification of soil Engineering properties of rock, etc Penetrability and shearing strength of soft soils	Design of port structures Design and costing of dredging and reclamation programmes
Analysis of water properties	*Physical chemistry of the water* Salinity Pollution Turbidity (muddiness)	Corrosion of structures Completes the data for sedimentation investigations Provides data for environmental impact study
Environmental impact study	Marine fauna and flora Existing and future uses of land	Effect of port works on different species Interference with fishing Impact of works on: agriculture; urban development; leisure activities; historic sites and monuments

Nevertheless, it may be reasonably expected that, for any port site, wind and rainfall records will be available from some adjacent location, which will serve at least for a preliminary study. Once the site has been selected, an anemometer, a rain gauge and a barograph should be set up to record the weather throughout the construction stage and eventually to become part of the operational activity of the port.

386. Knowledge of the frequency and severity of storms is important in designing maritime engineering works. With the continuously recording anemometer, wind speeds and directions and duration of gusts will be obtained.

4. OCEANOGRAPHIC SURVEY

387. Oceanography is the study of the behaviour of the sea, and covers a wide range of natural phenomena. For a port project, the particular factors of concern are waves, currents and tides.

388. The length, height and period of waves arriving offshore may be estimated from wind records. Waves depend on the wind's speed, duration and fetch (the distance over which the wind has acted on the water), and empirical relationships exist between these factors and the waves generated. Records of ships give further wave information, but direct measurement of

waves is the most reliable method. This is usually done by means of a wave recorder.

389. The major ocean currents are well known, but they are of much less significance for the designing of a new port than the local currents, which should be measured.

390. Tide records are usually fairly reliable, but care is often needed to ensure the correct datum of tides related to land survey and soundings. A datum can be obtained by recording the tide over a period of at least one month and establishing the mean water level. Tide gauges can then be fixed in relation to this datum and tide readings continued during the project period.

5. Coastal hydraulic survey

(a) *Waves*

391. It is preferable to measure the waves occurring at the port site directly. Many types of wave recorders are suitable and in the selection of an appropriate type, the most important factor is its suitability for local operation and maintenance. The statistical extrapolation of records taken over a period of time permits computation of the likely frequency of recurrence of a given height of wave, or alternatively, of the wave heights associated with storms of a certain frequency of recurrence (such as once a year, or once every 10. 50 or 100 years).

392. The interaction of the wave with the sea-bed as the wave travels towards the shore modifies the direction and height of the wave. The effects of shoaling and refraction are complex, but simplified approaches and computation are usually adopted for port planning purposes. Further details are available in the reports of the PIANC Commission on the Study of Waves.

(b) *Currents*

393. Currents must be studied in the vicinity of the port in order to establish their speed and directions at the various stages of the tidal range. Seasonal and lunar variations in the currents and the effects of fresh water flow, in the case of an estuary, must also be taken into account.

394. Coastal currents are measured by the use of floats, which are released at predetermined positions and their subsequent tracks plotted, or by use of current meters which record the variations of strength and direction at a fixed point.

(c) *Littoral drift*

395. When there is a current close to the coast, the combination of wave action on the shore, which loosens material, and the current, which transports beach material, can alter the coastline. This mechanism of sediment transport is called littoral drift. Over a period, littoral drift may occur in one direction and then in the reverse direction, but generally there will be one direction which predominates.

396. Where the beach is interrupted by a feature such as a tidal inlet or an estuary, a spit tends to form in the direction of the predominant movement of material. Similarly, if an obstruction such as a breakwater is placed across the beach, material will build up on one side of the obstruction and erosion will occur on the other side. (Figure 28 illustrates the effect of littoral drift in a constant direction). It is therefore important in planning a coastal harbour to estimate the amount of littoral drift and to investigate its likely effects.

397. When no simpler means of estimating littoral drift are available, tracers can be used. This method involves tracing the course of materials that have been marked and laid down on the sea-bed or on beaches, and which in addition to visual tracking can be traced by luminescence or radioactivity. Such surveys are normally carried out by specialized hydraulic laboratories.

6. Geotechnical survey

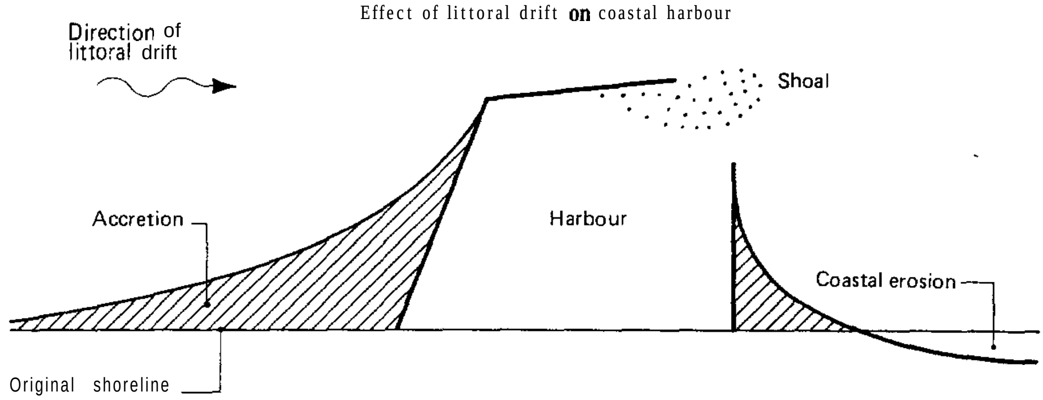
398. Geotechnical site investigation is an important preliminary to maritime construction. Exploratory offshore drilling either from floating craft or from a temporary platform is expensive, but the cost of the investigation is normally small relative to the value of the works constructed.

399. The following are the main methods used for investigating the subsoil:

(a) Boreholes formed by excavating within a lining tube. Also termed shell and auger drilling, this method

FIGURE 28

Effect of littoral drift on coastal harbour



uses a cylindrical cutter, with chisels for rock or other obstructions. Operation is by a wire rope connected to a winch. Undisturbed core samples are obtained for close examination.

(*b*) *Boreholes* formed by rotary drilling. A hardened drill is used to recover cores of rock. This method is slow and costly. and therefore used only when the precise engineering properties of the hard strata need to he determined for the purposes of the foundations of engineering works.

(*c*) *Penetrometer tests*. To investigate soft subsoils. a cone is forced down into the soil by steady pressure. The side friction and end resistance give the required data. It is usual to supplement the penetration test by conventional shell and auger boreholes

(d) *Wash probes*. Certain limited information about the general nature of certain soil strata may be achieved by use of a high-pressure water jet probe.

(e) Vane *tests*. For shearing strength measurements of subsoils, it is important to avoid structural disturbance of the samples. Thus, a borehole is sunk to the required depth. a four-bladed vane is inserted into the undisturbed subsoil at the bottom of the borehole and rotated until the subsoil has failed. providing a measure of its strength.

If) *Geophysical exploration*. Seismic soundings provide information on the boundaries between different subsoil strata. They must be supplemented by one or more of the direct exploratory methods described above.

400. The exact form of the geotechnical investigation will be different for each site and project. International standards agreed upon for the classification of soils should be used. The aim should be to improve knowledge of the quality of soils as the project develops. but since in many parts of the world the costs of the mobilization of personnel and equipment (particularly for offshore boreholes) are high, full value must be obtained from any programme of work: returning later to gather supplementary information can be very expensive.

7. HYDRAULIC MODEL STUDIES

401. The techniques of hydraulic modelling, both physical and mathematical. are advancing rapidly. In many projects the need for model studies will not arise, but in various special situations the use of models is important for the prediction of changes due to the proposed development works and for the achievement of economies in construction and maintenance costs.

402. Model investigations for port planning and design are normally undertaken in conjunction with a major hydraulic research institute, and the engineer would normally discuss the requirements of the project with one of these organtzations before formulating an applied research programme.

403. Three physical features of the port environment are normally studied through models: the movement of water and its effect on ships; the movement of soil and its effect on navigation areas: and the effects of the marine environment on the stability and safety of structures.

404. A physical hydraulic model of a proposed port layout enables wave action to be measured for various breakwater configurations and quay locations, and an optimum solution selected. The simple models compare wave heights by direct measurement, hut more sophisticated techniques are available to study the movement of model ships.

405. In a river or estuarial port. the construction of new facilities can alter tidal heights and velocities, which in turn can affect the movement of bed material and the siltation and erosion of navigation channels. Mathematical models and physical models are available for the prediction of such changes and they provide the engineer with a valuable means of judging the best form of development. This work is speciahzed. and considerable experience is needed; very careful on-the-spot measurements and considerable experimentation are often needed to ensure the most useful results.

406. Coastal movements caused by a new development may he conveniently studied by means of mathematical models, and similar techniques can. for example. determine the alteration in wave action caused by dredging a channel or by depositing dredged material offshore. In addttion to the normal three-dimensional models. two-dimensional physical models are frequently used in designing breakwaters in order to study the stability of the construction and the possible erosion of the sea-bed.

407. It is often the case that, although there may be considerable scope for model investigation during a project. the time required to carry out a full model test programme is not available during the period of a feasibility study, particularly when a lengthy programme in the field and in the laboratory is needed. In such a case it may be possible to formulate the initial investment programme in such a way that technically difficult decisions are left until iater stages. thus permitting a careful investigation during the earlier years of project implementation.

C. Water area requirements

1. SHIP DRAUGHT RULE OF THUMB

408. For water depth planning, the curves showing full-load draught, together with length and beam, for typical modern ships of each type, given in part two of the handbook (chapter VII, figure 35), may be used. A useful rule of thumb for planners who do not have permanent access to the curves is as follows:

Full-load draught in metres equals
square root of dwt, in thousands, plus 5.

For example. a 100,000-ton hulk carrier draws roughly $(\sqrt{100}+5)$ metres, i.e. 15 metres.

409. This formula will give the draught to within 1 metre over the range 10,000–500,000 dwt, for dry and liquid hulk carriers. It also gives a valid figure for general cargo ships down to about 5.000 dwt. For vessels below 5,000 dwt it gives an overestimate of the draught.

and for second- and third-generation container ships it gives an underestimate of the draught of about 1 metre.

2. APPROACHCHANNELS

(a) *Introduction*

410. In the immediate approaches to a harbour, shipping is usually obliged to sail within a prescribed approach channel. This corridor may be purely for the sake of navigational discipline, or it may be necessary in order to direct ships along a course where there is sufficient depth of water. Most major ports, particularly as ships increase in size, are likely to be approached by way of either an artificial channel or a natural channel which may require maintenance dredging. The planner is referred to the previous chapter ("Nautical aspects"), which also discusses approach channels.

(b) Site investigation data

411. The determination of the feasibility of constructing an access channel requires a knowledge of the direction and strength of the currents and the predominant direction of the waves since, under current and wave action, considerable movement of bed material can take place. This is most likely to happen where the channel nears a natural shoreline and the water becomes shallow, There have been cases of rapid infilling of channels caused by the action of waves and currents.

412. If the harbour is situated in the vicinity of a river, the amount of suspended sediment in the river flow must also be studied, preferably for at least one year. Insight into likely problems can be gained from a study of historical records of the site.

(c) Conceptual design of channel

413. The basic aim in approach channel design is the safe passage of all vessels requiring to call at the port from the sea to the berthing area.

414. If, for reasons of economy, it is decided to restrict the depth of the channel, the depth must nevertheless be sufficient to allow vessels with the deepest draught to pass through the shallowest reach of the channel at some stage in each tidal cycle. The design method includes the construction of time-related diagrams indicating the interrelation of vessel passage times, tide level and water depth.

415. The requirements with regard to speeds of vessels in the channel are to some extent conflicting. In a long channel the transit time, and hence speed, of a deep-draught vessel may be critical if the vessel is to pass through a shallow area at a given time, whereas increased speed results in increased squat of the vessel, thus reducing its under-keel clearance.

416. The channel dimensions, together with the depths of water to be provided at berths and moorings, will have a profound effect on the levels of service which the port can offer to the increasing number of larger ships. Normally, a joint economic and engineering study must be conducted to determine what policy should be adopted. In projects where the water area questions are important, the calculation of advantages and disadvantages for the range of options open can be difficult, but it must be carried out on the basis of the best information available, and it may be advisable to carry out a traffic simulation linking the time-and-tide-related vessel passage diagram to the traffic arrival rates and service times. This can be done by hand, with the aid of the planning chart given in part two of the handbook, but that might be laborious, and it would be useful if a computer-based simulation model could be used for this purpose.

(d) *Width of channel*

417. A major consideration will be whether the channel should be wide enough to allow ships to pass in opposite directions. Unless there are severe economic restraints, a two-way channel should be made in order to offer unrestricted access to the port. A secondary consideration is that if there is an accident in one lane of the channel, access to the port *will* still be possible and so there will be less disruption of traffic to and from the part.

418. Channel widths depend on the size of ship to be catered for and the physical conditions of the site. As a typical example, illustrated in figure 29 in a well-marked channel, the total width of full-depth channel required for two-lane traffic may be taken to comprise, on straight reaches, manoeuvring lanes of about twice the vessel beam for each direction, plus about 30 metres between vessels and up to one-and-a-half times the beam for bank clearance each side. For a typical 20,000 dwt cargo vessel, a total width of about 190 metres would be appropriate.

419. At bends in the channel, greater widths are required than on straight stretches because of the tendency of ships to drift on turning. An additional width, depending upon the radius of curvature of the bend but approximately equal to the beam of each vessel, will be required in order to allow for the projected width of vessels negotiating the bend. This feature of projected width will also occur on straight reaches of channel subject to the action of cross-winds and currents, which will also cause vessels to drift.

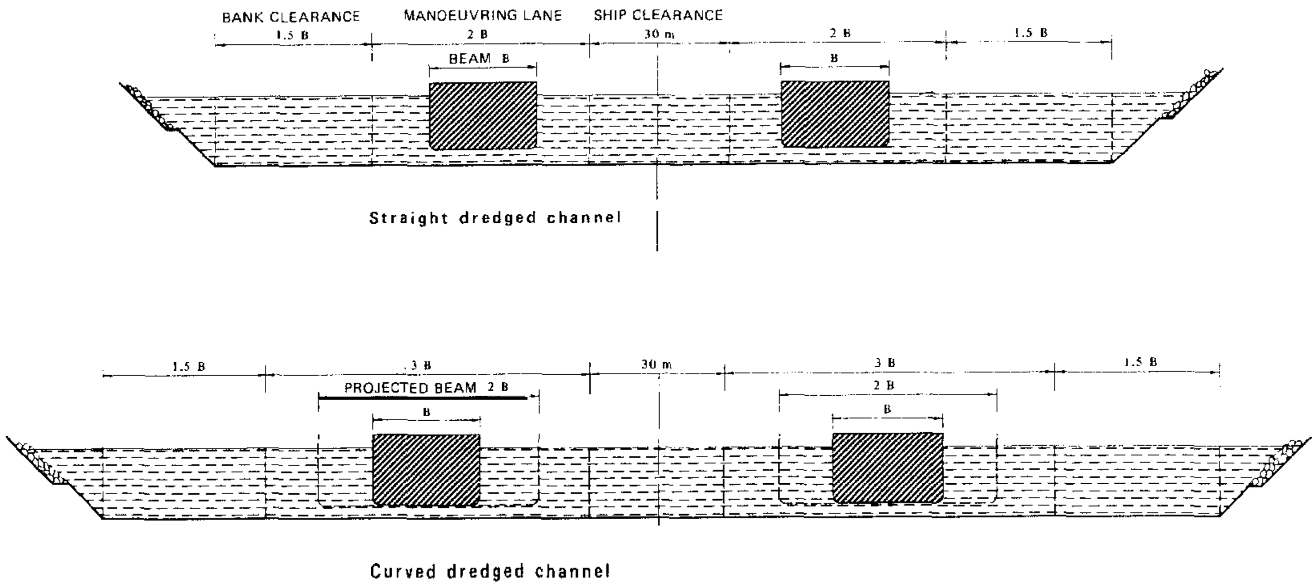
(e) Depth of channel

420. Consideration of the depth of water to be provided in a channel is complex and inevitably a compromise has to be reached between, on the one hand, allowing unimpeded access permitting the largest ship expected to use the channel at all stages of the tide, and on the other hand, excluding large vessels, imposing load-factor limitations on them or giving them access only at high tide. The cost of dredging to provide and maintain a deep channel for an occasional caller can be very high.

421. Where the nature of the traffic is such that the largest ships carry full loads in only one direction, i.e. either export or import, a deeper channel can be provided in the appropriate direction if a clear separation is possible.

FIGURE 29

Typical width dimensions of channel



422. Factors to be considered in deliberations of this kind are as follows:

(a) The transit times *of* vessels along the channel, both with and against the tidal stream. and the relationship of these times to the tidal cycle;

(b) The nature of the sea or river bed which, if of soft silt. for instance, might lead to a decision to reduce the designed under-keel clearance for vessels using the channel;

(c) The ship draught: upon entering an approach channel, the load-line draught of the vessel is modified by such factors as water density changes, which *may* occur along the length of the channel, the effect of squat and of wave action causing pitch and roll of the ship.

423. Each case and location must be studied to finalize channel depth design, but a preliminary assessment of the order of magnitude is usually possible and sufficient for initial studies. A general cargo ship with a draught of 9 m at sea would squat about 50 cm in a narrow channel; pitching would require about half the wave height in additional draught. and rolling somewhat less. Moving into fresh water would add about 25 cm to the draught but would usually occur only in sheltered water, where pitching and rolhng are not present. Thus, allowing 50 cm for bed clearance if the channel bed is soft, it might be assumed, for preliminary planning purposes, that a vessel drawing 9 m might require some 10.50 m of dredged depth in an approach channel. A greater depth would be necessary where the channel bed was hard. At certain ports having deposits of very soft mud, a zero or even a negative under-keel clearance may be acceptable, but such cases require very special consideration.

424. It should be appreciated that channels are not always of uniform depth, especially if they he along an improved natural feature such as a river or tidal inlet. For example, a relatively long channel may be limited in depth only over a small proportion of its length. Regular dredging of this localized area may provide the depth required to allow vessels to traverse the entire length of the channel unrestricted by considerations of tide and thus greatly facilitate accessibility to the port.

425. A ship that is to travel along an approach channel should have a draught no greater than that which will allow a specified safe clearance over the channel bed in the shallowest reaches of the channel. As suggested above, a minimum clearence of 1-1.50 m might be taken as appropriate for most vessels. The specified clearance usually allows for squat, so that the actual under-keel clearance will be less than that specified. Where the under-keel clearance of a vessel is expected to be critical, the transit time of the vessel along the channel, the time of the vessel's arrival at the shallow reaches and the state of the tide at that time must be carefully calculated, contingency provisions being made for vessels failing to traverse the shallow reach at the required time.

(f) *Channel alignment*

426. The manoeuvrability of a vessel moving in a confined waterway of limited depth is impaired two ways: (a) because the ship takes longer to respond to the helm, owing to the effects of shallow water: and *(b)* because the proximity of the sides of the channel tends to cause the vessel to be drawn towards them. This attraction or suction experienced by the ship towards the sides of the channel also applies between two vessels when passing.

427. Where there are changes of direction in the alignment of a channel, these limitations on ships' manoeuvrability must therefore be taken into account. The radii of bends must be as large as is practicable, and required ship movements must be kept as simple as possible.

428. The desirable geometry of bends in navigational channels for deep-sea general cargo ships may be taken as:

Angle of deflection not more than 30 degrees;
Radius of curvature not less than 1,500 metres.

429. A channel in the open sea should, if practicable, be aligned with the predominant storm direction and the principal current directions. Where these differ, and where other conflicting constraints arise, model studies are called for. Where a channel is situated within a large estuary or river, model studies will also be advisable, except in the simplest of cases.

3. Lay-bys and turning areas

430. Lay-bys are anchorages or berths where ships may be held for quarantine or other inspection, while awaiting change in weather conditions, or when queueing for service at the port. Special anchorages available for ships carrying explosives or dangerous cargo are separately provided and such areas should be so designated on charts. The anchorages are usually located away from the marine terminal and adjacent to main channels so that they are near deep water, but clear of other ship movement. Allowance must be made, in allocating lay-by areas, for the distance of swing out, during the tidal cycle, of a ship at anchor or moored at a buoy.

431. Lay-by areas may, in common with the harbour area, be protected either by natural features or by artificial structures such as breakwaters, but at many ports vessels wait for berths by anchoring off-shore.

432. In the immediate approaches to berths, vessels usually have to make more complicated manoeuvres than are necessary in the approach channel. Consequently, appropriately generous water areas must be provided and in most cases the assistance of a tug will be required.

433. The most basic of these manoeuvres is turning the vessel and it may be taken as a general indication of the space required to turn a vessel that a circle with a diameter four times the ship's length is required where there is no assistance from tugs. Where assistance from tugs is available, a circle half this size is adequate. These are average figures and the actual area needed will depend, in addition, on wind, wave and current conditions in any particular case. Shipping lines should be consulted during this stage of the planning.

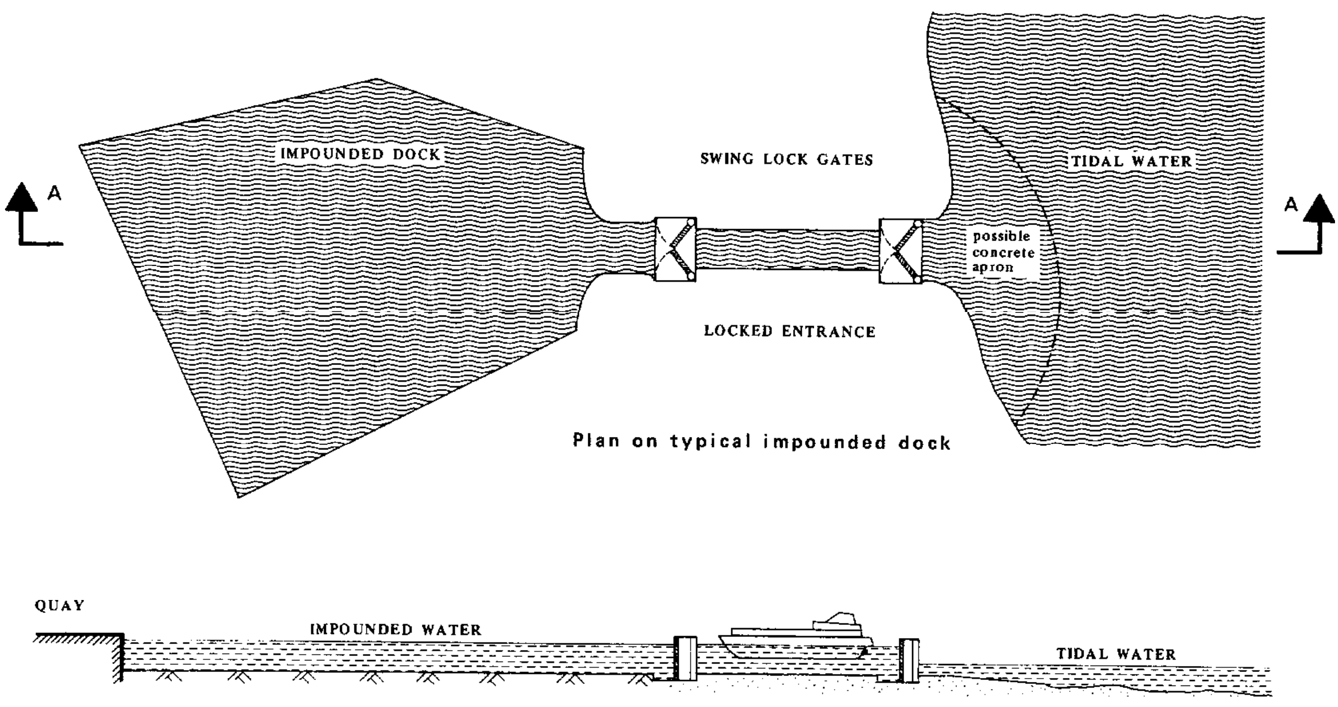
434. Where space is limited, the ship may be turned by warping around the end of a pier or a dolphin. Some modern vessels are equipped with bow thrusters which considerably enhance their manoeuvrability and for such vessels restricted sea room is possible. However, for the majority of ports there will still be many vessels requiring the larger areas referred to above.

4. Tidal harbours and locked basins

435. An important decision in the conceptual design of the port is whether berths in the harbour should be open to tidal influences or whether a locked basin may be justified. A locked basin-sometimes referred to as a wet dock-is one in which an area of water is maintained at a fixed level, usually equal to the high water level of the tidal water outside the dock. Access to the dock is achieved by means of a ship lock. This arrangement is illustrated in figure 30.

FIGURE 30

Example of a locked basin



436. Where the tidal range is so wide that an exceptionally deep harbour, and so high quay walls, would be required in order to allow ships to remain afloat at low water, there would be a strong argument in favour of having a locked entrance to the dock. Tidal fluctuations may also cause problems with regard to the loading and unloading of ships at quays. Some vessels, such as bulk carriers and oil tankers, can more easily accommodate tidal variations while loading and unloading than others, such as ro/ro ships. The type of traffic must therefore be taken into account when considering the possible need for a locked basin.

437. The disadvantages of the locked basin are:

(a) The high cost involved in providing the sealing dam and the ship lock itself, which is a complicated civil engineering construction, although the larger the number of berths over which the cost of the impounding dam and ship lock can be spread. the more viable the proposition becomes;

(b) The delays to shipping resulting from the locking operation;

(c) The rigid limitation on the maximum size of ship accommodated.

438. To take a specific example, at a port with a substantial number of berths and where the tidal range was about 3 metres, facilities for larger vessels were provided economically by impounding the whole basin at high water level, The cost of the new lock was less than it would have cost to deepen the harbour. A crucial factor in this case was the fact that it was possible to continue using the harbour during construction of the lock. In some cases, costs can be reduced by prefabricating a concrete lock in one or several sections away from its final location and floating it into position, with limited interference to port operations. The decision between the options of extending or improving a port is often governed by considerations as to the possibility of uninterrupted use of existing facilities.

439. The choice made is thus a matter of economic, operational and engineering analysis in each case, but the modern trend seems to be away from locked basins where possible. The advantage of the operational flexibility afforded by free access to the open sea is generally considered to outweigh the disadvantage of the increased capital cost involved.

5. NAVIGATIONAL AIDS

440. The alignments of the straight reaches of a channel are often delineated by at least two masts on shore ahead of the approaching vessel, clearly visible by day and provided with lights at night.

441. The boundaries of the navigable channel are marked by fixed markers or floating buoys. The latter are more common in deep offshore channels but in a river system the former are frequently more economical. Buoys must be able to withstand wave action and must remain visible at all times.

442. Systems of buoyage vary around the world and it is therefore important to establish which system is appropriate at a particular port. Essential advice is available from the national lighthouse authority. coastguards or navy departments in most countries.

443. The principal considerations leading to the choice of spacing of the visual aids for ships approaching and leaving a port are:

(a) The configuration of the channel;

(b) The incidence of low visibility:

(c) The usual sea condition in the channel;

(d) The presence of cross currents and winds.

Closer spacing of buoys will be required at bends and lit buoys are required if the port is to be approached by ships at night.

444. A new port will frequently require a main location beacon or lighthouse, and consideration should also be given in the general planning to radar reflectors. which ships can locate, port radar to monitor and control ship movements and radio communication between ship and shore.

445. Advice on these specialist navigational questions can be obtained from the International Maritime Grganization (IMO) which has its headquarters in London.

6. ECONOMICFACTORS

446. The capital cost of marine structures can vary with the cube of the depth while, in the case of dredged channels and basins, the greater the depth the greater also the maintenance burden, perhaps proportional to the square of the depth. Decisions concerning the depth and width of channels and basins. and the number of berths, should therefore usually be made only after thorough economic studies of each situation.

D. Dredging

1. INTRODUCTION

447. The removal of soil from the sea-bed or river bed to provide greater depth of water in the approaches to ports and adjacent to quays has a long historv. **As** the size of ships has increased, the dredging of existing ports has become increasingly important.

448. Great advances in dredging technology have been made in recent years, and various types of dredger currently used are described in section 3 below.

449. Dredging itself is essentially an excavating operation, but the selection of the correct equipment is vital in achieving economy. All dredging activity calls for special consideration of the nature of the ground to be dredged, the best means of removing soils and the optimum work programme. Both capital and maintenance dredging must be considered.

2. SITEINVESTIGATION DATA

450. The site investigations particularly required for dredging work should provide data on tides and

bathymetry, on wind, waves and currents and on the nature of the materials to be dredged, their ***in situ*** strengths, particle size distribution, degree of compaction and, in the case of silts, settling characteristics once disturbed. In all cases, standard classifications of material to be dredged should be used.

451. Section B above describes the carrying out of general investigations, of which those for dredging work form a part.

3. TYPES OF DREDGER

452. The following types of dredger are usually available for contract dredging work, and the mechanics of their operation are illustrated in figure 31.

(a) The ***bucket dredger.*** The modern bucket dredger comprises a continuous chain of buckets mounted on a ladder adjustable for depth. Each bucket discharges its load at the top of the ladder, into chutes which direct the material into a hopper barge.

Bucket dredgers are best confined to work in sheltered locations and are useful for fairly accurate trimming of the bed. They can deal with some hard material but large pieces in the bucket can cause serious delays.

(b) ***The grab dredger.*** The grab dredger is usually a self-propelled vessel with a hopper and a grab crane. A simpler version which requires attendant barges is simply a crane on a pontoon.

(c) The dipper dredger. Excavation is achieved by means of a forward or rearward-facing shovel mounted on an arm suspended in front of the pontoon body, which operates by digging into the underwater material.

(d) ***The suction dredger.*** The basic components of this type of dredger are a pontoon hull which houses the pumps and engines, a suction pipe suspended from the vessel to the sea-bed and a delivery pipe from the pumps to a dumping area or, in some instances, to barges.

Only small granular material can be dredged by suction and it is common for this type of dredger to be equipped with a rotating cutter on the end of the suction pipe. Cutters can be designed to suit the particular material to be dredged and cutter suction dredgers can remove sand and gravels, medium stiff clays and, with the addition of special cutting teeth, stiff clays and soft or broken rock. Output, however, varies considerably according to material type and conditions. Nevertheless, this cutter suction dredger is now the most usual dredging equipment for capital work and is particularly suited for reclaiming purposes.

(e) The trailing suction hopper dredger. The trailing suction hopper dredger is a self-propelled vessel with suction pipes suspended from one or from both sides. The dredged material is delivered through the suction pipes to the hopper. When the hopper is full, the vessel proceeds to the dumping ground.

This type of dredger is widely used in the maintenance of channels, where its ability to manoeuvre as a ship is a distinct advantage. A further advantage of this type of vessel, when compared with the other types discussed, is its ability to remain effective in rough water and offshore locations. It is, however, suitable only for relatively loose materials as would be found in maintenance dredging.

4. DREDGEROPERATION

453. The selection of the most suitable dredger depends upon the material to be dredged, the depth of dredging, the quantity and disposition of the material, the location of the dumping ground, the rate of production required and also on whether the dredger may have complete or partial possession of the waterway.

454. The programme and sequence of the dredging operations require careful consideration. If possible, dredging should commence in a location which would be least liable to siltation from later dredging. Timing of the dredging activity relative to the construction of other parts of the project, some of which, such as breakwaters or groynes, may give shelter or affect siltation, must be considered in the overall planning of the project. Timing may also depend on local seasonal variations of tidal currents and winds, which can render dredging activities much easier in one season than in another, especially in estuaries. A further factor which must be borne in mind is the date of the start of operations at a new port, which may be in advance of the completion of the whole project so that the construction requirements of, or the need for access to, particular berths will influence the sequence of dredging.

455. The removal of solid rock constitutes a specialized dredging activity in that some means must be found to fragment the rock before it can be lifted from the sea-bed by one of the conventional dredging methods described above. Usually a bucket or grab dredger is used to remove rock debris, but suction dredgers have also been employed to remove sufficiently fragmented rock.

456. The most commonly employed method of rock-breaking under water is that of drilling and blasting, although jointed rock with thin bedding layers may also be fragmented by a heavy chisel or a pneumatic hammer on the rock surface.

457. Drilling and blasting under water is a specialized, slow and expensive operation and many trials may be needed to obtain the right results for the dredgers to be used. The dredging of coral or cemented sand causes frequent problems. These can sometimes be easily fragmented and dredged by a powerful cutter suction dredger. However, only careful investigation will show whether this is likely, and massive formations may need to be treated as rock before dredging.

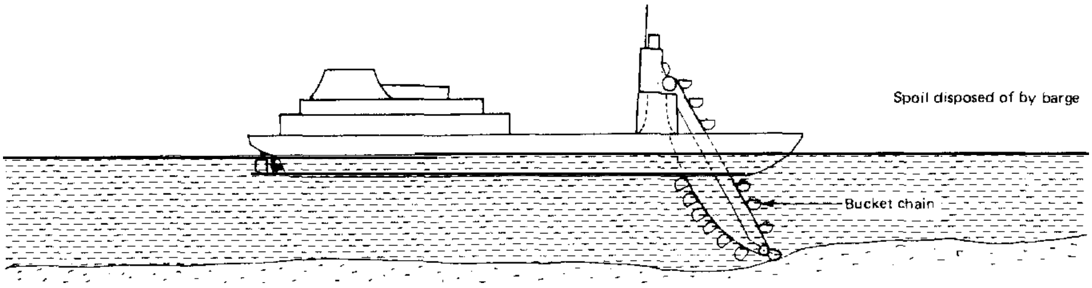
5. RECLAMATION

458. It is of considerable advantage if the dredged material from a port project can be used for reclamation projects, but only certain granular soils are suitable for this purpose. Silts and clays are generally much more difficult to use. A thorough geological and geotechnical survey of the extension area is required to

FIGURE 31

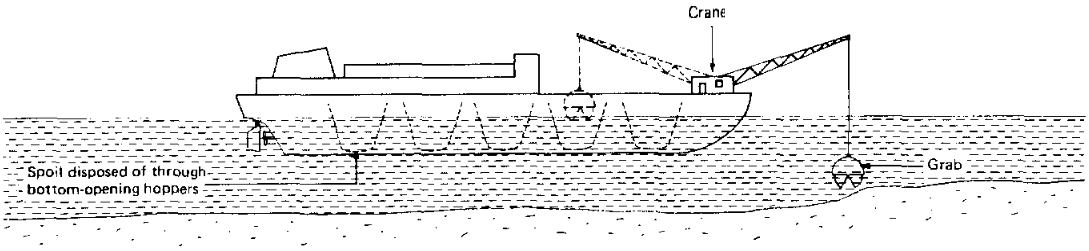
Five types of dredger in common use

a)



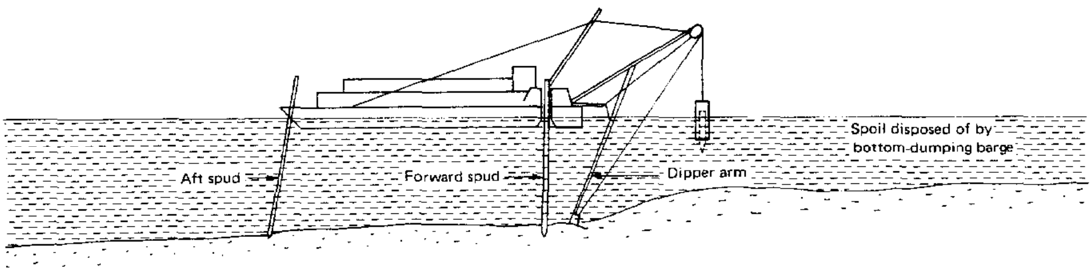
SELF-PROPELLING BUCKET DREDGER

b)



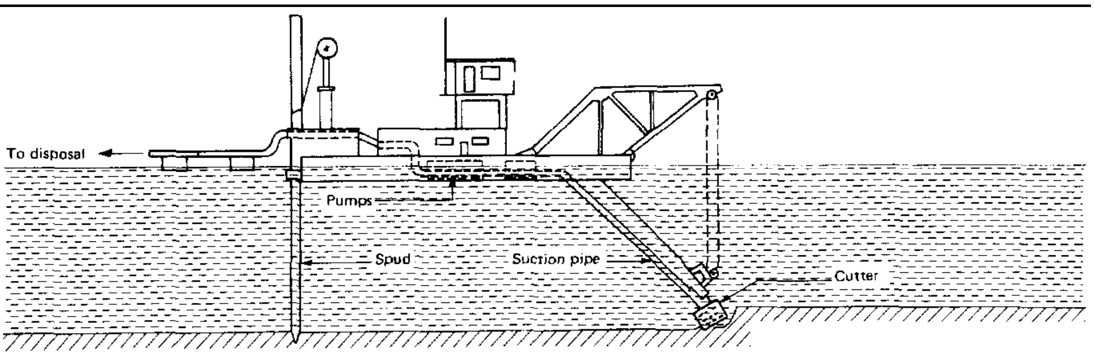
SELF-PROPELLING GRAB HOPPER DREDGER

c)



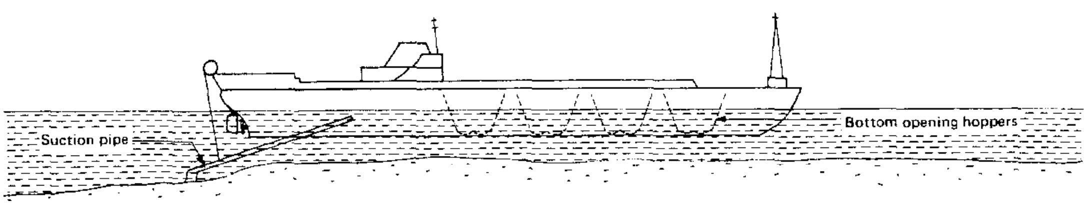
NON-SELF-PROPELLING DIPPER DREDGER

d)



NON-SELF-PROPELLING CUTTER SUCTION DREDGER

e)



SELF-PROPELLING TRAILING SUCTION HOPPER DREDGER ensure that the existing subsoils can support future buildings.

459. The settlement behaviour of the fill material should be carefully analysed and monitored before construction is permitted. Pre-loading through the construction of embankments may be needed to achieve settlement within a reasonable period before buildings are erected. Geotechnical analysis will generally provide the correct solutions.

460. An important aspect in project planning is the balance of dredging and reclamation, and this must be assessed in each case with a view to economy.

6. ECONOMIC FACTORS

461. In assessing dredging costs it is important to remember that in many places large equipment must be brought from far afield to do the work, with a consequent heavy mobiiization cost. The quantity of dredging required for any particular scheme therefore has a pronounced effect on the overall unit rate. For a modest amount of work it may be found economical to employ simple equipment such as excavators on barges. Even though their working costs and productivity are less favourable, the saving in mobilizing the less sophisticated equipment can more than offset the less efficient performance in the field.

462. Such judgements are difficult to make and are often best resolved when tenders for the work are invited, but during a project study the various factors must be considered so as to permit a realistic estimate of dredging costs to be prepared.

E. Breakwaters

1. DESIGN DATA REQUIRED

463. Where there is insufficient natural protection, breakwaters are needed in order to form an artificial harbour. Breakwaters deflect, reflect or absorb the energy of swell and storm waves which would otherwise enter the harbour area, and thus provide an area of relatively calm water.

464. The chief information needed for the design of breakwaters is the height and period of the storm waves likely to occur. The normal practice is to choose a design wave that represents the maximum wave measured during a storm which statistically will occur once in so many years, for example, once in 100 years. The likelihood of waves breaking against the structure is also a factor of importance in design. Data about the probable daily maximum wave must also be collected in areas of continuous swell, since this may have a significant effect upon the cross-sectional design of the breakwater.

465. The determination of the design wave requires the study of available oceanographic and meteorological data. It is preferable that direct recording of wave heights and periods should be made at the port site, but this is not always possible within the time available.

466. As waves are generated by winds, an estimate of wave activity can be made from wind records. Local reports of storm occurrence also assist in building up a statistical picture of the waves which can be expected. Tide and storm surge water levels should also be recorded or estimated, as waves are affected by water depth near port entrances.

467. The foundations of breakwaters warrant careful geotechnical investigation. Boreholes must be made and soil and rock samples taken over an area sufficiently large to allow variations in the position of the breakwater to be considered, and the possibility of scour of the sea-bed for some distance in front of the breakwater to be investigated. The strength and settlement properties of soils under a proposed breakwater require study to depth at least equal to the width of the breakwater base, since weak soils at depth may be overstressed by a large structure. Weak soils at the surface may have their bearing capacity enhanced by the placing of a blanket of sand or gravel on the surface prior to construction of the breakwater.

2. ALTERNATIVE TYPES OF BREAKWATER

468. Breakwaters may be in the form either of an offshore island or of an arm projecting from the shore. The breakwater may present a vertical or near vertical wall or a sloping surface composed of variously sized blocks. The two types are illustrated in figure 32. The structure may be submerged below sea level at some or all tide levels.

469. In the past, vertical- or near vertical-faced breakwaters often comprised two walls of masonry blocks laid in horizontal, well-bonded courses with rock rubble fill placed between the walls. In later years, concrete blocks replaced expensive masonry and, more recently, reinforced concrete caissons have been used. The caisson is constructed in a dock and then usually floated to its final position and sunk on to a prepared sea-bed or blanket of rock rubble. Some form of interlocking between the individual caissons is usually required. Another approach is to precast the caissons on land, then to transport them along the already completed length of breakwater and to lower them into position by means of a large cantilevered gantry crane.

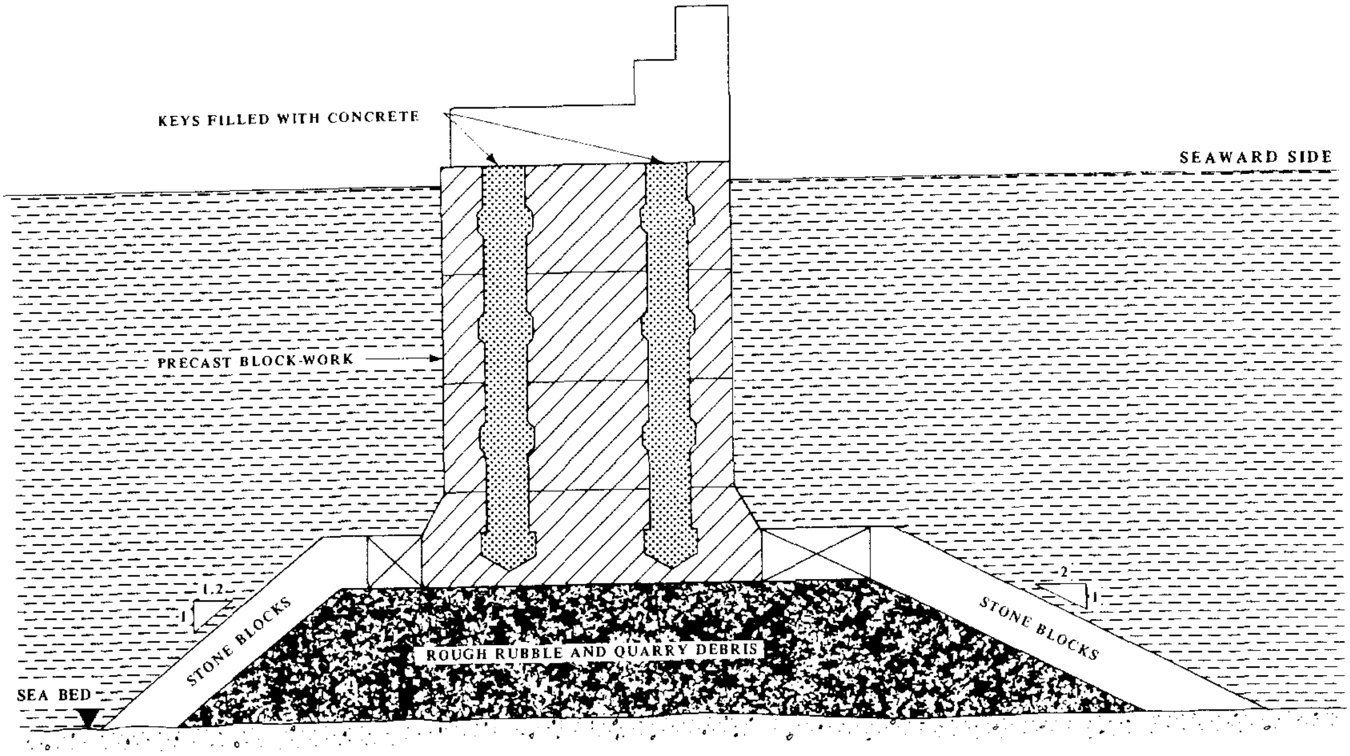
470. Rubble mound breakwaters vary in the type of primary armouring used. These breakwaters are of basic trapezoidal shape in cross-section, with a mound of smaller-sized rock called the core. Graded stone armouring is placed on the slopes and on top of this core. On the outside face of the breakwater, which dissipates the energy of the storm waves, the largest primary armour is placed. Many breakwaters of this type with natural rock primary armouring have been built and much published data is available.

471. In cases where it would be uneconomical to provide rock of adequate size, artificial concrete armour units are employed. Considerable research has enabled many specialized shapes to be evolved with high efficiency in resisting wave attack. In its simplest form (a concrete cube), artificial armour is a substitute for rock fill, but many of the special units have been designed to improve interlocking between units, while

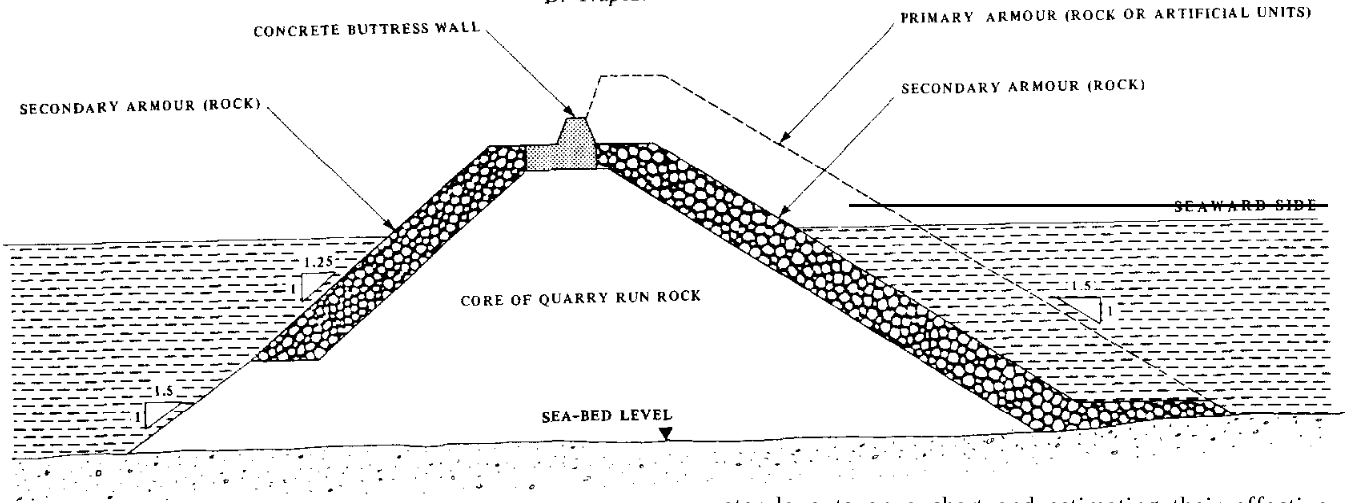
FIGURE 32

Examples of breakwaters

A. Vertically faced breakwater



B. Trapezoidal breakwater



providing the maximum voids in the armour layer to dissipate wave energy. Examples of artificial armour are shown in figure 33.

472. While designing the cross-section of a rubble mound breakwater, the source of rock fill should be investigated for quality and output. An assessment should be made of the likely proportions of rock which can be obtained from the quarry so that these proportions can be matched in the finished structure and waste of certain sizes minimized.

3. DESIGN PROCEDURE

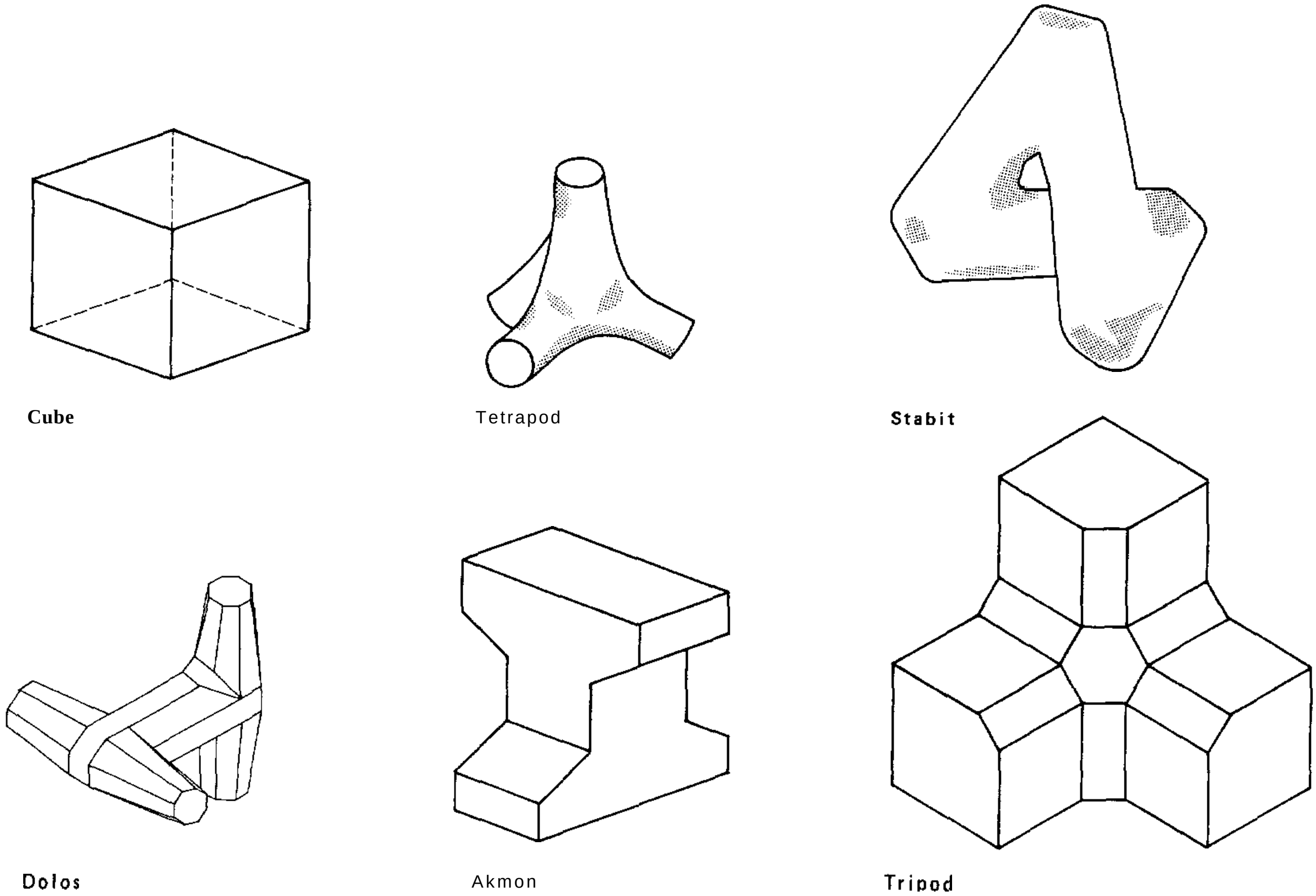
473. A preliminary assessment of breakwater requirements can be made by drawing possible breakwater layouts on a chart and estimating their effectiveness in intercepting anticipated wave attack. The effectiveness of the proposed breakwater layouts in reducing wave heights within the harbour can then be verified by model testing.

474. An element of compromise is usually found necessary between the most effective hydraulic solution to exclude wave energy from the harbour. and the ease of access and berthing of ships. The types of ships and methods of cargo handling need to be known so that residual wave activity in the port can be matched to the shipping requirements.

475. The design of the breakwater mass against the possibility of overturning is fairly straightforward, but the possibility of sliding on the foundation is frequently less easy to provide against. Measures to ensure an

FIGURE 33

Examples of various artificial armour units



adequate factor of safety against the latter type of failure may take the form of providing a sheet pile curtain or an additional build-up of material against the inside wall of the caisson.

476. A disadvantage of vertical-faced breakwaters lies in the scouring action on the foundation which may be set up by the refraction of waves from the face of the wall. This aspect should be carefully examined. Nevertheless, an approximate guide is that if the erodible bed material is situated at a depth of less than twice the wave height below the lowest water level, scour needs to be carefully guarded against.

4. CONSTRUCTION

477. The two major types of breakwater discussed in the preceding sections require totally different construction methods and plant.

478. The core of a rubble mound type of breakwater is commonly constructed by end-tipping progressively from the shore, but careful checks are needed against segregation of the rocks which may occur during loading and tipping. A large crane can then travel along the top of the core mound to place the upper core rock to finish the profile and then to place the outer armour layers of rock and/or artificial armour. A floating crane can be used but is economical only in areas where severe sea conditions are rare. Similarly, the lower part of the core can be placed in position from barges.

479. The caisson type of breakwater involves construction processes which usually take place off site. The caissons, which are made of concrete and have closed bottoms, are usually constructed in a dry dock or on a launching area on shore until the walls have attained sufficient height to allow the caisson to float. When the walls have been completed to the required height, the caissons are towed to the breakwater location where they are sunk on to a prepared sea-bed. A time of minimum current and wave activity should be selected for this operation. The caissons should be filled with material, usually sand, as soon as possible after sinking to give the earliest full weight against wave action.

5. ECONOMIC FACTORS

480. The selection of a particular type of breakwater also depends on such factors as the availability of materials, plant and labour. A vertical wall breakwater will place different demands on these factors than a trapezoidal rubble mound breakwater.

481. The rubble mound breakwater will require more material because of its shape. Thus in an area

which has an ample supply of rock strata capable of providing large primary rock armouring, this type of breakwater would be preferred. A major expense is the large crane required for rock handling. which is normally written off against the cost of the project. For short breakwaters this results in a high unit cost. This form of breakwater does not require a large **pool** of skilled labour.

482. The vertical wall breakwater in the form of caissons requires less material. Reinforced concrete provides the armouring and sand or gravel can be used as the fill material. More modest equipment is required but facilities are necessary to tow the caissons into position for placing, Such facilities, for example tugs, normally have a use in the port. To prepare the necessary forms to construct the caissons, a more skilled **pool** of labour is required.

F. Quays and jetties

1. INTRODUCTION

483. A distinction must be made between heavy structures on which cranes and large vehicles can operate, and light structures which can only support pipelines, conveyors and light vehicles, The heavy structures-interchangeably called quays and wharves-can be either marginal (i.e. parallel to the shoreline) or in the form of piers which project from the shore. The light structures, which also project out to deeper water, are called jetties.

484. A jetty is economical where the depth of water available for the ships calling is available only some distance offshore. It is suitable for bulk cargoes-dry or liquid-where the jetty head in deep water accommodates the specialized loading or unloading equipment and the cargo is conveyed ashore by pipeline or moving belt along the jetty approach. A jetty is unsuitable for general cargo, where storage area near the ship is important, unless a high tidal range makes it the only economical solution.

485. In any project there will be a variety of engineering possibilities which may call for either the improvement of outdated facilities or the construction of new facilities in accordance with modern standards. In the case of new structures, known engineering approaches can be utilized, but for the improvement of old facilities there are usually factors which impose considerable restraints on technical options and each case has to be considered as a special problem.

486. Using on-the-spot materials can often be a suitable and more economic solution. It is advisable in each construction project to identify such possibilities, rather than merely to adopt methods used in industrial countries. For example, in some cases jetties can be constructed with local wooden piles. or with bamboo piles air-driven into the mud. Another example of the use of local material occurred in the development of a bulk terminal. By designing heavier foundations which used local material, the use of locally produced steel, which required a greater cross-section and was thus heavier than stronger imported steel, was possible. This saved the country a great deal of foreign exchange.

2. QUAY WALLS

487. Several forms of construction are available, each suitable for certain conditions. They include the block-work retaining wall. the anchored bulkhead wall and open-piled marginal quays, as described below.

(a) *Block-work retaining wail*

488. This type of wall, shown in figure 34A, requires a firm, non-erodible foundation, preferably rock or a stiff clay, but a rock blanket over loose ground can be used to prevent scour.

489. Such a wall can be built up from individual blocks, usually placed under water. Among the possible variations **are** solid block-work, in which the blocks are laid in horizontal courses, slice-work, in which the blocks are laid on sloping courses which allow the quay to accommodate settlements. and hollow block-work, which reduces the weight of unit to be handled. If dry construction can be used for the wall, then mass concrete ***in situ*** construction is very suitable.

490. Concrete caissons can be used for quay walls, either by floating pre-formed boxes into place and sinking them, or by constructing a box in the final position and excavating inside it until it sinks to the desired level.

491. The suitability of each of these gravity walls depends greatly on ground conditions. Block-work and floating caissons would normally be used only where the quay is built in water which has a depth close to the final dredged depth. A caisson can be built in its final position where the wharf is at present dry land and where the ground above dredged level is soft.

(b) *Anchored bulkhead wall*

492. Anchored steel sheet pile retaining walls, as shown in figure 34B, have been widely used for quay walls and are to be recommended particularly where the quay height required is not unduly great and where the soil is a medium dense sand.

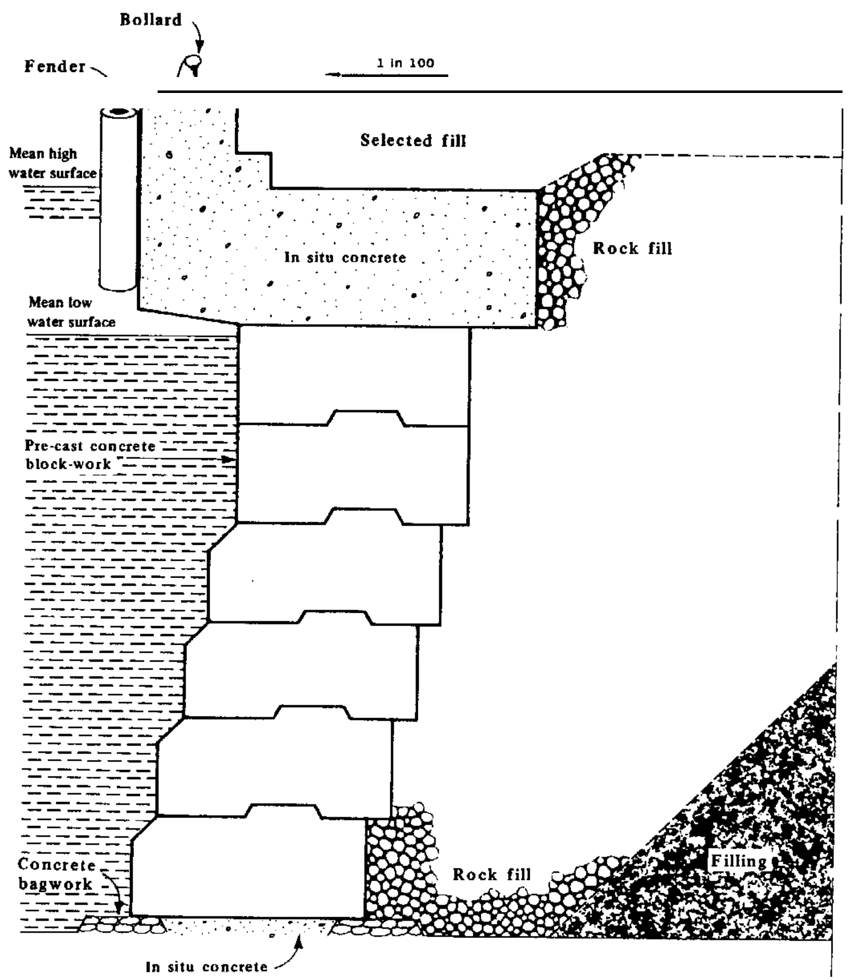
493. Higher sheet pile quay walls can be obtained by using special composite sheet and H-pile sections which are now available. Other measures which may be used to reduce the bending moment in the wall are to employ a double bank of tie bars or to form a relieving platform above the sheet piling. Concrete piles can be used in this type of wall and in many countries where the cost of steel piling is high, since it has to be imported, concrete may give considerable economies.

494. However, concrete piles are heavier, more difficult to drive and there are problems of ensuring a satisfactory seal against soil escaping between them. The purchase cost of steel piling may therefore still be justified. Table 13 compares factors which should be considered in each case.

(c) Open-piled marginal quays

495. One of the most widely used forms of marginal quay construction is the open-piled suspended slab as shown in figure 34C and D. This form of quay may

A. *Block-work retaining wall*



B. *Anchored steel sheet pile*

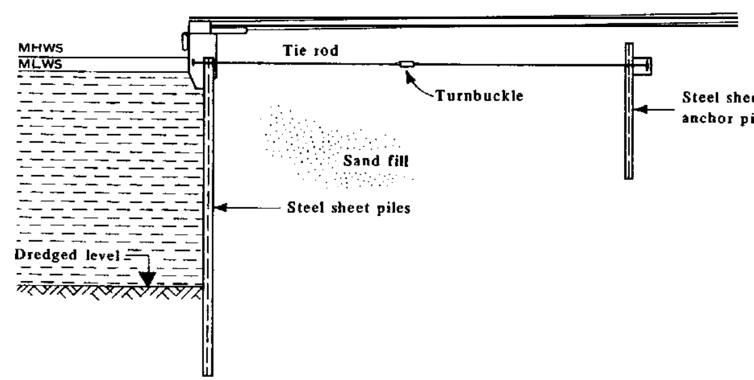


FIGURE 34 (*continued*)

C. *Open-piled quay with raking piles, typical cross-section*

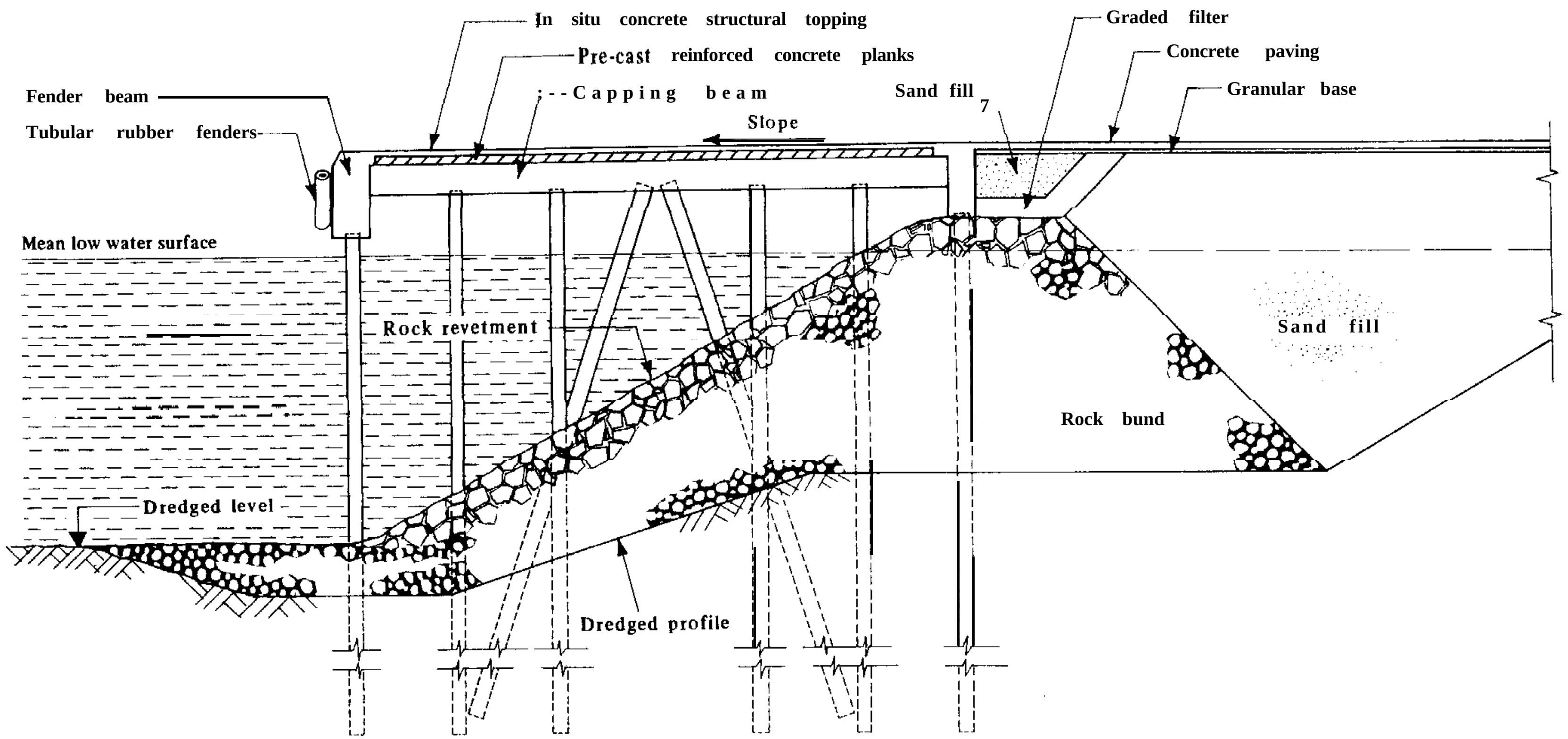
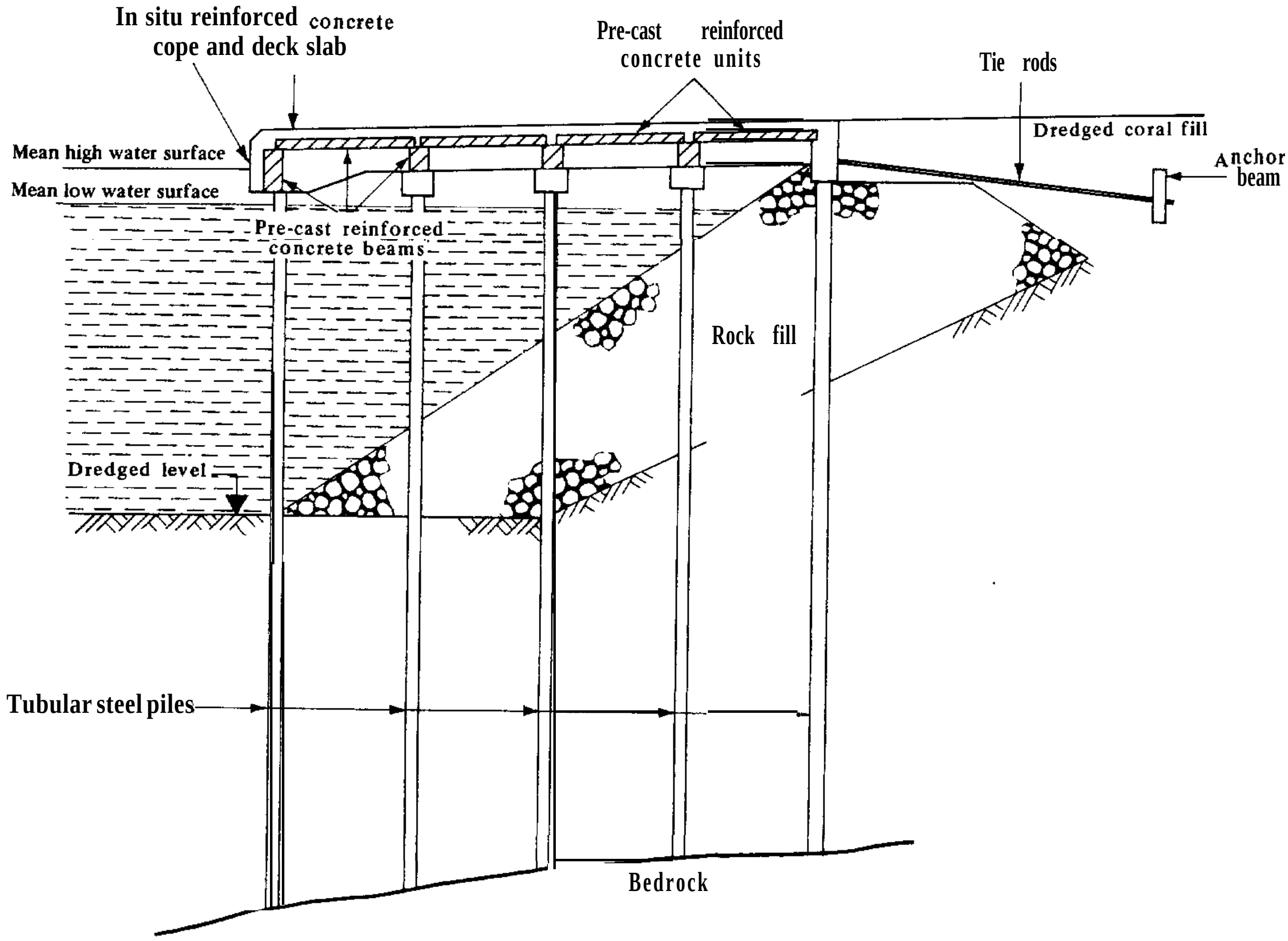


FIGURE 34 *(concluded)*

D. Open-piled quay with anchors, typical cross-section



include, in addition to normal vertical piles, raking (inclined) piles and/or tie rods connected to anchor blocks placed some distance behind the quay. This type of quay is built over a rock-revetted slope (a slope faced with harder rock) or over a rock embankment or dike which serves to retain the finer soils--usually reclaimed material-behind the quay.

496. In order to reduce the width of the apron slab, a low bulkhead wall is sometimes introduced at the rear of the quay to retain the upper fill material. A variety of construction techniques is available in steel, concrete or even, in modest structures, timber. The most economical deck width and the pile spacing have to be established by examining different solutions in each case.

497. Where there is heavy vertical loading, such as from container or bulk-handling cranes, large-diameter concrete cylinder piles may prove an appropriate solution for the quay structure. In addition, the spacing of crane rails can influence pile spacing and should be taken into account when planning the quay dimensions.

3. JETTIES AND DOLPHINS

498. A jetty provides a berth some distance from the shore. A trestle structure or causeway joins the jetty to the shore and may carry a roadway, pipelines or conveyors. In certain special cases the approach structure can be dispensed with by using, for example, submarine pipelines for oil, or cableways for bulk ore. A jetty may be built in sheltered harbour waters to provide a relatively cheap berth for specialized cargo vessels and in such cases a short approach structure is all that is usually needed.

499. Alternatively, a jetty may be built offshore in the open sea, with a long approach structure to reach adequate water depths. For tankers and bulk carriers a jetty can be an economical means of providing a facility, but the hostile construction environment and the periods when the berth is unusable because of weather conditions must be taken into consideration before this solution is adopted.

500. While a normal quay wall structure performs the two functions of providing a berthing position for the ship and a working platform for ship-working activities, in the case of a jetty it is usually economical to separate these two functions structurally. Therefore, a working platform (or jetty head) carries bulk cargo handling equipment, pipe handling gear, etc., while separate berthing and mooring dolphins are provided to hold and control the ship (see figure 35). The platform for cargo-handling gear is then not required to accept the horizontal impact from the ship berthing or

TABLE 13
Comparison of steel and concrete piles

Aspect	*Steel piles*	*Concrete piles*
Material	High cost	Lou cost
Transport	Usually have to he imported	Can bc made on site
Inspection and treatment	Require simple inspection and works quality certificates; cleaning and possibly sandblasting on the site	Require careful site checking of materials and workmanship
Handling	Comparatively light to handle and robust	Heavy and careful handling needed
Driving	Can withstand hard driving	Careful driving needed and risks of cracking
Extension	Readily extended by welding	Extension is time-consuming or needs sophisticated connections
Maintenance	Liable to corrosion and require painting, extra wall thickness or cathodic protection	Require little maintenance if well made and undamaged

the loading while it is berthed, as the ship makes contact only with the berthing dolphins.

501. Where the sizes of ships do not vary greatly, as at an oil or ore berth, berthing or breasting dolphins are usually placed on either side of the jetty platform at a spacing of about 0.4 times the length of the ship.

502. A group of raking piles with their tops held in a concrete pile-cap may form the dolphin, with rubber fenders on the berthing face to provide the necessary resilience. Alternatively, a berthing dolphin can be formed by using a group of large-diameter tubes of high tensile steel driven into or fixed in the sea-bed. The energy absorption of such flexible steel tube dolphins can be computed to suit the anticipated berthing energy of an approaching ship, and it is frequently economical to vary the section of the tubes over their vertical length. The degree of fixity of the pile in the ground is important for such calculations and the soil properties must therefore first be determined by a thorough ground investigation.

503. Mooring dolphins are provided at a jetty to support bollards for ships' mooring ropes. A group of piles or some other such structure which will take bollard pulls, depending on ship size, of up to 100 and sometimes 200 tons. is used for this purpose. In this case the piles are set some way back from the berthage line of the ship. Where the jetty is close to shore with a very short approach, the mooring dolphins can be constructed on the shoreline. Access for small boats carrying ropes should be provided at mooring dolphins.

504. The jetty head is usually a simple piled structure with fendertng for those small vessels or barges which may use the berth. Steel piles with a reinforced concrete deck are often used for this type of structure.

4. SPECIAL TYPES OF BERTH

505. In addition to the quays and jetties normal in any port, a number of unusual berth types have been developed for special shipping services. These are unlikely to fall within the scope of planning and designing common-use port facilities, as they are usually associated with a particular industrial development.

506. Bulk ores and petroleum are now transported in very large vessels and it is difficult to extend existing ports to include berths for such ships. Moreover, new sources of crude petroleum and ore are frequently in areas where no ports exist and so completely new facilities have to be set up.

507. While jetties may be extended a considerable distance offshore, natural or artificial islands created in favourable water conditions offshore can prove more economical. Cableways (for dry materials like ores) or submarine pipelines (for liquid products) replace the approach causeway. Sometimes such islands have the additional advantages of providing storage and facilitating subsequent transshipment.

508. A further development in recent years for petroleum discharge has been the single-point mooring for large tankers, as illustrated in figure 36. The use of ordinary mooring buoys and submarine pipelines for tankers has long been known but, more recently, single large buoys or fixed structures have been developed which hold the ship. There are a number of types, some of which include the hose connection within the mooring, others which separate the two functions, but the main feature of all such systems is that the vessel can take up the most favourable position with regard to sea currents and winds by rotating around the buoy.

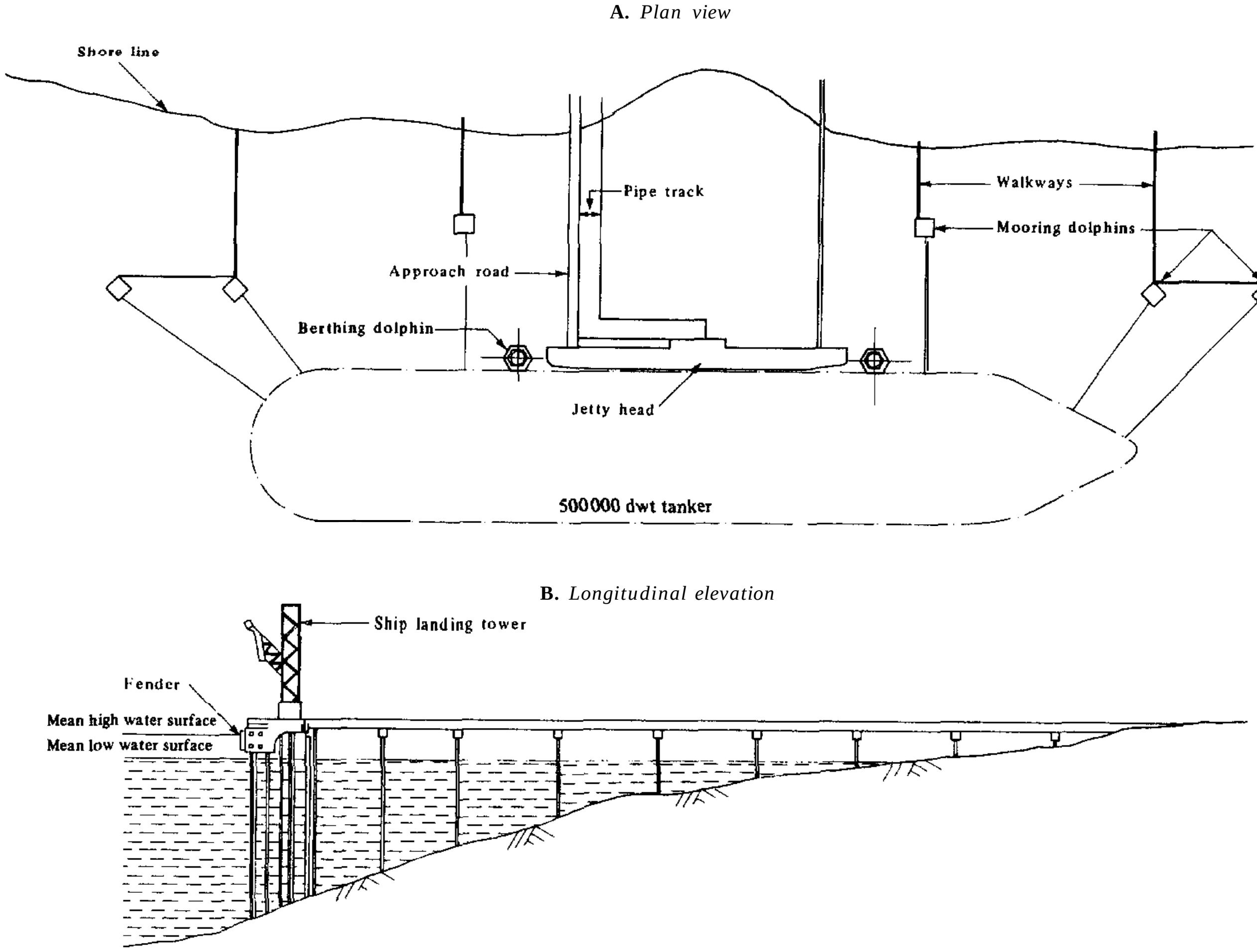
509. The major advantages of such systems are that down-time due to weather is less than would be the case at a fixed berth in the same location; capital outlay and commissioning time are generally less; berthing is easier, and the system is relatively easy to remove to a new location. These advantages may be offset by cost, maintenance problems and safety questions.

5. BERTH FITTINGS

510. The fitting required on a berth comprise fendering to absorb the energy of impact of the vessel,

FIGURE 35

Typical jetty for large oil tankers



mooring devices to secure the vessel during its stay at the berth, access ladders or landing steps for small vessels, and boats and services supplying the various needs of vessels in port. Fendering is discussed in more detail in section 6 below and the other features are briefly described in the paragraphs that follow.

(a) *Mooring devices*

511. Mooring devices vary progressively in size from those required for small boats to those for large bulk carriers, and include bollards, mooring rings, cleats and quick release hooks.

512. The most important and most commonly used device is the bollard, which should be a low cast-iron post, shaped with lobes such that ships' ropes may be securely held. Although bollards are classified according to the loads at which they will fail, the design should be such that failure takes place first in the holding-down bolts at a pre-determined failure load, the structure itself thus being safeguarded.

513. Bollard capacities and spacings appropriate to certain sizes of vessel are given in manufacturers' literature. For example, for 20,000 dwt cargo vessels, 50-tonne bollards at 25-metre intervals would be suitable. Quick-release hooks are usually employed on large vessel berths and proprietary designs are available to suit the requirements of the ship operators.

(b) *Ladders or landing steps*

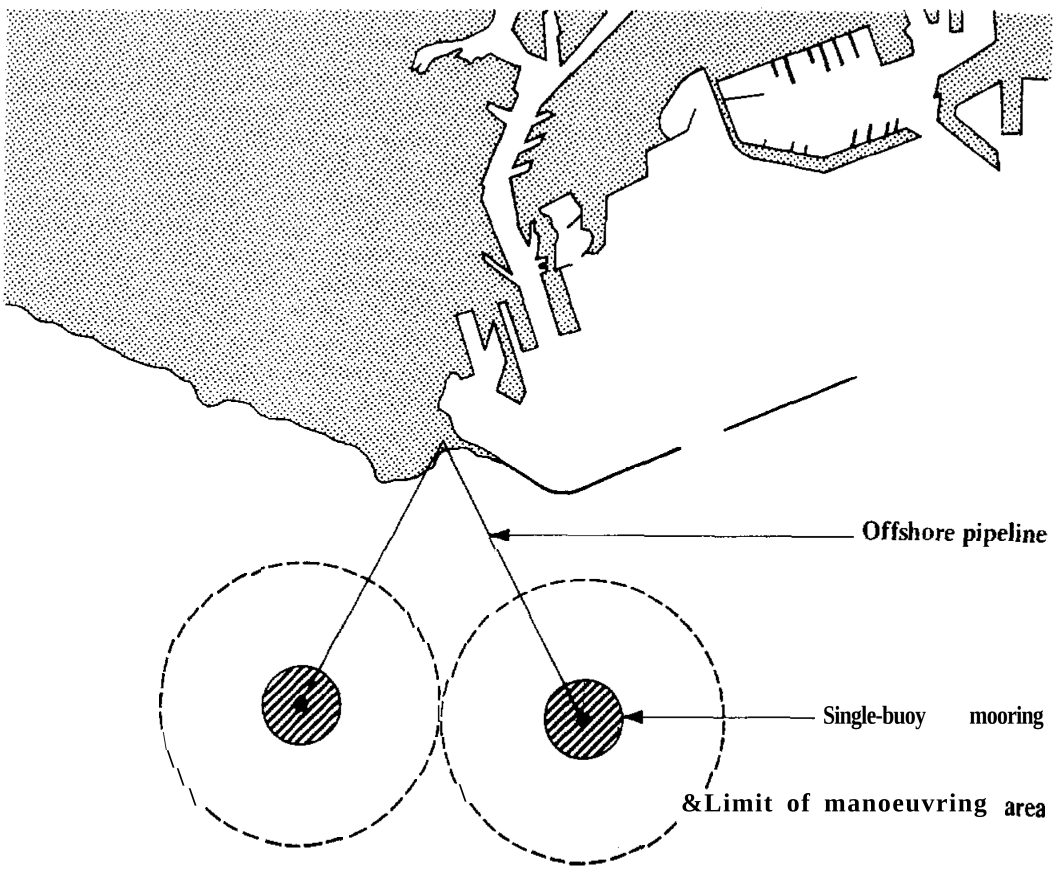
514. Ladders or landing steps should be provided along the face of the quay at about 40-metre intervals. They serve not only to allow access to vessels of low freeboard and to small boats, but also as a safety measure for anyone who falls in the water. Ladders or landing steps are also necessary on isolated mooring dolphins in order to allow access from the launch during rope-handling operations.

(c) Services

515. The port can offer a number of different services at a berth. The most common facility is the provision of fresh water. The water supply may be arranged at metered hydrant pits spaced at intervals of 50 to 100 metres along the length of the quay edge, fed by ring mains usually as an extension of the local water supply system. Any limitation on the fresh water supply per ship should be specified in port documents.

FIGURE 36

Water area requirements for single-buoy mooring



Source: "Port of Los Angeles Comprehensive Master Plan 1990"

516. Water must also be available for fire-fighting purposes. The use of fresh water, although it does least damage to cargo, may be expensive, and sea water can be used. Special salt-water mains can be laid which are left empty, to be charged with salt water in an emergency, by either a fixed or mobile pump installation. For a more effective system, pressure-charged mains and automatic pumps for instant use may be provided. This shore-based fire emergency system augments the usual provision of fire-fighting equipment on tugs.

(d) *Fuel bunkering*

517. At some ports there is a demand for the provision of ships with fuel. The alternative to using a fuelling barge or setting aside a special fuel berth is to provide a fuel supply at the cargo berth, so that the ship can be fuelled during its time at berth. According to the classes of traffic expected, fuel oil. marine gas oil, marine diesel oil and intermediates may be required. Not every berth needs to be so provided, but fuel hydrants served by buried pipelines should be provided at convenient locations. Blending valves may be needed and maximum and minimum supplying rates in tons per hour should be specified.

(e) Electrical power

518. It is not usual for the port authority to provide electrical power to vessels, but depending upon the normal usage of the ships calling at the port, this may be required. In this case, electrical plug boxes would be provided on the apron at each berth. Lighting of the aprons is needed for night operation and to avoid there being lamp posts which might obstruct cargo handling, lights are usually fixed on the transit shed. For an open berth, high light-towers away from the ship's side are preferable.

(f) *Ship-to-shore telephone*

519. Telephone communication direct from the ship is an increasingly important service. Ship-to-shore points are usually provided at each berth, preferably near either end to be conveniently placed for the ship's superstructure. Ducts are placed in the apron with draw wires through which telephone cables can be drawn when they are needed.

6. FENDERING OF BERTHS

520. The impact between a berthing vessel and a quay structure could cause damage both to the vessel

and to the quay wall unless a fendering system, examples of which are illustrated in figure 37, is provided to absorb the impact.

521. In the case of a solid quay, such as one of concrete blockwork construction, the maximum allowable force would be determined by the ship's ability to resist permanent deformation, the wall being able to sustain much higher forces than the vessel, In the case of open-pile designs the strength of the structure tends to be the determining factor in fender design. In both cases fenders must be placed so as to reduce the forces which are transmitted to a given part of the structure.

522. Fender systems vary from quite complicated arrangements to virtually no fendering at all for some berths servicing smaller vessels. The most usual form of modern fendering is rubber in various shapes which can be easily attached to the structure and designed to suit the particular conditions. Timber fenders are also widely used, particularly for general cargo berths, although the maintenance required is often considerable. A very economical possibility is to use large tyres, for example, from earth-moving equipment, suspended from cables, as fenders. Such fenders can be suitable, along solid wharfs, for up to 100,000-dwt ships.

523. The allowable berthing speed of a vessel is dependent on the size of the vessel, the navigational skill of the mariner or tug master and weather and harbour conditions. A higher than normal velocity should be selected as a design figure to enable the fenders and structures to cover all circumstances of berthing, but it is usually quite out of the question to design for an accidental collision. Manufacturers of proprietary fenders produce specifications of their fenders' energy absorption data and tables which enable a selection to be made.

57.4. Other types of fender would normally be designed as a mechanical/structural system to suit the particular application. For specialized berths, the ship operators would normally have opinions on the suitable types of fender for their vessels and should be consulted where possible. The following types of fender, illustrated in figure 37, cover the range of choice normally available.

525. Fender pile systems employ piles driven into the sea-bed along the quay face. Impact energy is absorbed mainly by the bending of the pile. For high berthing loads the capacity is usually enhanced by the inclusion of a rubber block between the head of the pile and the quay structure and by connecting the piles with Longitudinal members to spread the load.

526. Hollow cylindrical rubber fenders are very convenient and economical, but because of their limited capacity for energy absorption are generally used on structures that can absorb high-impact forces. They are easy to install, suspended by chains or steel cable and are easy to replace. To cope with both horizontal and vertical movements of ships, they are normally installed diagonally. In ports with high tidal ranges, several rows may be needed. In some cases rubber fenders are placed between a timber or steel rubbing strip and the quay wall. As the coefficient of friction of the ship's side against wood or steel is less than it is against rubber, the longitudinal forces are greatly reduced. Various other types of rubber fender have been designed to act in shear, in torsion or in bending and in some fenders rubber and steel are bonded together to act as a unit in absorbing energy.

527. Gravity-type fenders are designed to transform the kinetic energy of the moving ship into potential energy by raising a weight. Three general types have been developed which act by a system of cables, by a pendulum or by trunnions. A typical example, of the many which have been used, is that in which a large concrete block is suspended below the quay deck by two pairs of cables. The front face of the block, suitably faced with a timber rubbing strip, acts as the berthing face. The impact of the ship forces the concrete block to swing backwards and upwards until the ship has come to rest.

528. Pneumatic fender systems are pressurized airtight devices designed to absorb impact energy by compression of air inside a rubber envelope. One type floats freely but is tethered by ropes between the quay and the ship. Another type is the fixed air block fender, which has high energy absorption and consists of an enclosed rubber cylinder into which air is pumped. The assembly is bolted to the quay wall face.

529. Torque fender systems are designed to absorb the berthing energy by plastic deformation of metals in torsion. A mild steel torsion bar is used in such a manner that it is twisted by the motion of the ship against the fender.

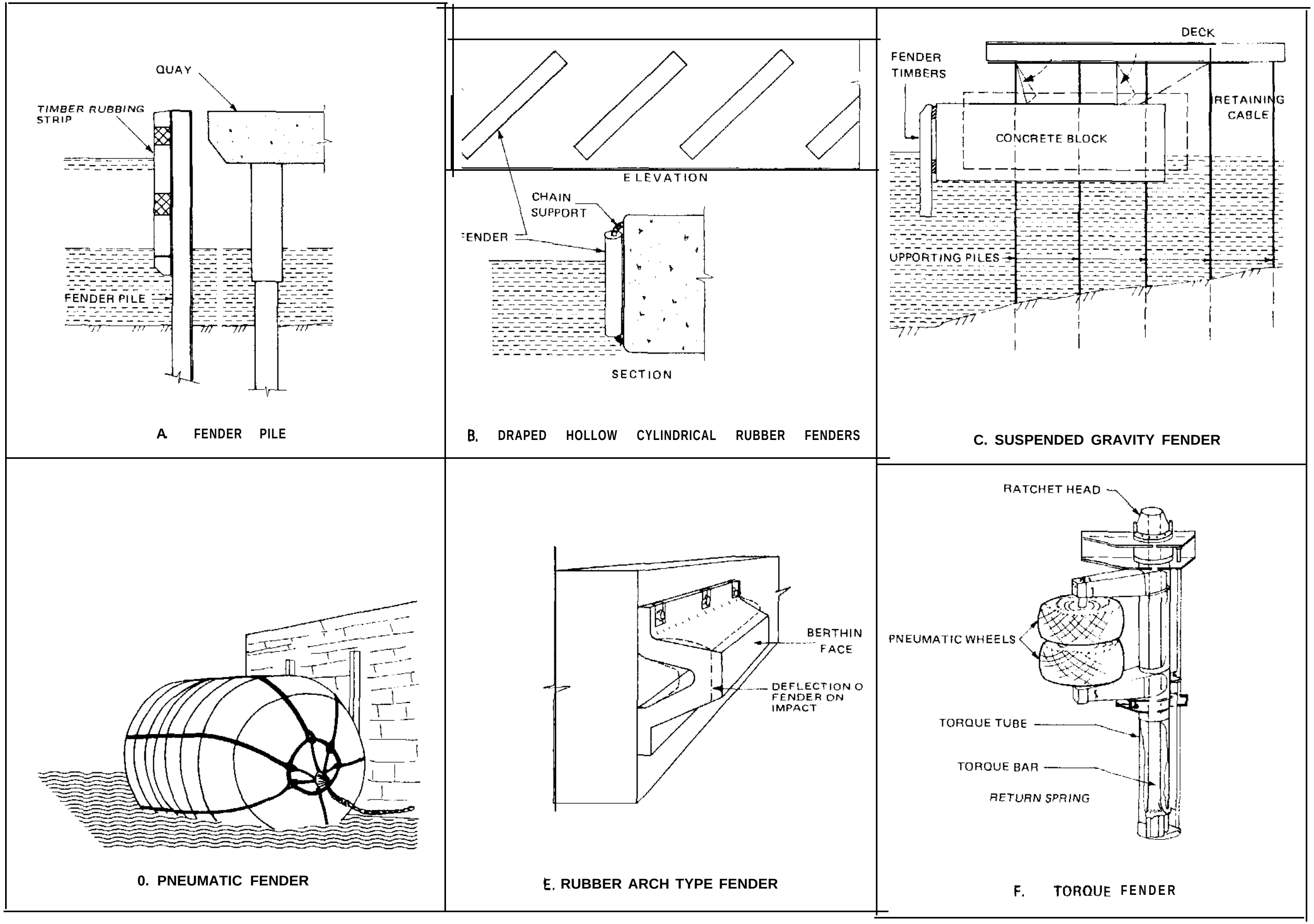
G. Engineering cost estimates

530. During the earlier stages of a port development project, the engineering studies aim at identifying possible solutions and providing sensible estimates for their capital and maintenance costs. As a project develops, the degree of confidence in the estimates will increase as further knowledge becomes available and more detailed design work is carried out. Contingency allowances should be made at each stage, decreasing as confidence increases. Only when the work is completed will the final cost be accurately known. A pretence of great accuracy in the early stages should be avoided, and usually a tolerance of ± 20 per cent is perfectly satisfactory for the economic evaluations, bearing in mind that traffic and shipping forecasts cannot be any more precise.

531. The engineer should, however, seek to make estimates for alternative schemes easily comparable. It is often necessary to provide the economic appraisal team with estimates for alternatives which may not have been foreseen at the outset when planning field investigations. An example of this is when the option of expanding an alternative port arises. In such cases the engineer may need to do a rapid investigation of another site, without time to carry out a full field survey and design appraisal. The engineer should not place a restriction on the number of alternative concepts and designs which the team generates, but should avoid embarking on too detailed an investigation before the list of options has begun to be narrowed.

FIGURE 37

Examples of rendering systems



532. The basis for estimating engineering costs must be defined by the project team, and it is frequently decided that present-day costs and benefits will be used throughout. Nevertheless, the engineer may need to assess inflation rates in construction costs, for use in the joint appraisal as appropriate.

533. The division of the cost estimates into proportions of local and foreign currency and taxation elements is often needed, and the engineer may obtain guidance from the economists. Nevertheless, these elements can be seriously influenced by whether a locally based or foreign contractor is chosen. The engineer must therefore at an early stage acquire a sound knowledge of the national construction industry and consider whether the project would be within its competence, or whether an international contractor would be needed, with a larger foreign exchange requirement.

534. It is important to consider the effect on cost estimates of different construction phasings. For example, an expanding port may require further break-bulk berths in future years. To build, say, one berth every two years might appear a theoretically attractive solution, but in practice a proper study of the relationship between costs and phasing may indicate that these berths should be built at the outset, with a further phase of berth-building commenced about five years later. A significant feature here is that mobilization costs would be much the same irrespective of the number of berths to be built under any one contract. Estimates for project alternatives are therefore best produced in two parts: the direct cost for each element of a package, and the mobiiization cost for whichever package is being considered added separately at the end. This facilitates the manipulation of a variety of alternative estimates in the economic comparisons.

Chapter VIII

ENVIRONMENTAL AND SAFETY ASPECTS

A. Introduction

535. Any port development project requires that port authorities should take into consideration economic and technical aspects. to which should now be added environmental and pollution prevention. The latter. which are sometimes much more exacting than technical and economic considerations, can lead the planner to alter the project.

536. The transport, the handling and the storage of dangerous goods in a port area require that special measures be taken to protect the port facilities and to ensure the safety of the people working on the port's premises or in the vicinity. Usually these measures concern port-operational aspects and involve the enforcement of safety regulations. However, within the context of the planning of a port infrastructure, one also has to consider the risks created by dangerous goods that may pass through the port and to adapt the port plan to these risks where possible.

B. Environmental aspects

1. General

537. Environment can be defined as all the physical, chemical, biological and social factors likely to have an effect directly or indirectly, immediately or later, on all living beings. Any blow to this system is defined as an impact and environmental surveys aim at finding, estimating and dealing with these impacts. When drawing up a port master plan, one should allow for all these aspects.

538. Developing a port can entail substantial alterations in the physico-chemical and biological characteristics of the marine medium. For instance, the consequences could be:

(a) A reduction of the fishing stocks through the destruction of the spawning grounds or the nurseries;

(b) Contamination or destruction of the shellfish breeding beds;

(c) A deterioration of the bacteriological content of the sea, which can threaten recreational activities such as swimming and boating.

539. Modern port operating techniques require the port planner to provide for large areas behind the quays. Port construction will usually result in the destruction of the existing vegetation on these land areas. In addition. port operations can create waste, whose storage should be controlled to avoid nuisances.

540. A port complex can be associated with an industrial area which sometimes generates air pollution (sulphur dioxide, nitrogen oxide, hydrocarbons, dust) that cause inconvenience to people and damage to vegetation and buildings. Furthermore, noise is a form of pollution which, depending on the level, can vary from annoyance to physical damage to hearing.

2. Impact surveys

541. The preparation of the port master plan will require a number of studies that will determine the requirements on one hand and the characteristics of the site on the other to make the project match with the site. The field survey should also take into account all environmental characteristics to gauge the impact of the project. The impact survey must be integrated into the technical and economic surveys and be concerned with the sea, land and atmosphere.

542. For the sea, the survey will determine the physico-chemical characteristics, especially the grade of the water. A review of biological resources will be undertaken to prepare a list of all benthic resources, spawning grounds, nurseries, shellfish breeding beds and primary production areas.

543. A special survey will be required to assess the dredging impact, to select the dumping grounds for dredged products and to control the damage. The disposal of dredged material at sea is regulated internationally under the Convention of 1972 on the Prevention of Marine Pollution by the Dumping of Wastes and Other Matter[13]. The dredging of a new area poses more problems to the marine environment than maintenance dredging in an environment that has already been disturbed. Dredging could have such far-reaching effects as destruction of the habitat of benthic species. alteration of salinity, change of currents and increase in turbidity.

544. A comprehensive review is required of the fauna and flora on the land and their characteristics. The hydrological conditions of the site will need investigation to determine the effect on the water table of the excavation of docks and channels and the possibility of the introduction of salt water into surrounding agricultural lands.

[13] Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London, 29 December 1972) [IMO publication. Sales No. 76.14.E].

3. Operational hazards

545. Spills or uncontrolled release of dangerous and harmful substances carried in bulk or in packaged form, such as LNG, LPG, oil, toxic substances and radioactive substances would give rise to serious safety and health hazards as well as harm to the marine environment. Ports should be provided with adequate equipment and materials for combatting pollution in the case of emergencies. Thus, an analysis of pollution risks in the port area arising from maritime casualties should be carried out. The analysis will also determine the selection of berth sites to minimize the environmental impact arising from accidents to ships.

546. Port planners should take into account the requirements of the International Convention of 1954 for the Prevention of Pollution of the Sea by Oil[14] and of the International Convention of 1973 for the Prevention of Pollution from Ships[15]. Regarding the provision of adequate facilities to receive and treat wastes from ships, planners should ensure that the necessary installations are supplied; an IMO publication on the provision of reception facilities in ports could be used as a guide for assessing such needs[16].

4. Port industrial areas

547. The planning of a port industrial area must also take into consideration environmental and pollution prevention aspects. Particular attention should be given to liquid and gaseous discharges. A survey of the projected growth of the industrial zone should be linked to an estimation of the quantity and quality of the pollutant discharge. This would be followed by a survey on the absorptive capacity of the receiving area? for example, inland drainage basins or the open sea. The surveys will set the dumping standards to be laid down for industrial companies.

548. Although the physico-chemical treatment of industrial liquid effluents at the plant outlet is usually efficient, it is often desirable to consider the establishment of an effluent-collecting system in the master plan with a common effluent and sewage purification plant.

549. To control the effects of atmospheric pollution, works may be planned with respect to the prevailing winds and to the relative location of urban areas. When there is a large concentration of industries, a monitoring system of atmospheric quality can be set up in strategic locations.

550. The question of industrial refuse should also be dealt with at the master planning stage. The planner can reserve areas of limited use for future dumping sites. Consideration could also be given at this stage to the establishment of a conditioning or disposal plant for special refuse.

551. Thermal pollution can be limited by setting a maximum temperature of the discharge of cooling water. The use of sea water for cooling can result in changes to its chemical and physical properties and this water, when discharged, can have positive or negative effects on all organisms living near the discharge.

552. Finally, the planner should draw up specifications outlining the obligations of industrial companies in the environmental field. They will include regulations on the treatment of liquid and gaseous effluents. The landscape development and the industrial environment can also be subject to regulations to assure as attractive as possible a visual aspect.

C. Dangerous goods

1. General

553. National or international regulations give different definitions of dangerous goods. Most of the time they refer to lists of substances regarded as hazardous. The lists which are most commonly used are:

(a) The IMO International Maritime Dangerous Goods Code (IMDG Code)" in which dangerous goods or substances are divided into nine classes of decreasing risk (class 1 being explosives);

(b) The list of substances numbered by the UN Committee of Experts on the Transport of Dangerous Goods'".

554. Generally, a dangerous substance can be defined as any substance that threatens the safety of people and of facilities by fire, explosion, combustion, toxicity, infection, radioactivity, corrosion or pollution. Also, any substance that presents risks during its transport in case of shock, contact with water or air, or contact with other dangerous substances is classified as dangerous. The term also includes an empty receptacle, portable tank or tank vehicle which has previously been used for the carriage of a dangerous substance, unless such receptacle has been cleaned and dried or has been securely closed, if the nature of the previous contents permits this with safety.

555. Planning for the reception of dangerous goods in a port can be summarized as follows:

(a) Take an inventory of the risks involved;

(b) Investigate the preventive measures to take to reduce the risks;

(c) Consider the measures and actions to be taken in case of an accident.

[14] International Convention far the Prevention of Pollution of the Sea by Oil (London, 12 May 1954), amended in 1962 and 1969 (IMO publication, Sales No 81.06.E).

[15] International Convention for the Prevention of Pollution from Ships (London, 2 November 1973) (IMO publication, Sales No. 74.01.E).

[16] IMO, *Guidelines on the Provision of Adequate Reception Facilities in Ports*, 4 parts in 3 volumes (Sales Nos.: Part I, 77.02.E; Part II, 80.03.E; Parts III and IV, 78 12.E).

[17] The IMDG Code (1977 edition including amendments 1-13) is published in 4 loose-leaf volumes (Sales No. 77.01.E). The IMO also publishes annual supplements including amendments to the Code.

[18] *Transport of dangerous* goods, 3rd rev. ed. (United Nations publication, Sales No. E.83. VIII.1).

2. INVENTORY OF RISKS

556. The handling of dangerous goods at general cargo terminals generally cannot be avoided, as this operation is part of the normal flow of goods through the port. In most ports the general cargo terminals are close to built-up areas.

557. The greatest risks for the population centres are associated with handling of poisonous gases and liquids. The introduction of special tanks and containers has significantly reduced the accident rate as compared to the use of conventional drums and crates. The storage of flammable substances also creates a risk for the port area. In general, the area affected by accidents with dangerous goods in the general cargo trade is small.

558. When dangerous goods are handled as bulk cargo. the port must be designed to receive the ships at special berths with handling equipment and shore-based storage facilities specially planned for the dangerous products. The nautical risks associated with collision or stranding can be catastrophic for transport of dangerous substances in bulk.

559. The loading and unloading operation of dangerous goods in bulk is more accident prone than general cargo because of the absence of protective packaging. Cargo-handling and safety devices need therefore to be designed with the utmost care. Risks to be considered with the bulk storage of dangerous goods in the port area are:

(a) Natural events: earthquakes, floods. storms, lightning;

(b) Human factors: operating errors, aeroplane crash, sabotage. accidents in adjacent industries, fire;

(c) Deterioration of the storage system through use or age.

3. PREVENTIVE MEASURES

560. Accident frequency can be reduced by the introduction and strict enforcement of codes, guidelines and procedures for all parties concerned. The guidelines, will refer to the packaging. handling and storage of the goods and should be based on study and experience. There is a wealth of regulations. particularly from the IMO, that stipulate structural and operational safety standards and procedures applicable both to ships and shore facilities. The need exists for excellent communication between ship and shore to co-ordinate activities during loading and unloading operations.

561. One of the most common measures in port planning is to set safety distances that separate the handling and storage of dangerous goods from other port areas. The safety distances to be maintained are subject to the quantities and the properties of the dangerous substance involved and tend to be greater for bulk handling and storage than for packaged products.

562. While no firm and comprehensive guidelines exist for these safety distances, order of magnitude figures may be given for specific products. For the handling of crude oil and gasoline. an explosion danger zone (with an explosive gas atmosphere) will be created whose size will depend on the rate of loading and unloading. The minimum distance to be maintained from a crude or product berth to offices, general cargo terminals or passenger terminals is around 1.000 metres. For LPG. which is heavier than air and very explosive, the minimum safety distance to vulnerable areas is estimated to be in the 3.000 to 4,000 metre range. LNG, due to its less explosive nature, would require a smaller safety distance than LPG.

563. Nautical aspects were discussed previously in this handbook. However. crude carriers and liquefied gas carriers are amongst the biggest ships a port may have to receive and the dangerous nature of their cargo calls for:

(a) Ample space for safe navigation within the port area;

(h) Adequate navigational aids: pilotage, towage and line-handling facilities;

(c) Traffic restrictions during navigation of these vessels such as limited times and tidal wmdows for entering and leaving port, or one-lane traffic;

(d) Location of berths to make the collision with other vessels impossible.

564. Specific safety measures for packaged dangerous goods are mostly in the operational and not the planning field. Certam dangerous goods, for example explosives, may be restricted to berths which are reasonably isolated and near the port entrance to allow ships to be towed out in case of fire. Often mooring buoys may be used for the transfer of explosives and other dangerous cargo to lighters outside the porr area.

565. Crude oil and product terminals should be grouped together as much as possible in reserved sections of the port area, as should liquid gas terminals. Whenever feasible. traffic lanes should be separated for petroleum vessels and other traffic. It is preferable to locate berths in distinct basins which can be easily closed by floating booms in case of spills or other accidents.

566. Dangerous goods as general cargo can be stored by separation into limited lot sizes. Alternatively, a special area or shed for the storage of all dangerous cargo may be planned. Such areas will comply with special standards of construction such as fire-proof materials, a large number of access points and special fire-fighting facilities.

567. For bulk cargoes there may be a limitation on lot sizes and on separation of these lots. For example, this may be done by the construction of an embankment around individual tanks containing dangerous liquids. As many terminals are owned or rented and operated by private or semi-governmental companies, the port authority will have to set safety regulations and check that they are followed.

568. Finally, the port authority will require a regulation for the declaration of all dangerous goods entering the port area. In addition, an easily retrievable information source which gives the properties of all dangerous goods is essential.

4. PROVISIONS FOR ACCIDENTS

569. Provisions for nautical accidents consist mainly of means for life saving, assistance in case of collision or stranding, tugs, fire-boats, and lifeboats. A whole range of pollution control equipment. such as dispersants, booms and recovery vessels, may have to be provided.

570. For onshore accidents the port authority needs to provide:

(a) The necessary infrastructure (fire hydrants, telephone lines, access routes, fire-fighting equipment and medical centres);

(b) Manpower trained in fire fighting, rescue techniques and first aid, with access to information on dangerous substances;

(c) A centre for the co-ordination of accident handling which may well be combined with a general port co-ordination centre.

5. COST CONSIDERATIONS

571. The consideration of environmental, pollution prevention and safety aspects in the planning of a commercial port may present substantial constraints and may lead to noticeable alterations to the plans. The alterations will be likely to involve a rise in the cost of the development. However, by considering these aspects, the planner will define works which will fit in harmoniously with the site and which will usually be easier to operate and will provide higher safety standards. The ignoring of these aspects can lead to higher operational costs and severe operating problems.

Chapter IX

INLAND TRANSPORT

A. The system as a whole

572. The importance of the port planner's looking beyond the port boundaries to the next transport leg has been emphasized in other chapters. He will often have little authority in planning that leg, but should always consider how goods are to be moved to and from the port and should try to influence the inland transport plan accordingly.

573. The starting-point is to consider what the modal split of the traffic in question will be, i.e.. what proportions will come and go by road, by rail and by waterway. This will often require a sample of existing consignments to be examined. In judging whether the modal split is likely to change, the main factor will be the extent to which waterway frontage, trunk road access and internal rail sidings are available at the shippers' premises (factories, warehouses or mines). These facilities change very slowly in view of the large investments involved.

574. For each main traffic class (e.g. break-bulk cargo, containers, ro/ro cargo and each of the principal bulk commodities) it is next necessary to forecast its own modal split and to link this with the future distribution system. In each case the possibility of bottle-necks in the system is a primary concern. The system can be considered as a series of connected tanks with taps which have to be shut off when any one tank becomes full, as illustrated in figure 38.

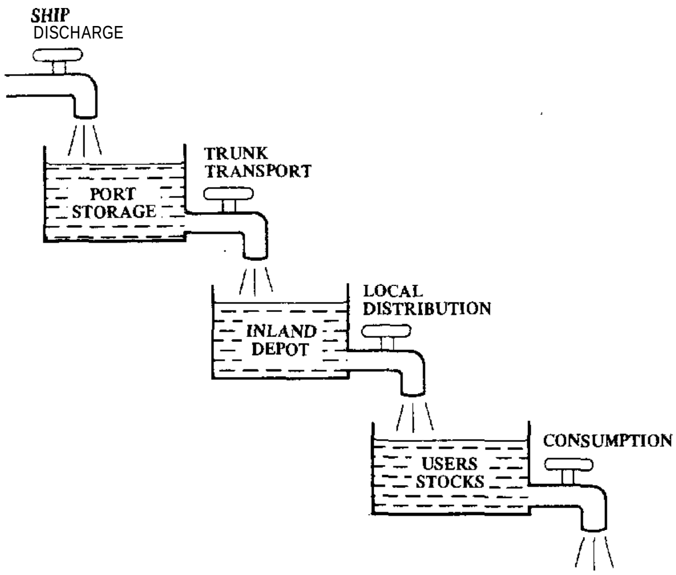
575. In accordance with this figure, if any one of the stores (port storage, inland depot or users' stocks) becomes full, then in the short term the normal solution is to stop the flow into it. This soon causes the preceding store to fill up. As regards the port import storage, port management has difficulty in turning off the ship discharge "tap" when there is a hold-up in the system, and consequently the port feels the overload. In the longer term, the solution may be to increase the size of the inland depots, but there is not often the possibility of increasing the outflow from any store since this would need to be passed down the line and can only end with increased consumption, which is not a transport solution.

576. Such diagrams illustrate the chain reaction principle involved, but in reality there will normally be a branching network of depots and transport connections, all of which taken together act to clear the port storage, as shown in figure 39. The total tonnage capacity of all these must be made sufficient to handle the total ship discharge rate.

577. **In** the case of barge transport, there may be the option-particularly if the barges can be manufactured locally and cheaply--of allowing the barges themselves to act as temporary storage. For export cargoes awaiting ships, this can be an economical solution compared with the cost of double handling through export warehouses. This approach is not likely to be possible with road or rail vehicles, where the cost in foreign currency terms is much higher per ton carried.

FIGURE 38

The import flow



B. Trading practices

578. The second "tap" shown in figure 38, which controls the flow of goods out of the port storage, is to some extent under the control of the port management, Import consignments are normally cleared from the port only when:

(a) All duties and charges have been paid;

(b) Documentary formalities have been completed;

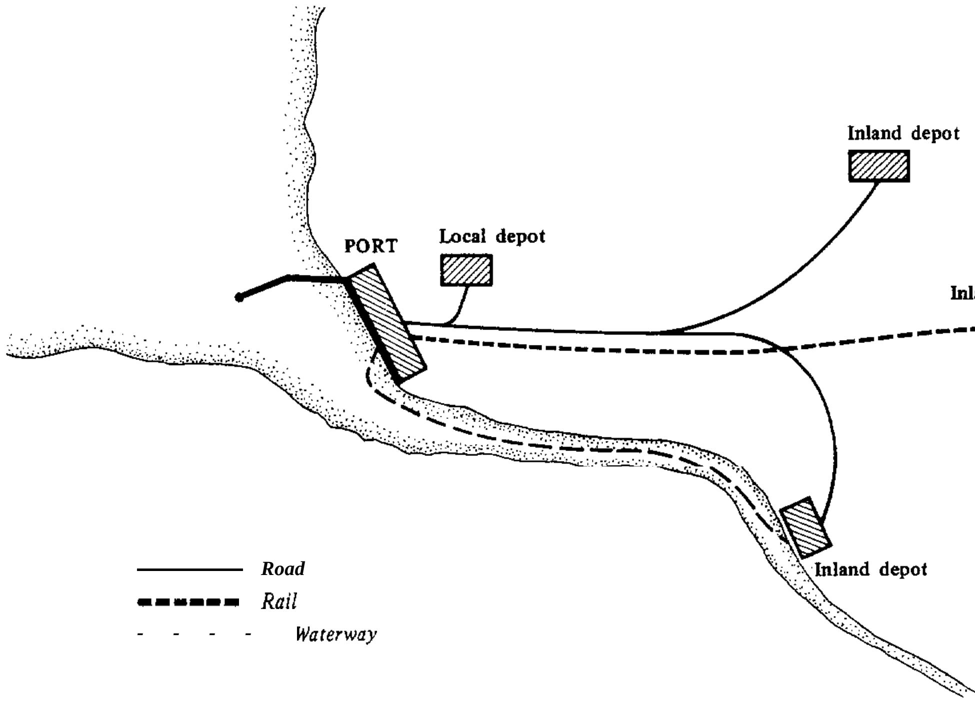
(c) Customs clearance has been given;

(d) The consignee wants the goods.

The port development plan should include as one objective the encouragement of better practice in all these matters.

FIGURE 39

Inland transportation network



579. Ideally, the physical flow of goods should never be slowed down by delays with respect to finance or paper work. It will be a long time before this ideal can be achieved, but there are several actions that the port and the customs authority can take jointly:

(a) Agents can be required to provide a financial guarantee which permits consignments to be cleared before dues are paid. A single monthly invoice can then be sent for payment. The introduction of such guarantees or deposits can also help by limiting the number of such authorized agents and so concentrating the clearance operation in fewer and more efficient hands.

(b) A routine organizational study of the flow of documents will often show up possibilities of substantial simplification. Fears of reductions in clerical staff can be to some extent offset by the need to transfer staff to the more useful control function mentioned below.

(c) Customs working hours and staffing levels are very often too limited to handle the work smoothly. Steps may be possible either to increase the customs effort or to reduce the workload of customs staff by limiting the sample of goods inspected or opened.

(d) Strict enforcement of the regulations concerning the transfer of goods to long-term warehousing after a limited period, with reasonable storage charges in the warehouse, can encourage consignees to clear their goods more quickly from port storage.

580. It is unfortunate that this area of the operation is sometimes subject to malpractices, for example, in the form of illegal payments to ensure priority of completion of the formalities. Managements may need to be vigilant in this respect, and it may be advisable to introduce systematic methods of recording the progress of the consignment documents, either manually or with electronic data processing, purely to avoid such practices. This control function can be an important responsibility of a special department with adequate clerical staffing.

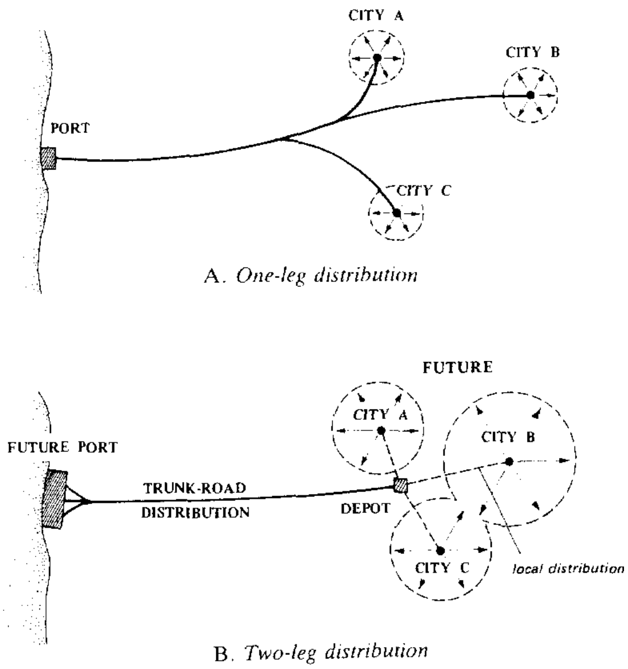
C. Inland transport capacity

581. When checking that proper provision is being made for the inland transport capacity needed to match the forecast port throughput, the port planner should look both at the vehicle and barge fleet and at the route capacity required. Both of these are heavily dependent on the inland distribution pattern.

582. It is not sufficient to calculate the number and type of vehicles and barges which will be needed per day to bring or take away the daily loading and discharge tonnages. This figure will show what the handling, marshalling and administrative needs are, and are thus a first step in planning the layout. But they give little indication of the transport problem because they leave out the vehicle journey time. For example, to clear 1,000 tons a day to the adjacent city area may call for about 42 local delivery vehicles of b-ton capacity fitting in an average of three round trips a day, whilst to clear the same 1,000 tons to an inland depot 600 kilometres from the port may call for about 200 vehicles of 20-ton capacity taking four days to make each round trip. The distribution pattern and the route capacity determine not only the number of vehicles and barges needed but also the type of vehicle and barge and the port handling facilities. The number and type of vehicles and barges should be roughly calculated, and the regional transport planner asked to confirm that provision of the vehicle fleet is included in the regional plan. The daily road, rail and barge traffic forecast for the port and the design surface loadings can also be discussed.

FIGURE 40

The effect of introducing intermediate depots



A. *One-leg distribution*

B. *Two-leg distribution*

583. When looking several years ahead it should be remembered that the growth in traffic volume combined with the spread of industrial and urban areas are very likely to cause basic changes in the pattern of inland distribution. One of the major effects, which has strong repercussions on the port, is the need to introduce intermediate depots to separate trunk-road transport from local distribution.

584. This effect is illustrated in figure 40. When there is a change from the one-leg pattern to the two-leg pattern, the type of vehicle serving the port is likely to increase in size and cost and will therefore demand faster servicing in port to match its shorter journey time in order to reduce unit costs. This is a similar trend to that in shipping.

585. Long routes tend to justify rail transport and in this case an option open to the transport planner is to introduce a third leg: this enables the port to load cargo on to road trailers. which are then taken to a railhead and carried by means of a "piggy-back" or "kangaroo" system using rail flatcars to the inland depot. In addition, this method removes pressure from the road network. This can be an economical system combining the best characteristics of short-haul road transport and long-haul rail transport. The port sees only the smaller. short-haul trailers. as shown in figure 41.

D. Vehicle access

586. Traditionally, general cargo berths have worked a mixture of indirect cargo (via the transit shed) and direct cargo (loaded or discharged direct to or from rail wagon or road vehicle at the ship's side). This suffers from certain drawbacks:

(a) The rail and road vehicle movements on the quay interfere with each other and with other operations;

(h) The rail track when not recessed causes circulation problems on the apron. which slow the movement of other vehicles and operating equipment;

(c) With the exception of large consignments of homogeneous cargo such as bags, the rigid planning of vehicle availability at the right time is difficult to maintain, with the result that direct working generally slows down the ship operation.

587. These problems have led to an approach which, although at first sight it appears restrictive, is more flexible and smoother in operation. This is to prevent any external vehicles' access to the apron for direct delivery. Through the introduction of a transfer system using, for example. tractors and trailers, to a temporary buffer area at the rail or road pick-up point, direct deliveries are still accommodated. The increased cost for transfer equipment is balanced by the improved working surface of the quay and the reduction in delays to ship working caused by the late arrival of vehicles. For berths dealing with large numbers of heavy loads to be lifted on to or from rail wagons, tracks flush with the apron surface can be utilized. Figure 42 illustrates the two approaches in which the alternative approach has a boundary beyond which external vehicles are not allowed to pass.

FIGURE 41

Combined road-rail hinterland distribution network

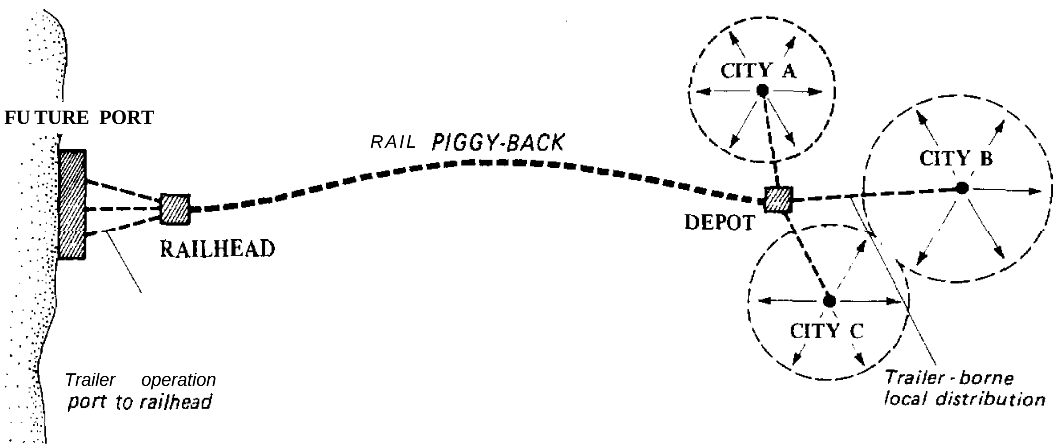
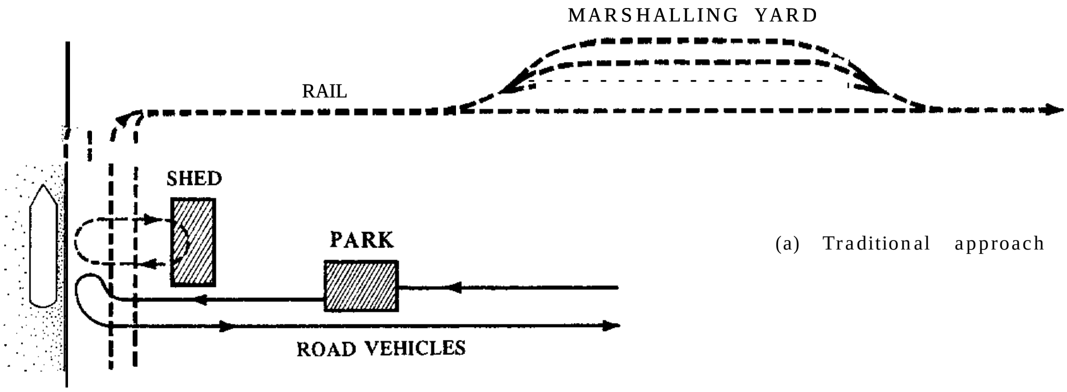


FIGURE 42

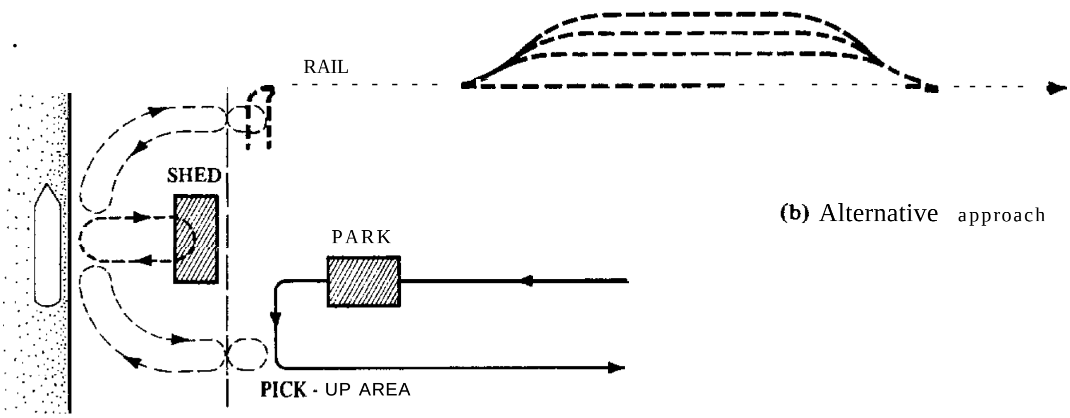
Limitation on vehicle access to quay

A. *Traditional approach*



(a) Traditional approach

B. *Alternative approach*



(b) Alternative approach

588. Another approach is to eliminate direct delivery by working all cargo through enlarged transit storage areas. While this alternative removes the problem caused by delays in the supply of direct delivery vehicles, the area requirements can be significantly increased as the transit time of goods will increase. However, this approach smooths the demand on hinterland transport and thus reduces the size of the vehicle fleet required to service the port.

589. The approaches eliminating direct delivery on the quay introduce double handling, but this cost is generally more than offset by the faster ship turn-round and the elimination of rail track, particularly in countries where labour costs are modest. They also introduce the need for additional tractor/trailer units, but these can be of a standard type and they will add flexibility to the operations.

590. In terms of labour requirements, the double handling introduced tends to involve a transfer of men from the quay apron to the transit area, rather than an overall increase in numbers. Furthermore, the transit area operation can make much better use of the labour since the operation can be closely planned instead of being dependent on improvisation owing to the unpredictable arrival times of vehicles and cargo, as in the traditional method.

591. This question of more systematic planning is fundamental to modern operations. Because the ship operation, which involves the need for intense working for short periods, is separated from the cargo arrival and delivery operation, the latter can go ahead more steadily, regardless of the peaks of ship demand. This has the important effect of reducing the size of the vehicle fleet required to service the port. In this more stable system, planned operations are possible without undue demands being placed on middle management.

592. There is a residual fraction of cargo on a break-bulk berth which, taken in isolation, would merit direct delivery either to rail wagon or to truck. Often this requirement can be overcome by resorting to overside operations to lighters. The cargo can then be taken to an older berth with the possibility of direct delivery. When this is not possible, the decision to accept the penalty of not working this cargo directly may be more reasonable than to make a change of system which would place a penalty on all the rest.

E. Through-transport systems

593. The principle of separating the ship operation from the onward transport operation applies with even

greater force to container and ro/ro operations. Although it would he attractive to the consignee. the transport vehicle should not be allowed on to the apron to pick up a load. Whether the unit load is for genuine through transport (pallets or a full container load (FCL)) or is a less-than-full container load (LCL) for discharging and re-routing in a container freight station. the transfer to and from the apron must be carried out under full port control using port vehicles-normally chassis, semi-trailers or straddle carrier-s.

594. In a new development there will be the opportunity to take this principle further and remove the container freight station from the port area to a point better situated for distribution to the urban area, thus freeing valuable port land. as illustrated in figure 43. This applies particularly when the development is for a traditional city port. When the proposal concerns the establishment of a new port it is likely that the port will in any case be located away from urban development so that the container freight station can again be located in the port area.

595. In the ideal through-transport arrangement, the port has no role as a storage or sorting point and is concerned only with the transfer of unit loads from one vehicle to another. All formalities can then be completed away from the port area. at a cleat-ante depot inland. as close as possible to the final consignees. In practice this ideal is rarely attainable in developing countries. since the proportion of FCLs is low, and traditional commercial practices often demand re-consignment at the port. even for ongoing FCLs. Even when an inland clearance depot is set up, it may be difficult to persuade agents to transfer their offices from the port. and it will also be necessary to solve the labour problems which arise from conversion of stevedores into inland clearance depot staff.

596. One specific type of development can readily use the inland clearance depot concept. This is where the coastal region is not a centre of production or consumption, so that the port's role is purely that of a staging-point en route to an inland region. In that case there will he many advantages in transferring as much of the operation to the inland point as possible particularly when the coastal climate is adverse.

F. Technical specifications

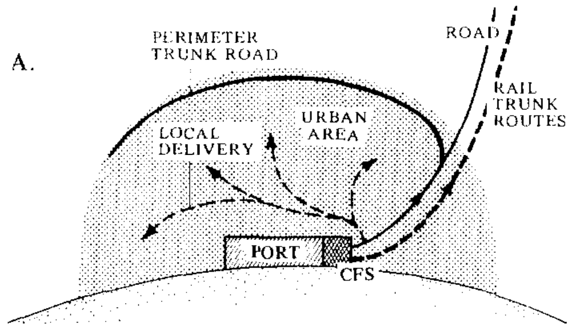
597. The warning on the danger of accepting manufacturers' claims without careful study of local technical requirements. which are given in other chapters, apply equally to land transport vehicles. There have been serious problems caused by purchases of vehicles unsuitable for the local climate. terrain and road surfacing. For example, roads in many developing countries necessitate stronger suspension if trucks are to operate without excessive breakdowns. In any case. the shortage of maintenance facilities on a long route can justify the setting up of a series of special roadside maintenance depots and a co-ordinating organization to control them.

598. In the case of rail, the future freight train is likely to be heavier and faster. Existing rolling-stock may need replacement, track may need upgrading and

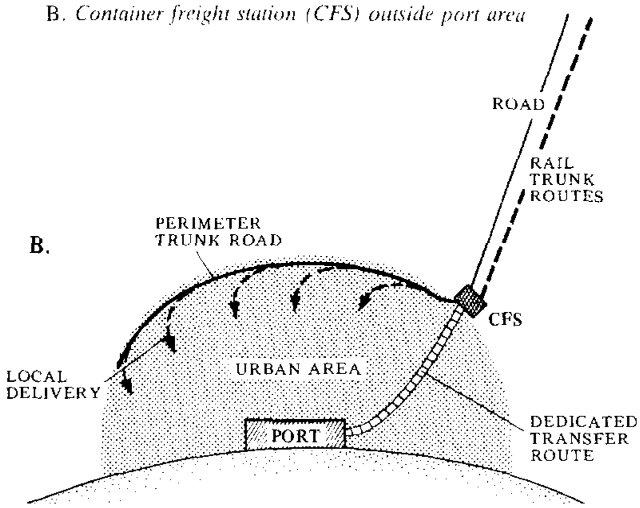
FIGURE 43

Comparison of locating container freight station within port area or outside it

A. *Container freight station (CFS) within port area*



B. *Container freight station (CFS) outside port area*



locomotives will need to be substantially more powerful. The port planner should ascertain whether appropriate specialist advice has been obtained in order to ensure that the design port loadings are accurate.

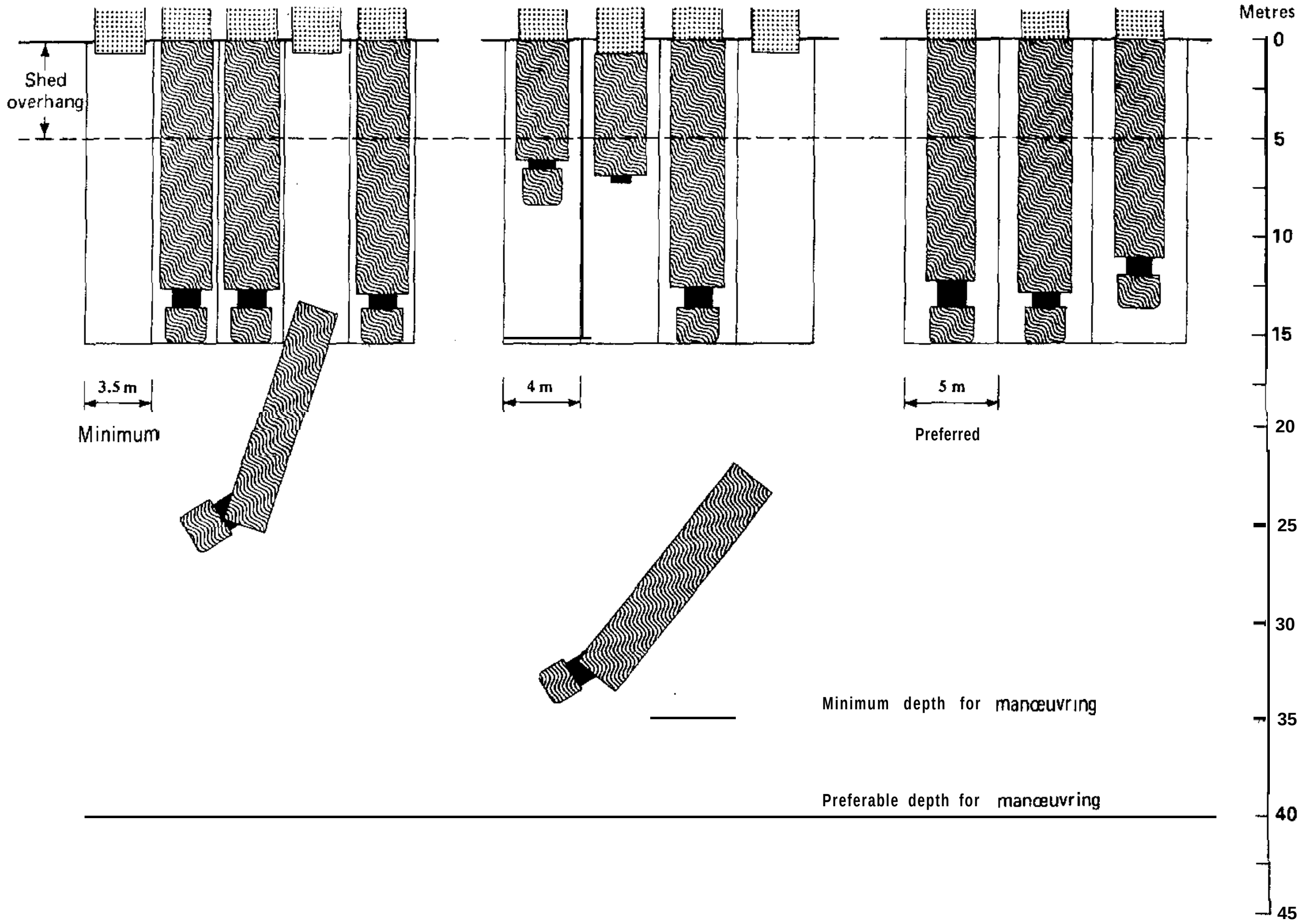
G. Information systems

599. The co-ordination of inland transport movements with consignment movements within the port area and with ship operations can be a difficult task. To keep down the cost of tying up expensive vehicles, to speed the movement of cargo and to make good use of port storage, it is advisable to give special attention to the method of transferring information about cargo bookings, transport loading and ship itineraries. The establishment of a vehicle movement information centre at the port can be a valuable means of improving the road/sea co-ordination.

600. Where the road vehicles are in short supply. or where there is limited parking space, useful gains can be made by setting up a vehicle booking centre. This can be an office with sufficient telephone facilities to permit operation of an appointments system whereby hauliers collect specific consignments during specific time-slots. so that waning is minimized. Priority in entering the berth area is then given to trucks arriving within the appointed time-slot (e.g. a half-hour period).

FIGURE 44

Loading bay configuration for road transport



H. Port access gates

601. It will normally be fully justified, to help in reducing the cost of pilferage and major thefts, to provide a substantial security fence plus a patrolling security service under port authority control. Such fences must be maintained in good condition to be effective. The number of access gates should be reduced to the minimum and a rigorous gate pass system should be imposed. Staffing of the gatehouse should be adequate to provide several parallel check-out points, sufficient to keep vehicles moving without too much interruption while exit permits are checked. In case of justified suspicion or improper loading, the vehicle should be removed from the exit into a special bay foreseen for this purpose next to the gate. Here the vehicle may be closely inspected or reloaded without impeding the movements of other trucks. A separate gate may be provided for the entry and exit of empty vehicles and private cars.

I. Loading bays

602. Loading bays provide a covered transfer area where goods requiring covered storage are loaded on to or unloaded from road vehicles. A sufficient number of loading bays should be provided to handle peak traffic flows, and loading bays should be adaptable to future conditions. The covered storage should have an overhang of about 5 metres to allow work to proceed during bad weather. The bays require a separate approach road within the site area, a marshalling area where trucks assemble before moving into the loading bay position, and a truck parking area or a secondary manoeuvring area for trucks to wait prior to being directed to specific loading bays. The parking areas should be supervised by a traffic office and be used for trucks waiting for document processing.

603. Raised platforms are very useful and should be used in conjunction with a platform levelling device, as truck bed heights vary from type to type and between unloaded and laden conditions. Figure 44 illustrates typical raised loading bay layouts for B-metre articulated vehicles. The additional 5 metres reeommended in the depth of the marshalling area permits accelerated manoeuvring by allowing articulated vehicles to pass each other.

J. Platform levellers

604. The correct choice and application of a platform levelling device is necessary for efficient operation. The proper choice will increase the numbers of vehicles handled and the pallet and fork-lift truck bat-

tery life, and reduce operating equipment tyre bills. The length of the platform leveller plate depends on the height differential between the vehicle and the platform. The gradient should never exceed 1 in 10. The leveller should be 1 .8–2.1 metres wide and have a non-skid surface. There is a large variety of platform levellers on the market, and expert advice should be obtained when making a selection.

K. Industrial doors

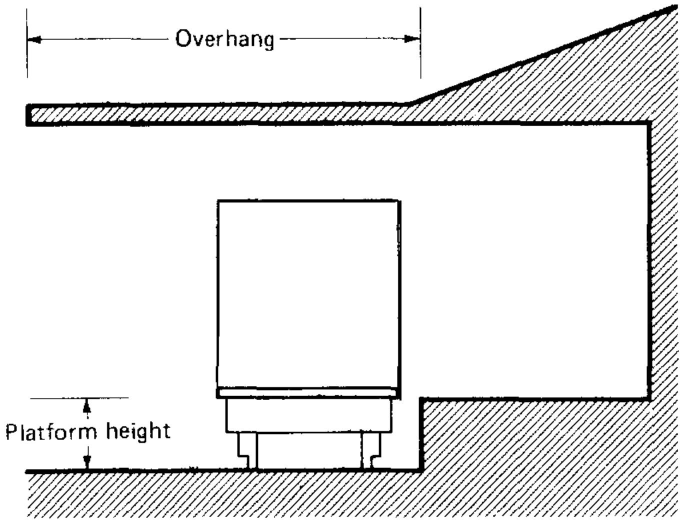
605. In addition to providing access to storage buildings, doors have to provide security and weather protection. They can be sliding. sliding-folding or vertical rolling and are normally made of steel, aluminium or timber. For power-operated doors, manual provision for operation should be provided in case of power cuts.

L. Rail loading bays

606. Where possible, loading bays should be constructed so that either road or rail vehicles can be used, for example by recessing the rail tracks to create a flush surface and allowing sufficient clearance for rail waggons beneath the shed overhang. If this approach is not possible, part of the transit shed loading bays will have to be dedicated to rail traffic. The local rail authorities should be requested to supply the information necessary for the designing of the platform. An overhang should also be provided to minimize delays due to inclement weather. Levelling devices should be used to adjust for variation between wagon platform heights. A typical rail loading plattorm is shown in figure 45

FIGURE 45

Typical rail loading platform



Chapter X

MAINTENANCE AND EQUIPMENT POLICY

A. General considerations

607. The standard of maintenance in ports must keep pace with the demands of modern plant and equipment. There are few ports in developing countries which have managed to avoid accumulating a permanent pool of equipment awaiting repair. In some cases the reactivation of such equipment would give the biggest single gain in performance that management could achieve.

608. Good maintenance is not cheap, and needs to be considered at the planning stage. Substantial sums need to be provided for workshops. for spare parts, and for ongoing maintenance. This is an extra expense but a necessary investment if the port is to function properly.

609. The care of civil engineering structures as well as of buildings and equipment. both fixed and mobile, must be considered. The various kinds of modern handling equipment used in ports. and particularly the larger items, are naturally expensive, and the desire to minimize capital outlay often results in insufficient consideration being given to maintenance costs and to the advantages of the standardization of equipment. Thus, designers are being pressed to design equipment for the lowest first cost, with insufficient emphasis on the costs of maintenance, and port engineers are under pressure to select the equipment with the lowest purchase price. Onlv by considering all the costs over the life of the equipment can the most economic selection be made.

610. Some of the mobile equipment used in ports is designed for use in the construction industry. The manufacturer tends to design for that industry's needs, producing equipment which can be used reliably and intensively (provided it is regularly maintained) for a short life before being jettisoned. Similarly, in the freight transport industry, trucks are frequently written off after as little as three years' intensive use. It is too optimistic to expect that. in ports in developing countries often far distant from the manufacturer's supporting services, and often in a more testing tropical environment, items of mobile equipment can be kept going for ten years or more. In the absence of experience to the contrary, ten years can be taken as the maximum useful life of much of the port's plant, while for more sensitive mobile equipment, such as fork-lift trucks, the maximum useful life is about five years only. For example, as regards fork-lift trucks, one port operator in a developing country experienced some 45 per cent down-time and in some areas of the port found it necessary to keep a complete second set of vehicles as spares. The average life of a unit was only two years. In this particular instance the fork-lift trucks spent a considerable proportion of their time travelling with their loads to and from the storage area.

611. There are two alternative policies for equipment selection: either ports must, as suggested above, accept short-life equipment and make regular provision for its replacement, or they must demand more robust and long-lived equipment for their own special needs. It is noteworthy that certain major European ports insist on the special strengthening and redesign of equipment to suit their own needs, and do not normally accept standard models. Ports that need only a limited amount of equipment or do not possess the necessary expertise are strongly advised to call in a specialist mechanical engineerwho has spent many years in the maintenance of port equipment.

612. Among the factors to be taken into account in selecting equipment are the following:

(a) The demands that will be placed on the equipment in terms of utilization;

(*b*) The standard of driver training;

(c) The possibility of buying robustness by using equipment of a higher rating than the job would otherwise demand:

(d) The general ease of maintenance:

(e) The choice of a design appropriate to low labour cost and high cost of foreign exchange, whenever possible; for example, traditional bearings fitted with a grease nipple may be preferable to sealed pre-packaged bearings which, although they need no regular greasing, have to be renewed every year.

613. On large items of specialist equipment such as ship-loaders and unloaders, together with their associated extensive conveyor systems, provision must be made for preventive maintenance to be carried out on an inspection basis. For example, once it is decided what needs to be inspected and at what frequency, a definite sequence for the inspections must be established. Any corrective attention needed should be given by the inspector concerned during the shut-down period, or, where there is duplicate equipment, when the standby equipment is running. Any equipment needing major repair should be removed to the workshops and a complete unit should be available for fitting into position. Another form of preventive maintenance which has been used is a replacement policy. A decision is taken from previous records on the length of economic life of all parts subject to wear, and they are replaced when they reach that age, irrespective of apparent condition. For example, it may be considered more economical to replace all the lighting lamps at once rather than having an electrician on constant patrol to replace faulty lamps. It may similarly be considered better to replace all fuses after a certain period of time has elapsed.

614. On mobile equipment. preventive maintenance takes the form of a regular servicing schedule. Spare units have to be provided in order that a complete unit can be taken out of service while it is still working and inspected under ideal conditions in a properly equipped workship. Broadly speaking, the maintenance of mobile equipment falls under the following three headings:

(a) Lubrication and cleaning. to prevent wear and corrosion;

(*b*) Adjustment. to keep the equipment in the condition for which it was designed;

(*c*) Checking. to replace worn components before they fail.

B. The central workshop

615. As major repairs and overhauls will have to be made to a wide variety of equipment. the central port workshop will require layout planning in order that work can be completed and equipment returned to service with the minimum delay. A few salient points should he noted. For example. the workshop should he divided into mechanical and electrical sections and, when sophisticated equipment is beginning to be used, a small specialist electronics section. The mechanical section should include some provision for the fabrication of light structural steelwork. pipework and plating. The main hay should have several entrances and be serviced by an overhead travelling crane of a capacity to suit the largest piece of machinery! to he handled. An adequate area for benchwork should he provided with easy access to the main bay hut not covered by the overhead crane. In addition, the following will be needed:

(a) Sets of special tools for each range of equipment to he serviced;

(*b*) A separate machine shop with adequate lifting appliances, with at least one lathe being able to turn the largest component;

(c) A separate section to deal with mobile equipment with inspection pits and hydraulic lifts;

(d) An area with the appropriate equipment for the testing and certification of ropes, wires. slings, etc.;

(e) An outside bay for the cleaning-down of pieces of equipment before they enter the shops;

(*f*) An adequate central store for all sections. controlled by a trained stores supervisor familiar with the principles of stock control and replenishment;

(*g*) Separate sections, with air conditioning, for the maintenance of fuel injection equipment for the diesel engines, and a battery room for the maintenance of batteries for fork-lift trucks;

(h) Administration offices with provision for the control of plant maintenance by means of modern wall charts and a card index.

616. The overall cost of equipping such a central workshop (excludmg the cost of buildings) is likely to be in the range of $2-5 million. Sufficient funds should he provided for during the funding phase of the development project.

C. Guidelines for estimating maintenance costs for mobile equipment

617. Table 14 sets out approximate annual maintenance costs as a percentage of the equipment purchase price for a range of equipment based on European experience. Half of these costs in Europe represent the cost of highly trained labour. Ports in developing countries will need to alter the labour cost element as appropriate, from the base used. namely $7 per hour (1973) for skilled electricians and mechanics. and to increase the amount budgeted for spare parts to include freight costs and to take account of the possibility of more rapid replacement in the local environment.

TABLE 14

Maintenance costs for mobile equipment: values adopted for estimating purposes

Type of equipment	*Annual maintenance costs (1973) as a percentage of purchase price*
Container crane	5
3/5-ton quay crane (rail-mounted)	5
Mobile crane (10 years at 20 m)	8
Mobile crane (25 tons at 25 m)	10
Straddle carrier	12
Fork-lift truck (20-ton)	8
Fork-lift truck (5-ton)	14
Road tractor	10
Trailer	3

Source: Paper on "Problèmes de manutention portuaire" presented by CERLIC (Centre d'Etudes et de Recherches de Logistique Industrielle et Commerciale) to the second UNCTAD/SIDA Port Training Course held in Algiers in 1973.

D. Spare parts provision

618. The provision of an adequate store of spare parts is an essential part of a port investment proposal and must on no account he the place for budget economies. The initial problem is to decide what spare parts are needed. bearing in mind that delivery delays and difficulties in securing foreign exchange at a later date might jeopardize port efficiency. Manufacturers' lists can he very misleading and. if possible, guidance from other ports using the equipment in similar conditions should be sought. Generally the user decides, from the lists provided and from previous experience, for how much of the equipment he should provide spare parts. The consumption rate under local conditions may he substantially higher than that foreseen by the manufacturer. hut there will rarely be adequate local records to prove this. Where possible. the standardization of components will reduce the multiplicity of spare parts required for different machines. For example. the use of a standard range of electric motors, gear-boxes or fluid couplings will reduce considerably the number of different spare parts to he carried.

619. The type of component used can have a marked effect on the ratio of labour costs and spare

parts costs, since the use of alternative designs for the same component can lead either to a throw-away policy, with consequent heavy foreign exchange costs, or to a virtually indefinite life', local labour stripping and overhauling, with simple local manufacture of parts.

E. Maintenance manuals

620. In a number of cases, the maintenance manual provided by the manufacturer will be insufficiently detailed. This is a result of the pressure to keep prices to a minimum, since such manuals can be very expensive to prepare. It would be wrong to demand too detailed information if the cost of this is going to be added to the purchase price. Nevertheless, the following information should be provided, whether or not it is published formally in a manual:

(n) Operating instructions;

(b) Servicing schedules and required repair standards;

(c) Spare parts lists, with identifying illustrations;

(d) Sets of drawings, especially of parts subject to wear that may be manufactured on site, for example, renewable liner plates for ship-loader chutes;

(*e*) Specifications for any special tools and jigs required for maintenance purposes.

F. Training

621. It is common practice to stipulate in the contract for the purchase of equipment a period of operator training by the suppliers' staff. However, the question of the training of maintenance personnel in the suppliers' workshops using the special tools to be provided is often overlooked. This provision should be written into the contract where appropriate. Training throughout the guarantee period (one to two years) is useful in order to form a sound base of skilled staff. Trainees should be bound to a contract for a period of time in order to retain their services in the port.

G. Defect reporting

622. It is advisable to set up a simple clerical system for recording each fault that occurs, to be used for estimating maintenance costs and future spare parts provision, and for judging the comparative performance of equipment of different makes and design. The report should come both from operators and from workshops, and should be regularly reviewed to determine areas of design weakness which may require action by management and may be considered in future development.

H. Maintenance of structures

623. While breakdowns in mechanical equipment or electricity supply and the deterioration of roads and buildings will be evident, the need for maintenance of the basic breakwater. wharf and jetty structures is less noticeable but no less important. Although there are many years' experience in many ports, there is a surprising shortage of reliable cost data on port structure maintenance. Yet a realistic estimate of maintenance costs is essential to complete the economic and financial appraisals of a proposed port project.

624. As part of the design studies, the engineer should consider the manner and cost of any necessary structural maintenance in future years. Although a large civil engineering project can accept a high level of technology in its capital investment phase, this is not the case during its later life when maintenance and repair have to be done with local facilities.

625. Similarly, a structure of a certain design may involve less capital cost but require more maintenance with a resulting increased overall operating cost. In theory, alternatives can be evaluated on an economic basis. In practice, however, such calculations are bound to be imprecise. Therefore, the selection of the appropriate design and provision for future maintenance is a question of judgement, in which both engineer and port management must co-operate.

626. As a guide, table 15 gives suggested percentages of capital cost which should be allowed in estimates for yearly maintenance during the whole economic life of the facilities. These are very general figures and should be used only in the absence of local information.

TABLE 15

Maintenance costs for structural elements: values adopted for estimating purposes

Class of structure and type	*Annual average maintenance costs as a percentage of current new cost or replacement value*
Quay structures	
Steel sheet piling	0.30
Steel piling with reinforced concrete deck	1.00
Reinforced concrete piles and deck	0.75
Rubber fendering	1 .00
Embankments	
Rock-fill	0.75
Surfacing	
Concrete aprons or roads	1.00
Asphalt	1.50
Other surfaces (gravel, etc.)	7 50
Breakwater	2.00

627. The arrangements for the maintenance of port structures would normally be under the direction of the engineering department of the port authority. In some places it is found convenient to include such work in the general responsibilities of a local engineering or public works department which is responsible for other civil engineering maintenance in the area. The precise arrangement is a matter for local decision but in any case an adequate maintenance fund is needed and table 1.5 indicates the order of magnitude of finance which should be made available.

628. A most important feature of maintenance is regular inspection and reporting, upon which a routine maintenance system can be built up, so that structures are kept in good repair rather than allowed to deteriorate for a long period. Accidents should be dealt with immediately and here prompt reporting is essential, to allow dangerous conditions to be removed and clearly to establish financial responsibility.

629. Most reinforced concrete structures will not need maintenance until deterioration may be observed in the form of slight cracking. Cracks, other than hair-line cracks, should be sealed immediately to prevent the ingress of moisture and rusting of reinforcement.

630. Steel structures, on the other hand, normally require regular maintenance, particularly in the moist, salt-laden air prevalent at most ports. A steel structure exposed to a marine environment is subjected to corrosion which can seriously affect its structural integrity. Paint systems are used in many places, and recent research has resulted in many proprietory products with excellent protective properties. Nevertheless, paint systems deteriorate and suffer damage and are very difficult to maintain in first-class condition, particularly under water.

631. An alternative is to design the structure taking into account a rate of corrosion based on previous experience. If an additional steel thickness is provided at the outset, sufficient metal remains after some years of corrosion (say a 40-year design life) to carry working loads without excess stress. As steel corrosion in a marine environment is an electrochemical process, special steels with copper additives have also been used, in order to reduce corrosion. An alternative method is cathodic protection, whereby a sacrificial anode, normally zinc, is positioned on or near the structure so that the iron in the structure becomes cathodic and does not corrode. A second approach is to use a continuous electric current to maintain a potential difference between the structure and a separate anode.

632. The general quay fittings such as fenders, ladders and mooring rings, and the service facilities at the berth, require regular inspection; fenders, particularly, need to be replaced as soon as any damage or serious wear has occurred. Spare fittings are normally kept in the port authority's store, ready for immediate use when required.

I. Equipment replacement

633. Equipment replacement may be needed on two accounts: gradual deterioration or obsolescence, and sudden failure. Generally, port equipment falls in the first class and the problem consists of balancing the cost of new equipment against the rising cost of maintaining efficiency on the old. There is an age at which the replacement of old equipment is more economical than continuation at the increased operating cost. The problem for management is to determine a replacement policy such that the saving in operating costs resulting from the use of new equipment more than compensates for the initial cost of that equipment. There is no general solution to this problem but, given satisfactory cost information, techniques have been developed to assist management in choosing the appropriate point in time at which to replace equipment. The procedure consists of determining the economic life for each type of equipment. The minimum cost solution is a starting-point, but it will be necessary to depart from this when the march of technology makes equipment obsolete for reasons other than the cost of maintaining it. Moreover, before placing an order for new equipment, it is wise to check:

(a) Whether improved equipment is available;

(b) Whether the opportunity can be taken to reduce the variety of types of equipment operating in the port.

634. For the purpose of comparing alternative replacement policies, the discounted value of all future costs associated with each policy should ideally be known, if such costs change with the age of the machine or, in the case of selecting between two machines, if they differ between machines. Future costs include labour, power, maintenance and down-time costs. Care must be taken, however, to exclude from each year's maintenance costs the cost of repairs due to accidental damage, since these are largely independent of age and are not relevant for economic life calculations.

635. A satisfactory replacement policy based on historical cost records is one that replaces the equipment if the cost of replacing every $n + 1$ years is greater than the cost of replacing every n years. The mathematical basis for this policy and a numerical example are given in annex II, section F.

TABLE 16

Average length of economic life for port facilities and equipment

Facilities and equipment	*Average economic life (Years)*
Breakwaters	50
Wharfs:	
Concrete	40
Steel	25
Rubber fenders	10
Tugs	20
Pilot launches	20
Warehouses and sheds	25
Cranes:	
Grabbing	20
Quay	20
Gantry	15
Mobile	8
Mobile tower	15
Floating	20
Ship-loaders	25
Stackers and reclaimers	25
Belt conveyors	20
Belts	3[a]
Idlers	7
Mobile mechanical shovels	6
Straddle-carriers	6
Tractors and trailers	8
Ro/ro ramps	15
Fork-lift trucks	8
Dump trucks	6

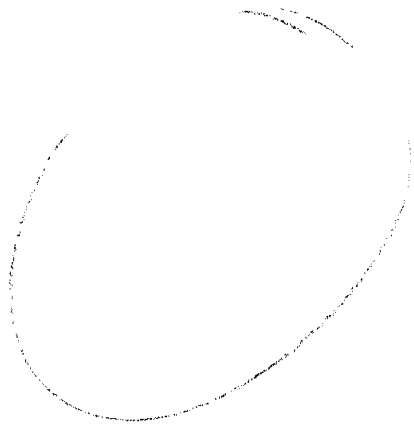
Source: Based on data collected by the UNCTAD secretariat

[a] Normally replaced in sections on a regular schedule.

J. Guidelines for economic life

636. Guidelines can be given on the appropriate economic life, for use when data on maintenance cost trends are not available. Table 16 gives a set of figures for a range of equipment. These figures are basically derived from European experience, but they are broadly applicable to developing countries since the longer life justified by the lower labour cost is offset by the generally more intensive use under more arduous climatic conditions. The economic life takes into account the risk of obsolescence. Some facilities could be used longer because of good maintenance, but are no longer in use due to the evolution of maritime transport techniques.

Part Two



Chapter I

TERMINAL PLANNING CONSIDERATIONS

A. The changing pattern

1. Before setting out to plan the future terminals and groups of berths, the port planner must have a clear view of the stages of development which a port normally goes through, and of the particular stage which his own port has reached. Five phases of development are shown in figure 1 but other patterns of development may also exist. In very rough terms, the blocks in these diagrams represent, in width, the number of facilities or length of quay wall and, in height, the annual throughput of each.

(a) ***Phase 1:*** Traditional

A group of general-purpose berths handling a mixture of break-bulk general cargo plus bulk shipments of commodities in packaged form (e.g. part-loads of wheat in bags, or of oil in drums) or in loose form that are packaged in the hold.

(b) ***Phase*** 2: Bulking of dry cargo

When quantities of the bulk shipments grow to an economical level, they are carried loose in bulk carriers, for which the port has to provide a separate dry bulk terminal. At the same time the break-bulk facilities have to be expanded to handle increased general cargo traffic.

(c) ***Phase*** 3: Advent of unit loads

When unit loads such as pallets, containers or packaged timber begin to arrive at a port, they are in small numbers and are carried on conventional ships. At the same time, the volume of break-bulk cargo begins to decline, and the volume of dry bulk cargoes reaches the point where separate terminals are needed for different classes of material.

(d) ***Phase*** 4: Transitional multi-purpose terminal

With increasing volumes of unit loads, including the arrival of the first cellular container ships, special unit load facilities are needed. But since the way in which the traffic will develop is still uncertain, a flexible and adaptable multi-purpose terminal is needed which replaces part of the old break-bulk berths. Meanwhile, dry bulk continues to grow and diversify even though several different classes of material can be handled on a multi-purpose bulk terminal.

(e) Phase 5: Specialized

Although in the case of a developing country it may take a long time, the specialization of many forms of carriage is a continuous trend and eventually the volumes in each of several specialized forms of unit load traffic, such as containers, packaged timber and ro/ro, will grow to the point where they need separate terminals. A phase-4 multi-purpose terminal can easily be converted into a specialized container terminal through the provision of additional and slightly different equipment. By the time phase 5 is reached, the residual break-bulk volume will have shrunk considerably and older facilities for this type of traffic will have been closed down. Meanwhile, other major cargoes (timber, iron and steel) will be grouped in multi-purpose terminals of various types.

2. It is important to note that experience in recent years has shown that attempting to go direct from phase 3 to phase 5 can give serious financial problems unless transition to specialized traffic is quite definite and proceeding at a rapid pace. Investment in a special-purpose terminal before the pattern of traffic has developed sufficiently means not only under-utilization but also a high risk of built-in obsolescence. Another form of obsolescence which mistaken investment can produce is the continued building of conventional break-bulk berths after a port has moved into phase 3.

B. Study of existing port facilities

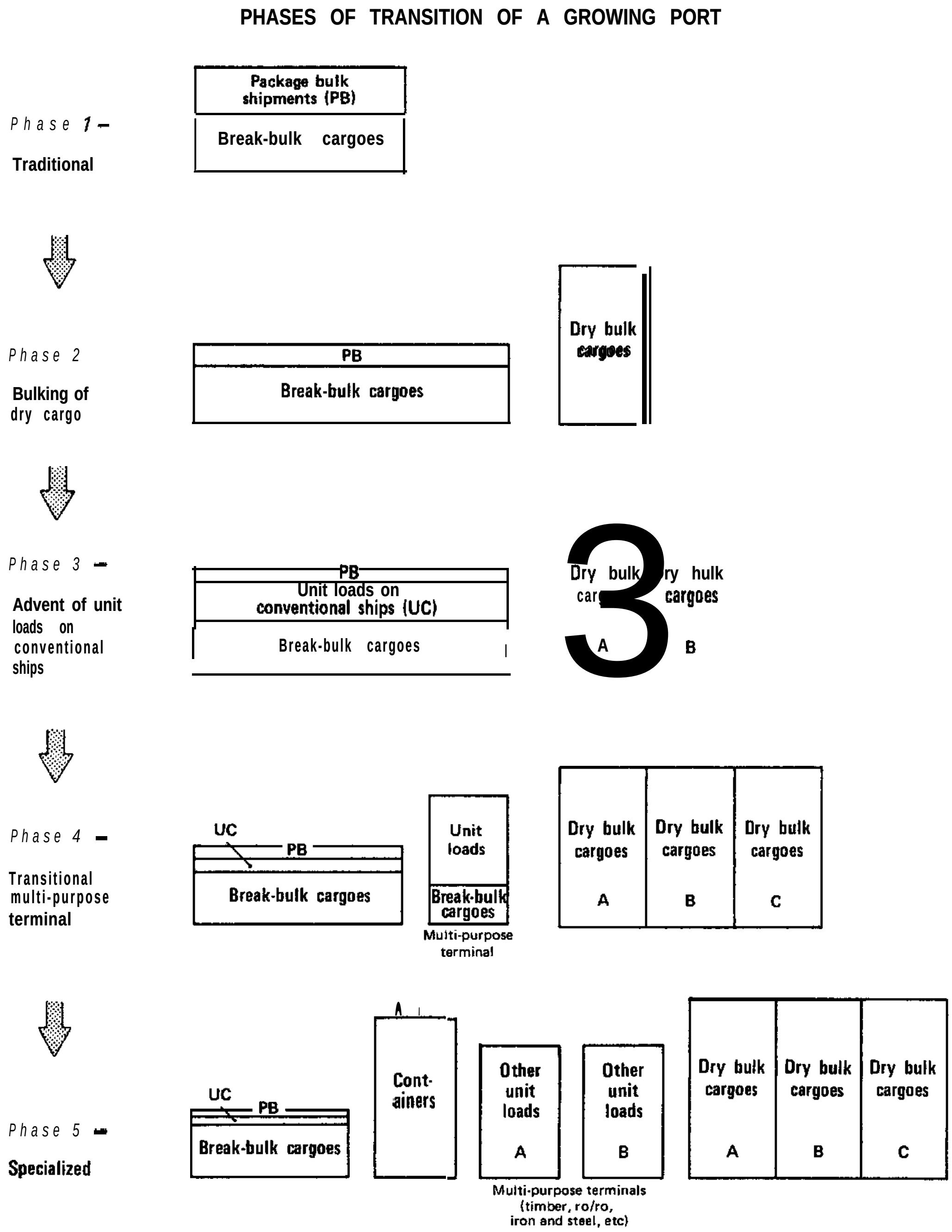
3. Port development projects can be roughly divided into two categories: the building of an entirely new port or of a major specialized terminal in a new location, or-a much more frequent case-a major extension or renovation of an existing port. In both cases, a necessary step is to study the port facilities that already exist in order to determine their real capacity and to find out possible deficiencies in their design and use.

4. The first aim of the study is to see whether a part of the expected increase in demand could be met simply by a better organization of the existing port facilities and minor technical changes or additions. The second aim is to gather information on probable conditions under which the new berth groups or terminals will have to be operated and to bring to light mistakes in previous design to be avoided.

5. However, the findings of the investigating team need to be treated with caution. The future traffic mix and technological conditions may be very different, and a theoretical possibility of increasing the capacity of older installations may prove difficult to achieve in practice. It might be safer to consider the potential and unused capacity of an existing facility as a kind of safety valve to be used for coping with peaks of traffic or sudden increases in demand. These principles are discussed in part one, chapter II.

6. The critical analysis of the performance at existing port facilities must be made separately for each group of berths or specialized terminals. The zone for

FIGURE 1
Phases of transition of a growing port



general cargo is the obvious candidate for the start of the analysis.

C. General cargo berth group

7. The work of the investigating team must begin with an examination of port statistics in order to determine how much cargo has been handled on the berths under study and what was the mix of the cargo, whether predominantly general cargo in break-bulk form, or a sizeable proportion of bagged goods (sugar, rice, flour, etc.), or increasing quantities of unitized consignments (packaged timber and steel) and containers which may require special facilities.

8. A review of the statistics will allow the team to determine what phase of traffic development the general cargo zone has reached, and whether port extension plans should provide for the construction of additional conventional general cargo berths, or a multi-purpose terminal, or whether traffic increases and technological changes have been so rapid that the time is ripe for the construction of specialized terminals for containers and dry bulk cargoes.

9. Statistical figures will also give a first approximation as to whether the actual throughput has amounted to a reasonable proportion of the estimated capacity of the berth group. Approximate figures rather than accurate calculations of berth capacity are needed at this stage. In most developing countries a throughput of

about 100,000 tons a year at a berth with a predominant proportion of break-bulk cargo can be obtained without unacceptable waiting times for vessels. When bagged cargoes and some unitized cargoes account for 30 to 40 per cent of the total, higher throughputs of up to 150,000 tons can be reached.

10. If the actual performance at the berth group has been drastically below the approximate figures and yet there have been periods during the year when ships have had to wait for a berth, this would indicate that serious deficiencies must exist, either in the way the general cargo zone is managed, operated and equipped, or in the design and layout of facilities. The duty of the team will be to scrutinize carefully all sources of delay and to find the reasons.

11. The findings of the investigating team should be examined with a view to determining the best way of co-ordinating the planned new facilities with the existing group of berths. The possibility of activating any unused older installations in full or in part should be assessed. A preliminary decision should be taken as to whether the prevailing trend towards a gradual increase in unit loads and containers would justify the construction of conventional berths or of multi-purpose terminals or even of a specialized container terminal. All conclusions will have a tentative character at this stage but they may help to put the port extension problem in a proper perspective and to indicate points which should be analysed with particular care during the main phase of port planning.

D. Bulk cargo terminals

12. The procedure for the examination of existing bulk cargo terminals is very different from that for the examination of general cargo berths, but the aims are basically the same: to find out whether there is a substantial unused capacity and to detect mistakes in planning and operating the terminal.

13. Terminals for the export of mineral ores most frequently require a considerable increase in the yearly capacity owing to the rapid development of mining and to the discovery of new deposits. The first important question facing port planners will be whether to build a new terminal or whether the existing one can be expanded sufficiently without a long-lasting interruption of traffic. This question and the experience gained so far in operating the terminal should be the subject of thorough examination as a first step towards actual planning. Attention should be focused on the following points:

(a) Was the existing terminal planned in advance for considerable extension in case of need, and if so, was the procedure for extension properly documented?

(b) Are all phases of operations at the terminals sufficiently co-ordinated? If not. where are the bottlenecks and what exactly is their cause?

(c) Is the size of the stock of cargo for loading in proper proportion to the volume of traffic? Has it happened that no cargo was available for loading upon the arrival of a vessel?

(d) Have the means of inland transport been adequate for the present traffic and suitable for a radical increase of capacity within the same system of transport, by road or rail?

(e) Have the dust-collecting and anti-pollution measures worked in a satisfactory way?

14. Such a thorough examination of existing port facilities is an indispensable preliminary step to planning a major port extension. Time spent on this task can save much time during the main planning phase and reduce the number of alternatives to be closely studied to a manageable level.

E. Terminal capacity calculations

15. The role of capacity calculations is to provide a link between the level of service achieved and three factors: the demand placed on port facilities. the capacity provided and the performance that can be expected in local conditions. This task is also known as performance analysis. The results of the calculations will be required for financial and economic analyses.

16. When planning facilities, it is generally necessary to try out several different capacities with several different traffic forecasts, and to do this for different points of time. A good method must therefore be quick and easy. The calculation will be used in various ways: for example, setting performance (productivity) and proposed capacity (number of berths) and varying traffic demand to determine the effect on level of service (ship waiting time). Alternatively, for a proposed waiting time, traffic and number of berths for the required productivity can be determined.

17. All the calculations use linear equations except the calculation of ship waiting or queuing times for berths. This is a complex mathematical expression which for different assumptions may not have a numerical solution. For a planner unfamiliar with this branch of statistics, the possibility of errors is large. The use of theoretical queuing formulae and computer simulation models have been used to estimate ship waiting time.

18. Both these techniques have dangers associated with them. Results from queuing theory are dependent on the statistical distribution of ship arrivals and ship servicing time. Research by UNCTAD has shown that the distributions often used are not the most accurate ones. This point is discussed further in annex II, section D.

19. The main difficulty with computer simulation is that the amount of effort needed often greatly outweighs the gain in accuracy that the technique aims to give. The technique also suffers from the need for considerable data collection.

20. For the above reasons, the use of planning charts is introduced in the handbook. The charts are graphical statements of the linear equations and the planner may prefer for greater precision to use the equations given in annex II. The relationship between berth utilization and ship waiting time is plotted by a curve based on queuing theory in the charts. but the waiting time factors are also given in annex II and can be used in the equations.

21. However, it is recommended that the charts are used, first to obtain a clear understanding of the relationships and their sensitivities, and later as a cross-check on calculations. The use of the graphical method forces the planner to estimate all the component figures which should be considered.

22. For mixed traffic, for example, when a bulk berth is also used for break-bulk operations if it is not occupied by bulk vessels, the application of the planning charts becomes difficult. In such cases a computer simulation may be justified, but it is more likely that simple calculations will give a satisfactory answer. A simple approach would be to assume that break-bulk vessels are shifted from the berth when a bulk vessel arrives. The charts may then be used to calculate the performance for bulk vessels and also to determine the remaining capacity for break-bulk vessels. The waiting times for break-bulk vessels will, however, be difficult to determine.

23. The procedures for calculating the capacity of each type of terminal differ. The various procedures are given in chapters devoted to the following groups: break-bulk berth group; specialized container terminal; multi-purpose general cargo terminal; specialized ro/ro terminal; barge-carrier terminal; dry bulk terminal; and liquid bulk terminal.

Chapter 11

THE BREAK-BULK BERTH GROUP

A. Need for break-bulk berths

24. Some ports in developing countries, particularly the smaller ports, may still be in the initial phase of development. For these countries it is possible that conventional break-bulk traffic will continue to grow for ten years or more, thus justifying the building of additional traditional berths. In any case, there will be a substantial residue of break-bulk cargo passing through ports in developing countries for several decades at least, and old facilities will need improving or renewing. For all these reasons, port planners will still be faced with the planning and design of the break-bulk berth group. Ports which conclude that there is no longer such a need should refer to the chapters on the multi-purpose terminal and the container terminal, In many rapidly developing ports there might be a need for both specialized terminals and conventional break-bulk berths. The latter should be planned for easy conversion to special uses. In fact, any new traditional berths should be able to be converted to a multi-purpose facility.

B. The berth group

25. The term "berth group" has been used deliberately for break-bulk facilities, for the following reason. The planning of port capacity must always be on the basis of the set of berthing-points which share the same stream of traffic. When several different berthing areas can deal with the same kinds of traffic, then-provided ships can be equally serviced in each area-there is a disadvantage in restricting a group of ships to one area. This is because splitting a stream of traffic into several separate streams (say, according to region of origin) destroys the smoothing effect of the possibility of allocating ships to berths over the whole berth group in a co-ordinated way, and leads to longer waiting times. The way in which ports have grown has often led to there being several distinct wharves or basins which together form the facilities available for break-bulk cargo operations. It is the totality of these facilities which forms the break-bulk berth group for which the planning procedure is given in this chapter.

26. Where the operational staff systematically send some of the ships in the break-bulk traffic stream to one berthing area and the rest to another, then this should be treated as two traffic streams and two separate berth groups. Separate traffic statistics, forecasts and capacity calculations should be made. This happens when there are two berthing areas of substantially different depth and as a matter of routine deep-draught and shallow-draught ships are berthed accordingly. The management information system should distinguish between these two traffic classes. Another example may be where a particular berthing area is dedicated to ships on a given trade-route or conference. For operational purposes it must be accepted that such berthing policies are seldom rigid and the segregation policy will sometimes be broken according to the daily berthing situation. However, in spite of this, it is better to plan the facilities separately.

C. Economy of scale and berth occupany

27. The combining of the berthing plans for small, physically distinct groups of berths into one berthing plan for the stream of traffic results in a reduction in ship waiting time. The greater risk of queueing when groups of berths are treated independently arises as a result of the possibility of a ship having to queue for a berth in one group at a time when there is actually a vacant berth in another group. A numerical example will show the significant advantage of joint berthing plan, although the operations on each berth or small groups of berths may best be managed separately.

28. Let us consider two independent break-bulk general cargo five-berth groups, each with an average ship service time of three and a half days and a ship arrival rate of one ship a day. Another way to consider service time is the service rate, the number of ships serviced over a period of time. For this example, the service rate would be 1/3.5 or 0.29 ships per day. Each group has an average berth occupancy given by dividing the arrival rate by the product of the number of berths and the service rate which, for this example is 0.7. This would give an average queueing time of 19 per cent of the discharging/loading time, which is close to the limit for which a port should be designed (see annex II, section D, table VII).

29. If the traffic were combined and handled as a single stream over the 10 berths, the berth group would now receive two ships a day, but the berth occupancy would remain unchanged at 0.7. However, this same berth occupancy on 10 berths gives an average queueing time of only 6 per cent of the service time, an important increase in the quality of service and an insurance against serious congestion during peaks.

30. As a quick guide, berth occupancies for conventional general cargo operations should be set so as not to exceed the figures given in the table below, which are based on a ratio of ship cost to berth cost of 4 to 1:

Number of berths in the group	Recommended maximum berth occupancy (Percentage)
1	40
2	50
3	55
4	60
5	65
6-10	70

Since port administrations of small ports would be reluctant to accept a 40–50 per cent berth occupancy and the resulting under-utihzation of port facilities and labour, the retaining of an efficient lighterage service would be an economical way to allow the utilization of facilities to be increased without running the risk of excessive waiting time. The lighterage service would then act as a safety valve for the handling of ships that could not be berthed alongside during periods of peak demand. Investment decisions cannot normally be based on these limits alone, however, and require the more detailed procedure described later in this chapter (see section G below).

D. Quays or moorings for general cargo

31. Over the years there has been discussion as to whether a modern port should dispense entirely with working general cargo ships at moorings. One view is that working to lighters introduces double handling costs and increases the risk of damaging cargo, which makes the operation less economical than working at berths. The contrary view has also been held, namely, that moorings are a cheap and useful facility for supplementing, during periods of peak demand, the limited number of berths that many ports are restricted to by space or funds.

32. There will in fact be circumstances when each view is economically justified. The decision should be based on the following factors:

(a) The importance to the shipowner of alongside berthing, there being other reasons for preferring berthing than merely ease of cargo handling, for example, the need for bunkering and other port services;

(b) The relative price of land and of labour, which can bring the economic advantage either to berthing or a combination of berthing and working at moorings;

(c) The existence or lack of a large and well-organized lighterage fleet with labour;

(d) The local destination or origin of the cargo: for example, cargo going to private shallow-draught wharves or destined for onward transport via barge would be best discharged to lighters at a mooring;

(e) The weather pattern at the port: it will generally be possible to work at berths for more days in the year than at moorings.

33. The rate of working to and from lighters, for conventional general cargo or bagged bulk commodities, cannot be clearly said to be higher than the rate of working at berth. In general, the difference is not significant for certain cargoes, while for others berth working is clearly superior. In addition, working at berth provides the opportunity to introduce a variety of modern handling techniques which cannot be used when working to lighters. This factor, together with the assurance of easier and more accurate tallying and reduced damage, weighs in favour of berth working in a new development.

34. The strongest case for working at moorings is to provide a major port contingency capacity, even when the standard method is to work at berths. It is relatively easy to reintroduce working in the stream when traffic builds up above the immediate berthing capacity, provided that a reserve fleet of lighters with labour and some lighter-handling facilities are available.

E. How many berths are there now?

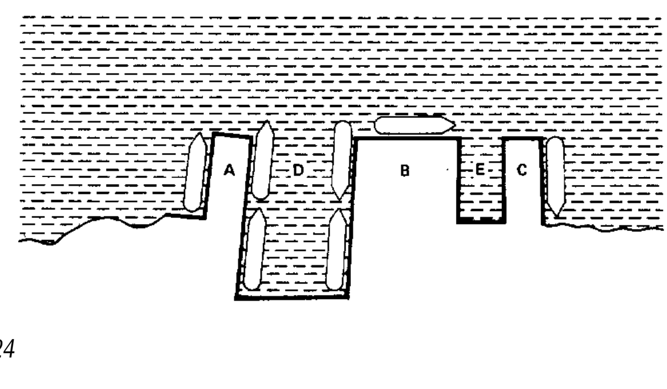
35. Port extension proposals are generally justified by comparing the level of service which is given by the existing facilities with that which would be given by providing additional berths. To do this it is necessary to describe the existing facilities in terms of the number of berths that they represent. Often this is not obvious, where there are complicated waterfront layouts. It is not permissible to add up the separate lengths of quay in a berth group and from this work out the number of effective berths this total length represents. This will overestimate the capacity, since the capacity of an irregular quay is usually less than that of a linear quay.

36. The correct approach is to use a map of the acutal waterfront layout to determine how many ships of the average length for that traffic stream can be simultaneously berthed at the berth group. The port marine superintendent or harbour-master should be consulted. This number of ships can then be taken as the number of berths for planning purposes. Where there are lengths of quay too short to handle average length ships, then these can be excluded and may be allocated to another traffic stream.

37. The illustration in figure 2 depicts a case of old facilities where a planner could be misled into believing that there are 11 berths, whereas there are in fact only seven for the forecast average size of ship. In this example there is a total quay wall of 2 km. The length of quay wall excluding the end faces of piers A and C and the inner face of slip E is 1.77 km. The theoretical berthing capacity with the forecast average ship length of 160 m is 11 ships. However, the **actual** berthing capacity, as shown, is seven ships, since it is not safe to berth more than four ships of average length in

FIGURE 2

ESTIMATING THE EXISTING NUMBER OF BERTHS



basin D, and berthing is so difficult in slip E that it is only used for lighters and barges. The reason for the large discrepancy here is the unsuitability of the old slip E for ships of this average size.

38. This example also shows how unreliable are operational performance measures based on overall quay wall length. For example, if the whole 1.77 km berthing length of this berth group were achieving an annual throughput of 1.05 million tons of general cargo, this would give 590 tons per linear metre of quay, which would generally be considered low. In terms of throughput per berth for the seven berths. this would be better stated as 150,000 tons per berth, which is generally considered good.

39. The number of effective berths used in capacity calculations will often be different from the formal berth numbering system. For administrative purposes, it will often be advisable to maintain distinct berth identities, laid out, numbered, staffed and monitored separately, even when ships overlap berth limits. This should not affect the planner's capacity calculations.

F. Berth capacity calculations

40. The two major quantitative decisions for the planner are:

(a) How many berths there should be in the future berth group;

(b) How much storage space should be provided for each new berth, and whether any additional storage space is needed at existing berths.

Procedures for each of the decisions are set out below.

41. Supplementary planning decisions are, of course. needed with respect to each of the following:

(a) The appropriate depth of water at quays or moorings;

(b) The appropriate quay layout for the operational plan proposed;

(c) The berth equipment needed;

(d) The appropriate level of manpower;

(e) The cargo delivery and receiving system.

G. Number of berths required

42. For the break-bulk cargo terminal, planning charts I and II should be used for deciding the appropriate number of berths. The first chart (see figure 3) allows the planner to determine the berth-day requirement (the number of days ships are at berthing points) and the appropriate number of berths required. These values are used as a starting-point for the second chart (see figure 4). which gives the expected ship time at port and can be used as the basis for a cost-benefit analysis. The relationships used to prepare these charts are given in annex II, section E.

43. The following three terms used in chart I are defined as follows:

(u) Overall fraction of time berthed ships worked: for example, for a berth group working two eight-hour shifts on six days a week, the fraction would be (16 x 6)/(24 x 7), or 0.57:

(b) Number of commission days per year: the number of days in the year on which the berth is available for cargo handling irrespective of the standard shift arrangements. The following lost days would be excluded from this factor:

(i) Days, on average, on which the berth is out of action for maintenance or dredging;

(ii) Days on which it is known that bad weather will normally interrupt working completely;

(iii) Days on which the berth is occupied by non-cargo ships, for example naval vessels and passenger cruise ships;

(iv) National and religious holidays which cannot be worked under normal circumstances (note that the weekly rest-day is not excluded as it is included in the above fraction);

(c) Berth-day requirement: the total number of days that ships will be at berthing-points to work cargo. For example, 100 ships each requiring a berth for four days give a berth-day requirement of 400.

44. The procedure for the use of chart I is as follows (refer to figure 5):

(a) Enter the chart at point A on the scale indicating average tons per gang-hour; the figure corresponding to point A should be taken from actual performance data;

(b) Draw a vertical line down to the line indicating the fraction of time that berthed ships are worked, to give a turning-point B;

(c) Draw a horizontal line to the left from point B to reach the turning-point C on the line indicating the average number of gangs employed per ship per shift;

(d) Draw a vertical line down to the curve indicating the annual tonnage forecast, to give a turning-point D;

(e) Draw a horizontal line to the right to reach the vertical scale of berth-day requirement at point X. This value is the main output from this chart. for use with planning chart II;

(f) Extend the line past X to the right to give a turning-point E on the curve indicating the commission days per year, then draw a line vertically upward on the horizontal scale to obtain the approximate number of berths needed (point F).

45. When a detailed breakdown of the components making up berth productivity is not required, the planner may start at the left-hand horizontal scale (tons per ship-day) and descend directly to point D. Tons per ship-day at berth is a useful measure of performance which incorporates the first three factors (i.e. average tons per gang-hour, overall fraction of time berthed ships worked and average number of gangs employed per ship per shift).

FIGURE 3

Break-bulk general cargo terminal, planning chart I: berth requirements

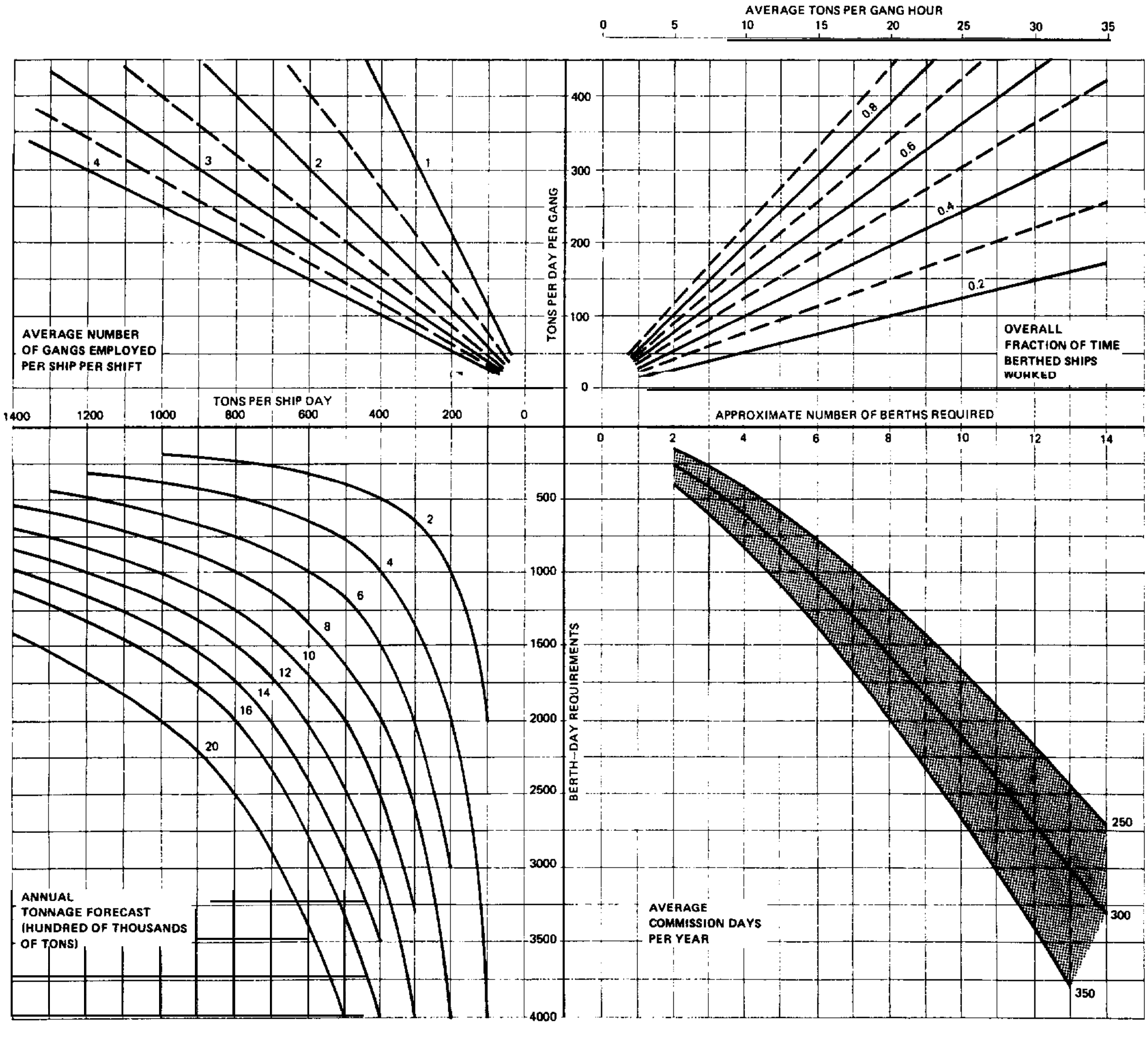


FIGURE 4

Break-bulk general cargo terminal, planning chart II: ship cost

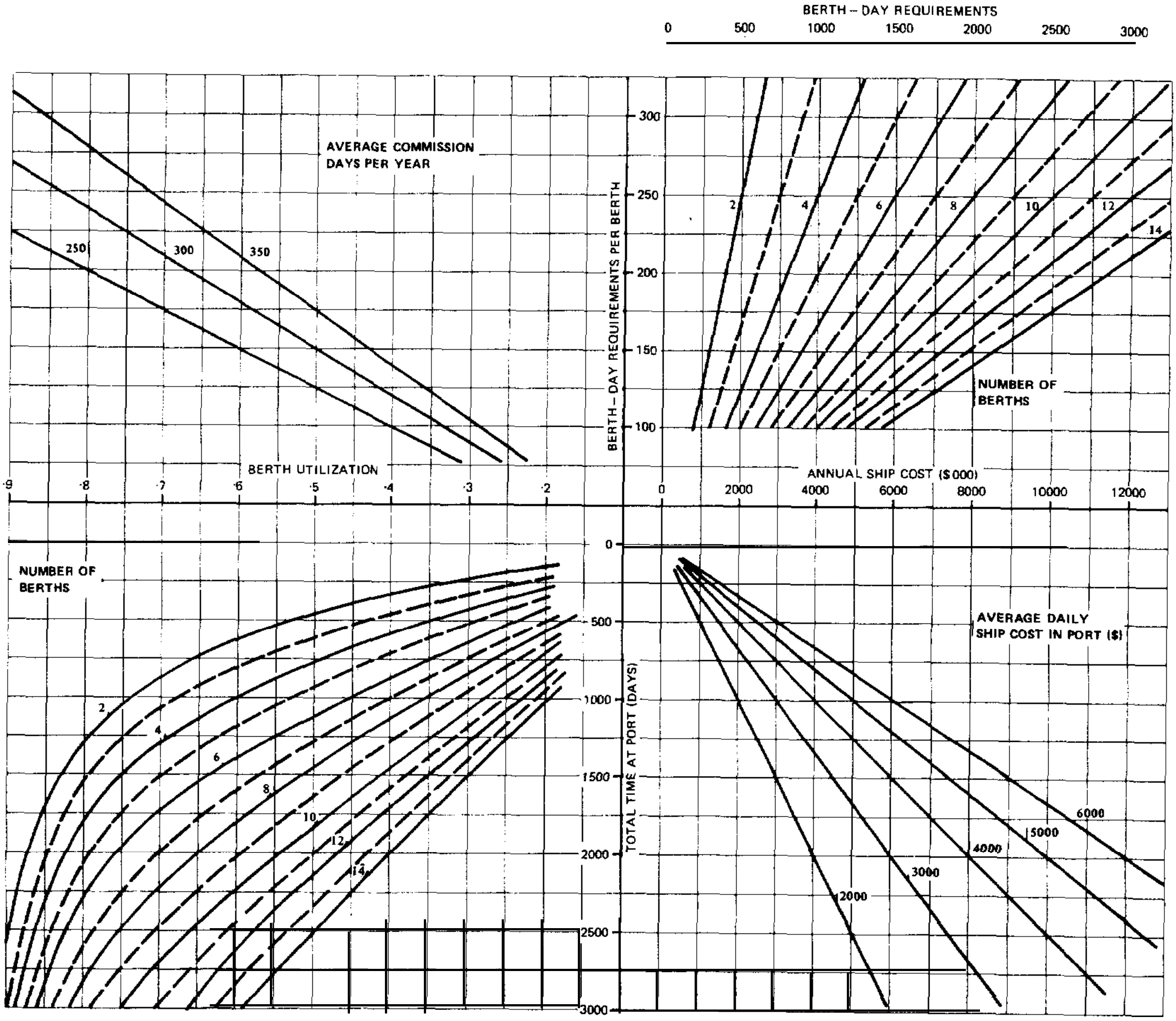


FIGURE 5

Example of use of planning chart I

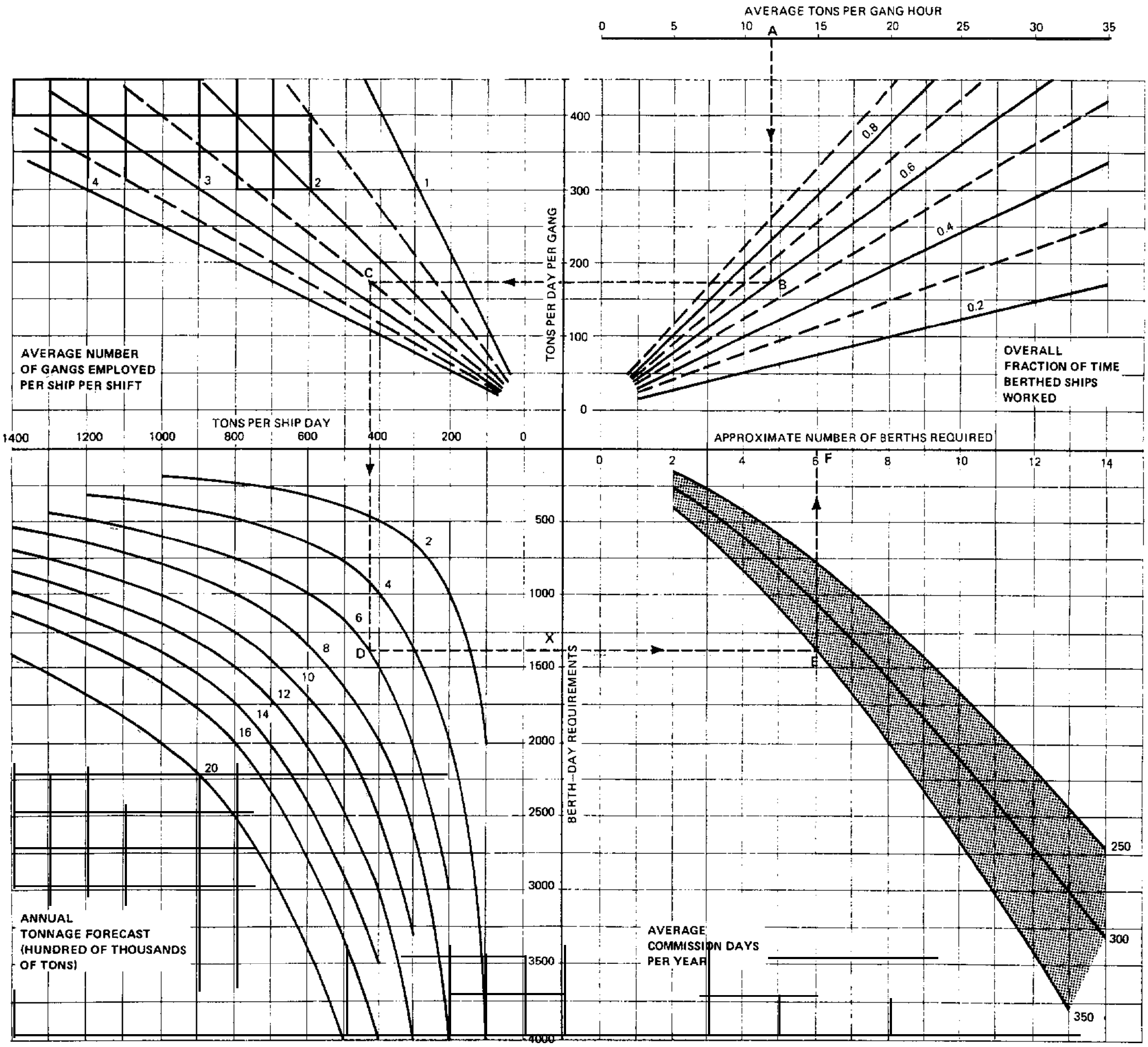
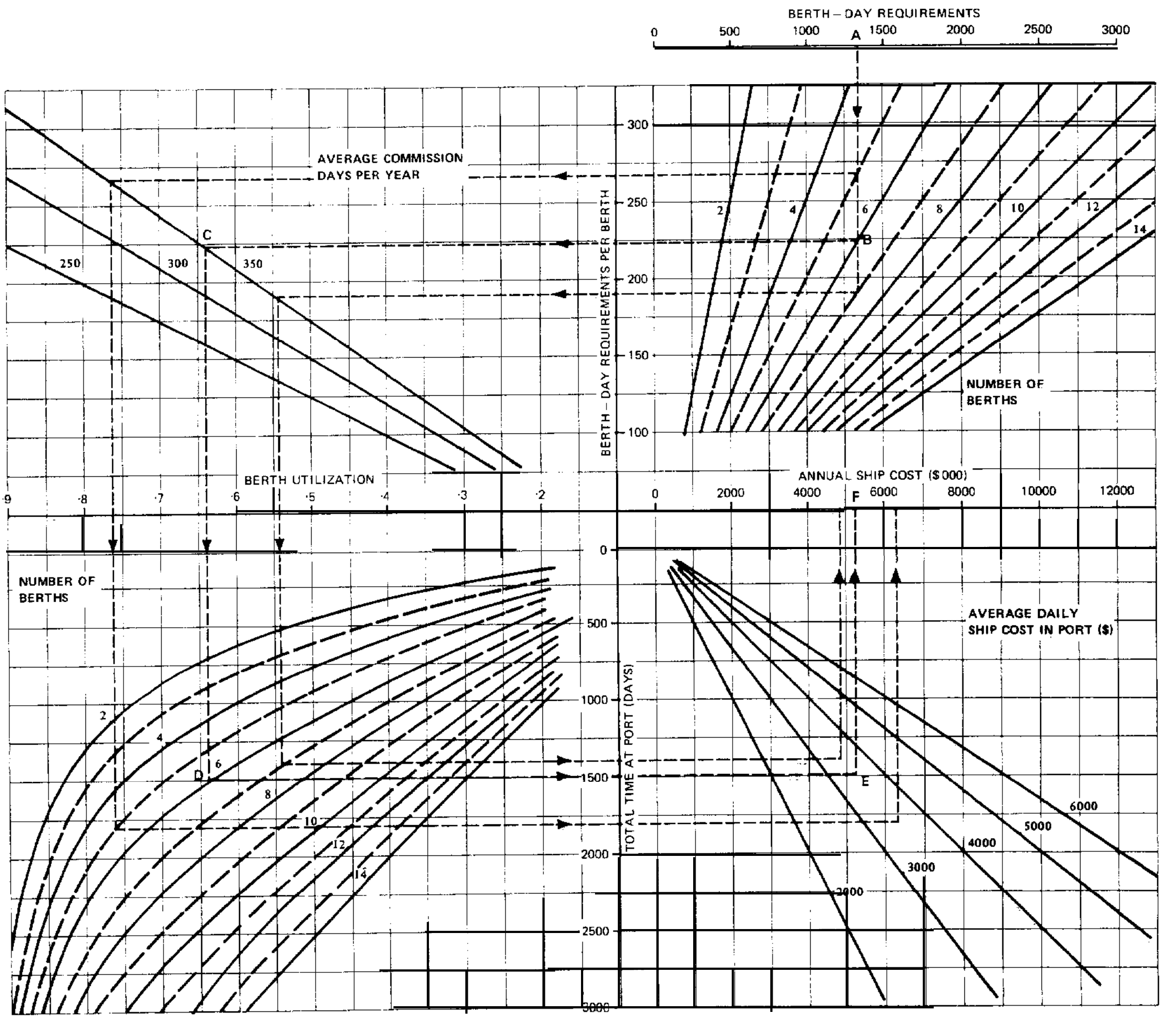


FIGURE 6

Example of use of planning chart II



46. The example of the use of planning chart I given in figure 5 has the following input data:

Number of tons per gang-hour ..	12.5
Fraction of time berthed ships worked	0.6
Number of gangs employed per ship	2.5
Tonnage forecast	600,000
Number of commission days per year	350

47. These inputs will give a mean ship productivity of 450 tons per day, and a berth-day requirement of 1,330 days per year which requires approximately six berths. However, this is only a rough indication based on typical berth utilization and does not show the cost of ship time in port. To obtain this cost, the berth-day requirement obtained from planning chart I is entered on planning chart II (see figure 4). A similar method as for the first chart is then used with the following procedure (refer to figure 6):

(a) Enter the chart at point A on the scale indicating the berth-day requirement; the figure corresponding to point A is obtained from chart I;

(b) Draw a vertical line down to the line indicating the number of berths (from chart I) to be tried out, to give a turning-point B;

(c) Draw a horizontal line to the left from point B to the line indicating the number of commission days per year, to give a turning-point C;

(d) Draw a vertical line down to the curve indicating the number of berths (the same number as at point B), to give a turning-point D;

(e) Draw a horizontal line to the right to reach the line indicating the average daily ship cost in dollars, to give a turning-point E;

(*f*) Draw a vertical line upwards to obtain annual ship cost (point 5).

48. The procedure can be repeated with one more berth and then with one less berth. This will give a set of values of total annual ship cost for the three alternatives. The separation into waiting time and service time has been avoided in order to emphasize the importance of planning only for total performance, which is the best measure of the level of service given to ships.

49. The example of the use of planning chart II, given in figure 6, has the following input data:

Berth-day requirement	1,300
Number of berths	Either 5, 6 or 7
Number of commission days per year ..	350
Ship cost per day	$3,500

For the five-berth case the total time at port is 1,800 days, while for the six-berth case the total time at port is reduced to 1,500 days. There is a further 75-day reduction in ship time for the seven-berth case. Bearing in mind that losses due to scarcity of port facilities in the event of an unpredicted turn for the better in a country's economic development could be many times the cost of an additional berth, these alternatives need to be evaluated. The planner would have to ascertain whether the saving in ship time between the five-berth and the six-berth alternatives justified the investment in the additional berth and, if so, then if the seven-berth alternative were justified. This would normally be done in a cost-benefit analysis as described in part one, chapter II.

H. Berth length

50. Once the number of berths required has been determined, the length of new berths must be set to enable cost estimates to be made. A wasteful tradition in port planning has been to use the currently fashionable berth length for a class of traffic irrespective of the local requirement. It is argued that it does not matter if the length used is not the economic optimum since on a linear quay there is less meaning to the individual berth. This, however, introduces yet another error into the analyses of economic advantages and disadvantages. Each port should consider for each of its zones what is the most appropriate berth length, and for this it needs a broad analysis of the ship lengths in the traffic stream in question.

51. The governing factor is the average ship length for that particular stream of traffic. Experiments made by the UNCTAD secretariat using different typical length distributions show that there is a general relationship between the amount by which the average berth length exceeds the average ship length and the amount of ship waiting time involved. This relationship is given in figure 7 in the form of a correction factor to be applied to the total ship time at port given by planning chart II. With a safety margin of 10 per cent, there is no correction to be made. In this way the effect of providing a greater or lesser berth length can be tested in the cost-benefit analyses.

52. The correction factor indicated in figure 7 applies to all berth group sizes except for the single berth, where the berth length must of course be that of the maximum ship length. The correction factor is not particularly dependent on the number of berths since the economies of scale achieved by shifting vessels daily to make the best use of gaps, on a linear quay, rarely apply to more than a three-berth length.

I. Sensitivity studies

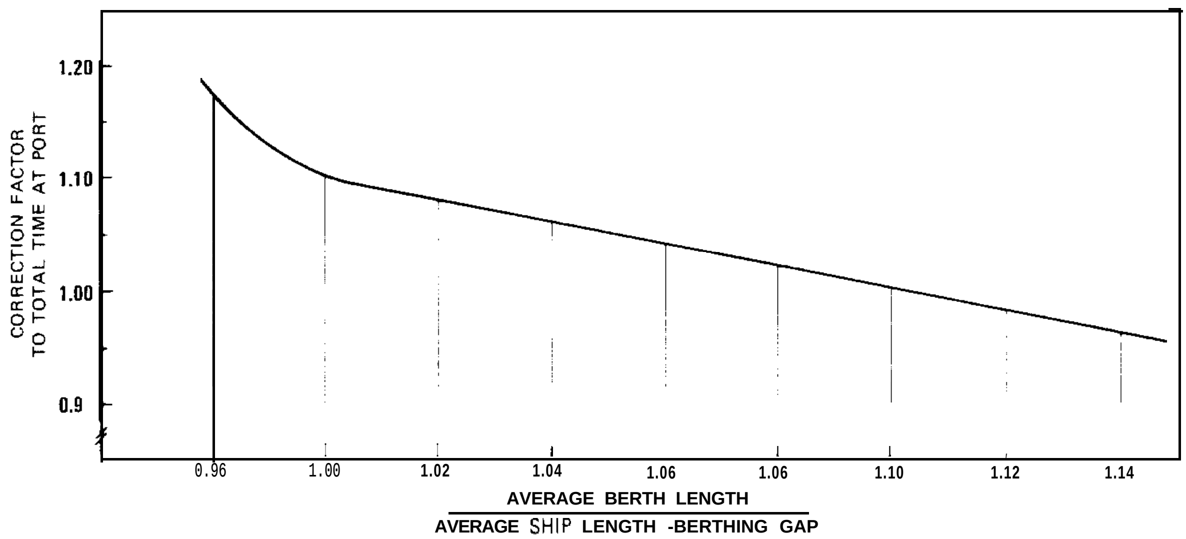
53. Each of the figures used in the input data should have a sound basis. For example, the productivity used must be based on a practical operating plan for the berth, the fraction of time worked must be based on an agreed labour policy, and the number of commission days must be based on weather constraints and a berth maintenance and dredging plan.

54. There will often be alternative values for these figures, depending on other management policies and sometimes on other port investments. Planners should evaluate the costs or savings resulting from varying the values. Where there is a real choice involving related investment-for example, where the extension of a breakwater will increase the number of commission days per year-the various output values given by planning chart II should be used to carry out an economic sensitivity study.

55. Where the alternative value demands management action, such as a change to a new shift system, it should be remembered that such a change may involve costs either in extra staff, in upgrading existing staff, in hiring an external adviser or in higher pay for shift-

FIGURE 7

Berth length correction factor for break-bulk general cargo terminal planning



working. These costs should be set out in the economic sensitivity study in such a way that if this alternative is chosen the necessary funds will be provided.

J. Dimensioning of storage areas

56. Break-bulk storage areas should be planned independently for each type of area: for example. transit sheds, open areas and warehouses. A systematic procedure can be used for each type by the planner. This procedure is summarized in figure 8 (planning chart III). and the relationships used to prepare this chart are given in annex II. section E. The various factors influencing the area requirements are discussed below.

57. Of the annual tonnage worked over a berth. part will be for direct delivery and part for storage. either in transit sheds or open areas. The proportion likely to follow each course, and thus the proportion likely to pass through the storage areas, must be estimated. This figure is the starting point for planning chart III. Next. the average transit time for the cargo must be estimated. Unless a great deal ofemphasis is to be placed on cargo clearance, the present transit delay should be assumed. The average transit time is defined as the average time that elapses between a consignment being placed in the store and its removal from the store. This value can be estimated by sampling a number of consignments from storage ledger records. Normally steps should be taken to reduce the average transit delay if it exceeds ten days. From these two factors the required holding capacity in tons is-determined.

58. The average weight/measurement ratio or density of the cargo mix making up the traffic using the storage must now be estimated. Although the density of a cargo is often significantly different from the stowage factor of that cargo, owing to the lost spaces in the hold of the ship that carries it, it is usually satisfactory to use the latter, bearing in mind the levels of accuracy of tonnage forecasts and the similar need to allow for lost space in the store. Typical ratios are given in annex I. table I. For the estimated density. the net holding volume required can be calculated; this is the theoretical volume for the holding capacity if the cargo were all one consignment stacked in a solid block. To this volume must be -added an allowance for broken stowage. that is. for the extra space needed when consignments are taken apart and the various items placed separately. A typical figure would be a 20 per cent allowance, which has been incorporated in planning chart III The planner now has the gross holding volume required. which must be converted to the stacking area required.

59. For the cargo mix concerned, the average stacking height must be estimated. For planning purposes. this height is the average of the stacking heights of the various cargoes that make up the mix, in a full store. The stacking height is a function of cargo type-and packaging type. and these should be the determining factors. In the case of break-bulk cargo. different commodities may be stacked to a height from 1 to 3 metres, the average figure being 2 metres. A simple way to obtain average stacking height is to walk along the aisles and measure the stacking height every ten paces. From this height the stacking area required can be determined.

60. There may also be a choice to be made between the cost of providing facilities for higher stacking and the cost of the larger area requirements caused by lower stacking. In this connection there are several considerations to be taken into account:

(a) The cost of providing stacking equipment which can work to the full height chosen:

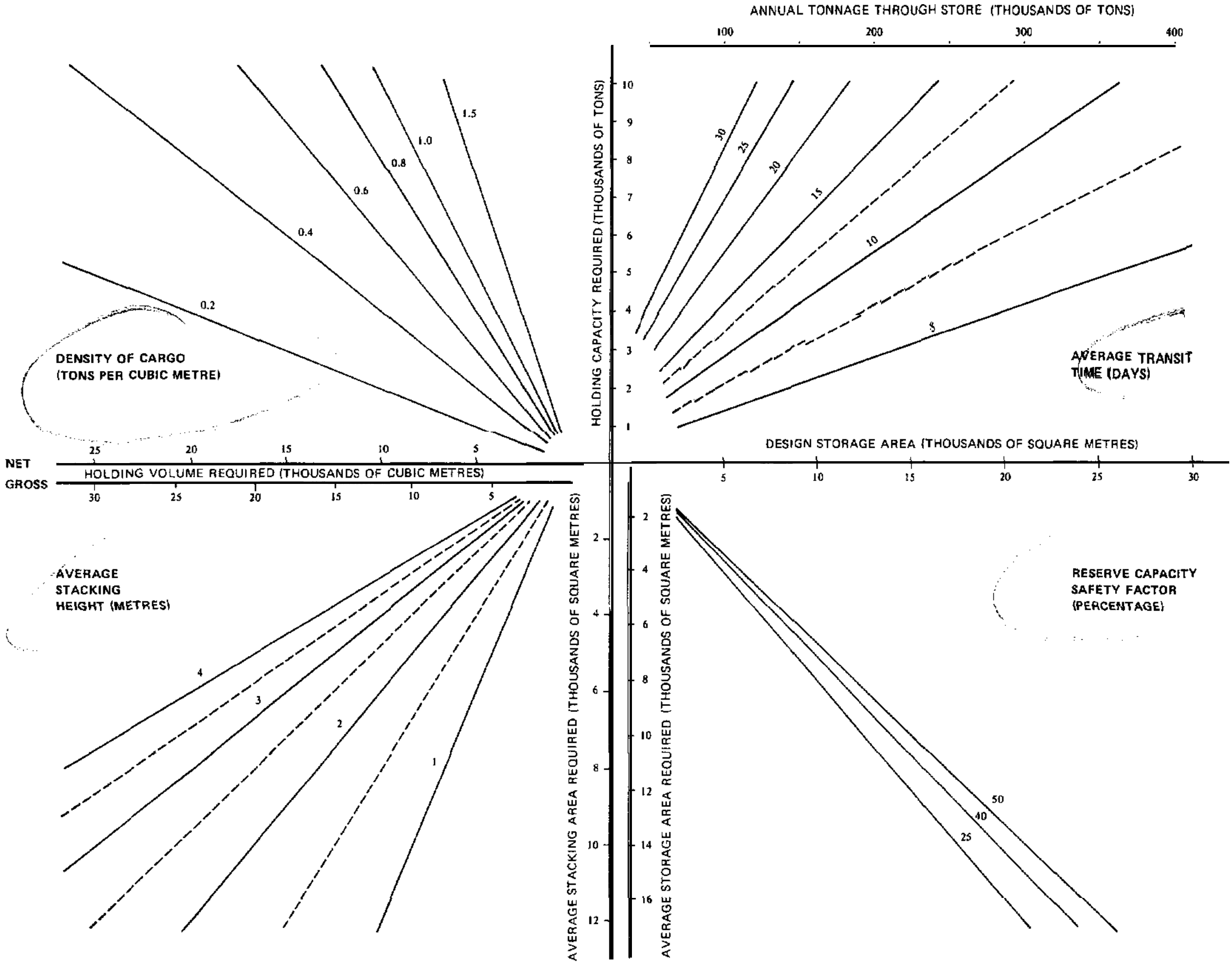
(h) The cost of building a store of sufficient height;

(c) The limitations imposed by lateral forces from the stack acting on the walls of the store:

(d) The limitations imposed by floor weight restrictions.

FIGURE 8

Break-bulk **general cargo terminal, planning chart III: storage area requirements**



Floor weight restrictions are not generally critical at modern terminals, where the berth surfacing is more often governed by wheel loadings of mobile equipment and where shed location is flexible, but a check must always be made that the storage area design loading is consistent with the floor slab design specification. The floor loading, in tons per square metre, is obtained by multiplying the maximum stacking height by the cargo density in tons per cubic metre.

61. The average stacking area required must be increased by an allowance for all space not used for stacking, for example alley-ways, offices within the storage area, customs checking-points and social amenities. At the early planning stage when detailed layouts have not yet been prepared, an average figure must be used. For a break-bulk transit shed, a typical allowance would be 40 per cent. This figure has been used in the planning chart to give the average storage area required.

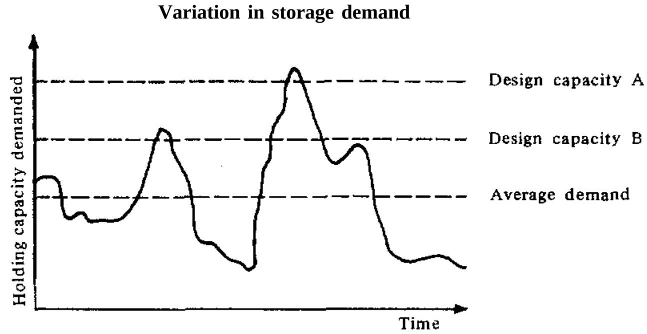
62. A reserve of storage capacity must be provided over and above the average holding capacity, to handle the variation in demand. It will rarely be economical to provide a design capacity to cope with the very highest peaks of demand, but the capacity chosen should be sufficient for handling the majority of peaks or surges.

For example, with respect to figure 9, which shows a varying demand on a store, it is clear that to design for the average demand would be quite unsatisfactory. Whether the design capacity should be set at level A or at level B, for example, depends on the relative cost of providing and maintaining the extra capacity which is idle for a large part of the time as against the cost of running out of capacity and having to take emergency action to prevent or cure the resulting congestion.

63. Where the form of the variation is known-for

FIGURE 9

Variation in storage demand



example, where the size and frequency of the shiploads which give rise to it are known. as well as the hinterland transport movements-the cost calculation can he reasonably accurate. and a design capacity can he found which is an economic minimum. Such calculations will sometimes show that the cost of congestion will he so much higher than the cost of idle storage that the best decision is to provide for the maximum likely demand.

64. However. when there is little knowledge of the expected shape of the demand variation—for example. in a common-user terminal—there is little scope for finding the minimum economic design. Here it is more appropriate to rely on experience. The UNCTAD secretariat has examined a number ot different cases and found that as a general rule it is desirable to provide an additional 40 per cent as reserve capability over and above the basic capacity. This margin is applied in addition to the extra spaces needed for access. broken stowage and administrative areas. To provide less than a 25 per cent reserve would be unwise under any circumstances.

65. The average demand for space in a transit shed is a mathematical concept, used as an intermediate step in the calculations. Transit sheds in a port are similar in function to lungs in that they draw cargo in and out. just as the lungs draw air in and out. Neither are meant for storage. The maximum capacity of the lungs is the amount of air drawn in with a deep breath. Equally. the transit sheds must be able to hold the maximum demand. The definition of the maximum, however, is difficult as at any one time there is cargo from several ships in the shed and capacity is required for several imminent ships Thus the average demand is calculated. and then the extra or reserve capacity is added on to take account of the variation.

K. Transit areas

66. The purpose of transit areas within the port **is** primarily to provide a buffer zone to harmonize the faster ship-shore flow with the slower shore-inland movement. In addition. these areas provide a safe place for checking the condition of all consignments and their correspondence with the manifest and bills of lading. and for accomplishing the necessary customs and delivery formalities. In no event should transit sheds be used for long-term storage, which should be a function of warehousing areas not adjacent to the waterfront.

67. A rough preliminary estimate of the requisite size of transit sheds can be made on the basis of experience of existing berths or in neighbouring ports. While the length of the sheds is usually limited to about 110-120 metres by the average length of the berth [about 160-180 metres) and the necessity of leaving wide access space between two neighbouring sheds. there is more freedom in selecting the width of the shed. Experience in many developing countries has shown that sheds should preferably be not less than 60 metres wide, with 50 metres as an absolute minimum when there is a shortage of available space on land.

68. In most countries ample storage should he provided in the open, especially when the rainy seasons are short. Vehicles and agricultural and road-building equipment do not require covered storage. nor do construction steel, oil in drums and many other goods. As much storage in the open should be provided as local land conditions permit, within, of course. some reasonable limits. Open storage yards should be well marked and clearly separated from roads and parking and loading areas. They should be levelled and properly paved, with adequate provisions for the drainage of rainwater.

L. Transit shed design

69. In the selection of a design for the transit sheds, the following errors of design should be avoided:

(a) Insufficient width of shed, below the absolute minimum of 50 metres, with a resultant shortage of storage space;

(*b*) An excessive number of interior columns supporting the roof. which will impede the free movement of mechanical equipment in addition to reducing the usable space on the floor;

(c) Inadequate ventilation and lighting making cargo handling and reading the marks slower and more difficult:

(d) Poor quality of the floor, not smooth and resistant enough:

(e) An Insufficient number of doors. and poor suspension of doors so that opening or closing them is difficult and slow:

(*f*) Waste of space within the sheds on offices which could be located on an upper level;

(*g*) Too solid and monumental a construction. unsuitable for alterations or dismantling of the shed and its erection on another site.

With the sole exception of the last point. all the deficiencies listed above may have an unfavourable effect on the efficiency of operations within transit sheds.

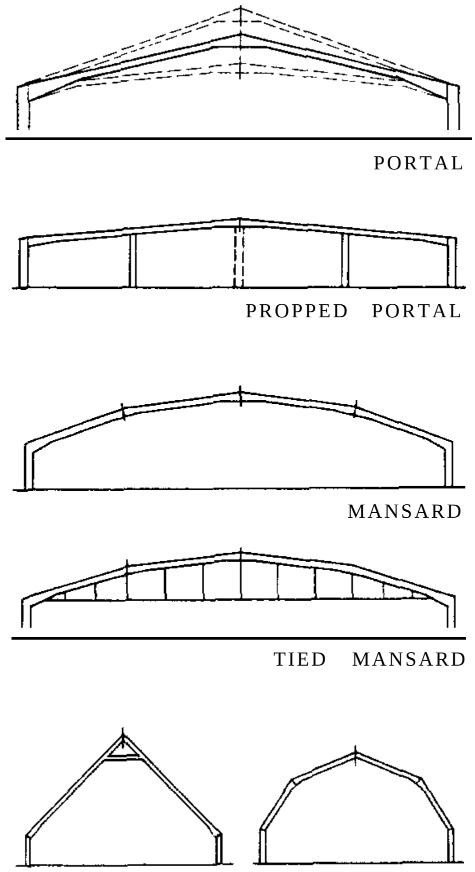
70. Multi-storey sheds are not normally appropriate either for transit sheds or for port warehouses. Single-storey sheds greatly simplify cargo handling and obviate the need for expensive foundations and cargo lifts. Various types of shed are shown in figure 10 which create an interior unencumbered by internal support structures. However. the complete absence of interior columns will result in a more expensive structure than a shed with a limited number of columns. which can be placed in such a way as not to obstruct operations.

71. To achieve the goal of flexibility in the face of changing terminal requirements, it is an advantage to be able to dismantle a transit shed and re-erect it in a different location. This may be a factor in choosing the form of construction. A certain amount of material is damaged in dismantling and re-erection. but normally none of the main members is affected. If the work is done carefully. with professional supervision. the only loss may be the holding-down bolts and a few roofing sheets.

72. A further design point which affects the flexibility of future operations is the design for loading platforms-at the rear of the transit shed. For berths which are expected to continue to be used for break-bulk car-

FIGURE 10

Types of transit shed construction



goes for some considerable time, the rear-loading platform running the whole length. of the shed is advantageous, as trucks may be loaded or discharged without the use of fork-lift trucks.

73. A s&which gives a level entrance at the quay side and a raised platform at the delivery side is useful if the slope can be kept very slight; a slope of 1 in 50 is often needed for drainage purposes, but a slope of more than about 1 in 40 can make stacking by fork-lift truck difficult. Thus, for the average truck tail-board height, it will only be possible to keep the slope acceptable in shed widths of 40 metres and upwards.

74. If the shed-long loading platform is considered unacceptable, then it may be preferable to keep the surface at one level and to use mobile loading ramps. This point must be studied at the time of design, and the cost of a sufficient number of mobile ramps must be added to the list of berth equipment included in the project costs. For this form of shed, the shed floor can be sloped on both sides with a slightly raised rib in the centre. This arrangement can help in saving cargo lying on the other side of the rib from water damage in the event of fire-fighting or washing of the shed.

M. Warehousing

75. Warehouse storage is needed:

(a) When the maximum cargo flow exceeds the storage capacity of a reasonably sized transit shed;

(b) Where the port wishes to engage in the commercial busines of long-term storage of cargo, for example, for cargo that must be aged, or cargo which is to be sorted, packaged and sold from the warehouse.

76. In deciding what is a reasonable size of warehouse it should be recognized that the transit shed and the warehouse in the rear are complementary: it is their total which makes up the storage capacity. In deciding how to divide the total storage capacity between them, the following factors must be considered:

(a) In many developing countries the cost of the labour needed to transfer goods to the warehouse is low and the cost of quayside land is high;

(b) There is both a minimum space needed for satisfactory operations and a maximum shed dimension before internal travel distances become too great;

(c) The financial incentive to consignees of avoiding the cost of transferring goods to the warehouse can be a useful means of preventing excessive clearance delays.

N. Layout for deep-sea berths

77. The modern break-bulk berth, especially in developed countries, will be required to accept an increasing amount of palletized or equivalent (e.g. pre-slung or bundled) cargo. Very few pure pallet berths are likely to be needed, but the changes in break-bulk berths made necessary by the increasing size of ships entail the gradual incorporation of many of the operational characteristics of the pallet berth concept. These include increased berth length and the provision of a large total terminal area including a wide, well-lit quay apron with a width of not less than 25 metres and preferably one of 30 metres. If large numbers of containers are to be handled, then we are no longer discussing break-bulk but rather multi-purpose facilities, which are described later. The need for better protection of most break-bulk general cargo results in the increase of the total shed area.

78. A typical berth layout for a modern break-bulk berth group handling conventional deep-sea liner traffic is given in figure 11. This diagram illustrates several points:

(a) The concept of a self-contained zone where the operations are planned and co-ordinated by a single management team;

(b) The substantial areas needed for operations, delivery zones and vehicle parks and movement;

(c) The provision of offices for agents of all kinds in the immediate vicinity of the operating area, to speed up the documentation and clearance of consignments;

(d) The provision of substantial parking areas for trucks and for private cars;

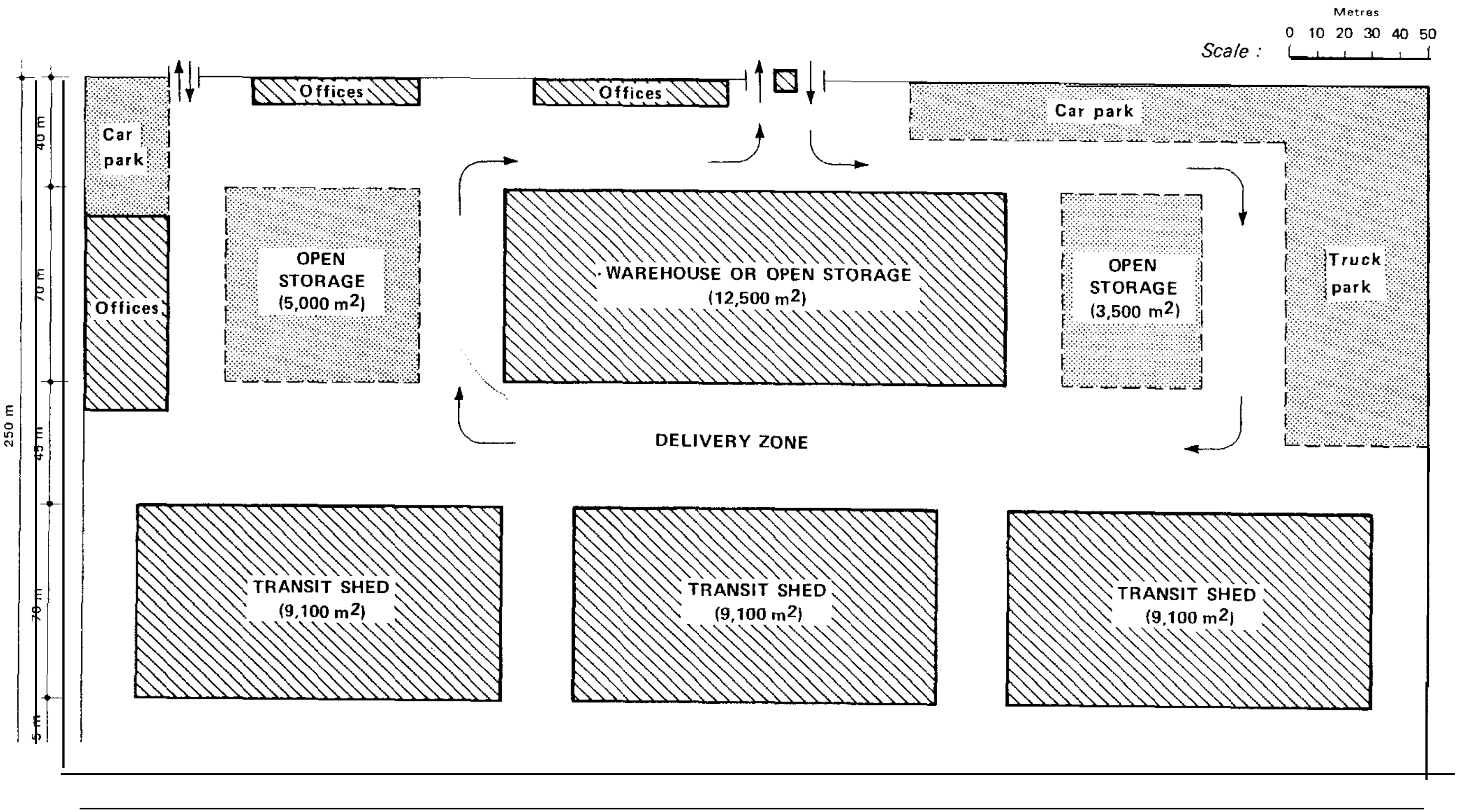
(e) The clearly laid one-way road circuit;

(f) The central road and rail delivery zone.

79. Each shed, with an area of over 9,000 square metres, will typically hold a maximum of 5,400 tons of

FIGURE 11

Typical modern three-berth break-bulk zone
(480 × 250 metres)



mixed cargo. For berths handling 100,000 tons per year through the shed, this size of store would allow goods to have an average transit time of 14 days on the assumption of 1 ton of goods per square metre of stacking area. The warehouse could be located further away without serious disadvantage, or it could be replaced by an open storage zone if there were a high proportion of open storage cargo. If a large number of 15-metre-long trucks were used for delivery, the road/rail delivery zone would have to be widened. In all cases the rail tracks should be set flush with the concrete surface to allow easy passage of road vehicles and wheeled port equipment.

80. In addition, space must be available in the area of the rear of the berth for some auxiliary facilities such as a small shelter for mobile equipment, sanitary facilities, changing rooms, a first-aid station and a canteen to serve the group of berths. A separate shelter for explosives or inflammable goods may also be needed and its location will depend on local port regulations. Altogether, a 200-metre-wide strip is the minimum usually needed to provide adequate space for all essential facilities-cargo-handling facilities, transit storage, delivery and receiving areas and ancillary services. The offices in the vicinity of the operating area should be used only for the personnel needed for daily routine operations.

0. Layout for coastal or island berth

81. A layout suggested by the UNCTAD secretariat for a small berth for coastal trade or as the general cargo facility for a small island is shown in figure 12. The features to be noted here are the ro/ro ramp and the clear road access to it. Substantial covered storage area is often needed at such berths since they may also be required to assume a limited warehousing role in view of the absence of users' depots in the local area.

P. Manpower planning

82. The principles governing the organization and planning of the use of labour are discussed in the IL0 publication (A.A. Evans, *Technical and Social* Changes in the *World's* Ports) mentioned in section B of the reference list given in annex II. That publication places the emphasis on the social aspects of changing methods of cargo handling, since these are the constraints which usually limit the port management's freedom of action.

83. Purely from a quantitative point of view, there is the requirement for the planner to specify the size of the cargo-handling labour force needed to operate a port. It is necessary, as with berthing-points and storage, to plan the size of the labour force separately for each berth group or zone, since there are not likely to be significant economies of scale extending beyond the boundaries of a port zone and, furthermore, productivity and labour motivation should be improved through a reasonable degree of specialization.

84. The composition or strength of a gang will be the subject of negotiation between the parties and the outcome will be arrived at by agreement. It is difficult to lay down what the minimum size of a gang should be for different types of cargo, and there is room for marked differences of opinion. There is, therefore, a great deal to be said in favour of not fixing gang strengths too rigidly in advance, but allowing them to be adapted to meet real needs. The first step is to decide the approximate labour requirements for the berth group and to plan in terms of number of gangs rather than in terms of manpower. The appropriate gang-pool size for each shift for the berth group may be calculated approximately as follows:

Gang-pool size per shift = Average number of gangs per ship per shift times the number of berths in the zone

Thus the total gang-pool size for the zone will be the gang-pool size per shift times the number of shifts per day.

85. However, this rough rule takes no account of the need, when all berths are occupied, to provide extra labour for peaks of demand caused by the simultaneous starting of work on a group of ships or by the need for intensive working on a number of vessels. Where there are more than six berths in a group sharing the same labour pool, no significant allowance need be made, but for smaller numbers of berths a reserve capacity of extra gangs above the number given by the approximate calculation may be needed. A shortage of gangs during periods of peak demand can have a direct effect on ship turn-round time. For typical traffic streams and berth occupancies, a simulation technique has been used to quantify this relationship.

86. Figure 13 shows, for two, four or six berths in the group, the increase in waiting time caused by various levels of gang-pool size expressed as the ratio of the number of gangs available to the gang-pool size given by the approximate calculation mentioned above. The effective gang-pool size is defined as the average number of gangs that are available to work at the terminal during a shift. Thus the number of gangs in the pool for one shift must be increased by a factor to take account of holidays and illness. A typical factor is 1.3. The average number of gangs per ship per shift is one of the elements used in planning chart I. As figure 13 shows, as the number of berths increases, the demand is smoothed, and the benefits of a ratio greater than 1.0 are reduced.

87. For example, a two-berth port, with an effective gang-pool size of four gangs and utilizing an average of two gangs per ship per shift, would have a ratio of 1.0. Therefore the ship time at port for this case, determined from planning chart II, would have to be increased by a factor of 1.2 which is obtained from figure 13. This increase in time is caused by shortages of gangs during peak periods. The waiting-time correction factor can be used in cost-benefit analyses to assist management in deciding how large the gang pool should be. In the above example, increasing the effective gang-pool size to five gangs would give a ratio of 1.2 and reduce the correction factor to 1.1. The 10 per cent reduction in ship turn-round time would have to be compared with the cost of increasing the gang-pool size. This analysis would assist management to deter-

FIGURE 12

Small modern coastal or island berth

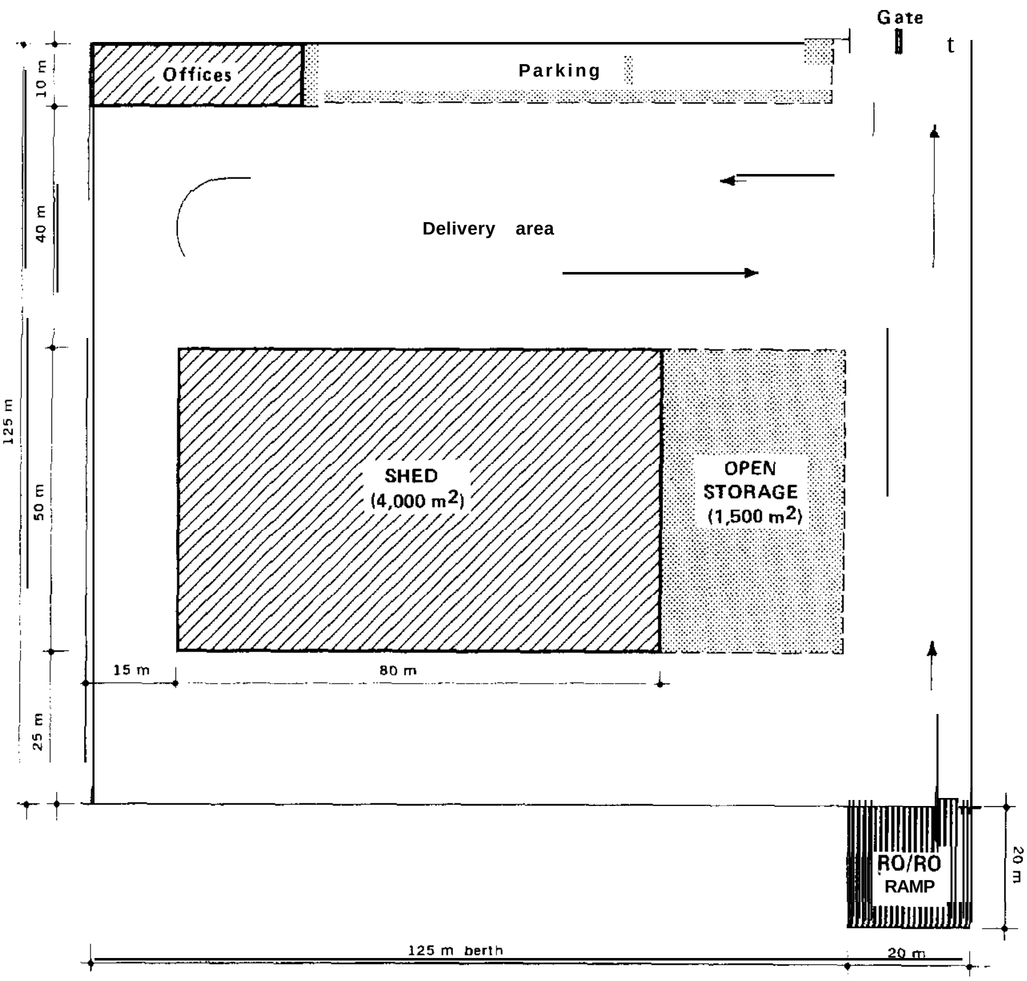
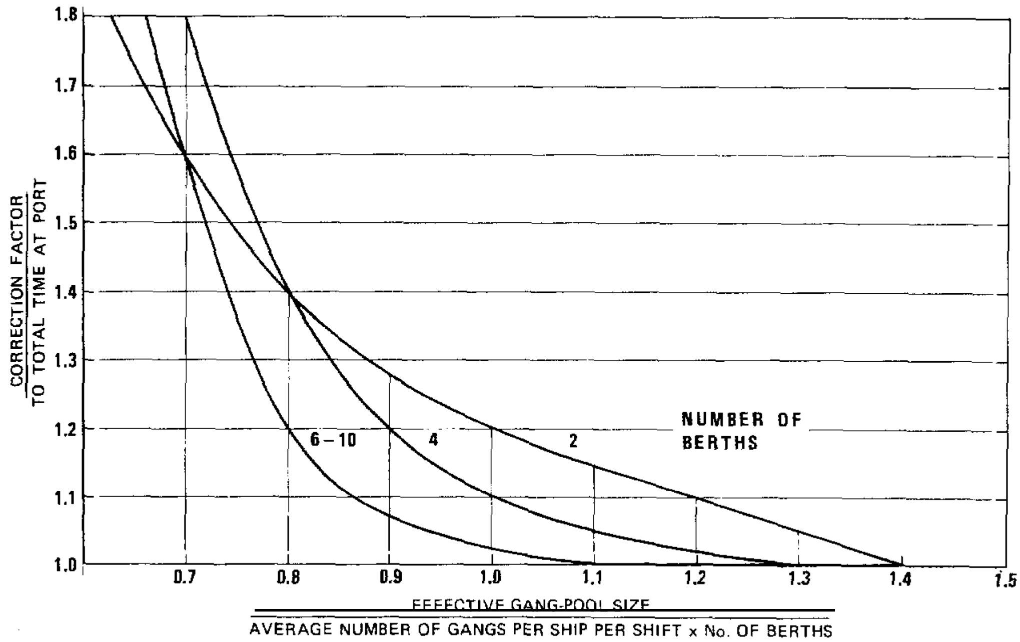


FIGURE 13

Gang-pool size correction factor for break-bulk general cargo terminal planning



mine the best gang-pool size.

Q. Quayside rail track

88. Although the volume of cargo for direct discharging to and loading from rail will be the governing factor, there is a strong case in general against quayside direct delivery to rail for break-bulk operations, Quayside wagon-shunting operations are very difficult to organize in such a way that high productivity can be achieved at the hatch being worked without interference with gangs working other hatches or other ships, Where possible, the loading to rail for onward transport in the case of imports, and the sorting of consignments from up-country for export, should be carried out in a rail yard away from the quay, with transfer from and to the quay being carried out on port mobile equipment. normally trailers. This move away from direct delivery to and from rail transport is due to the declining volumes of packaged bulk shipments being carried on general cargo liners. Only where a continuing and large volume of cargo in the form of heavy machinery, iron or steel and large bundles is foreseen, would the provision of quayside rail track be justified.

R. Quay cranes

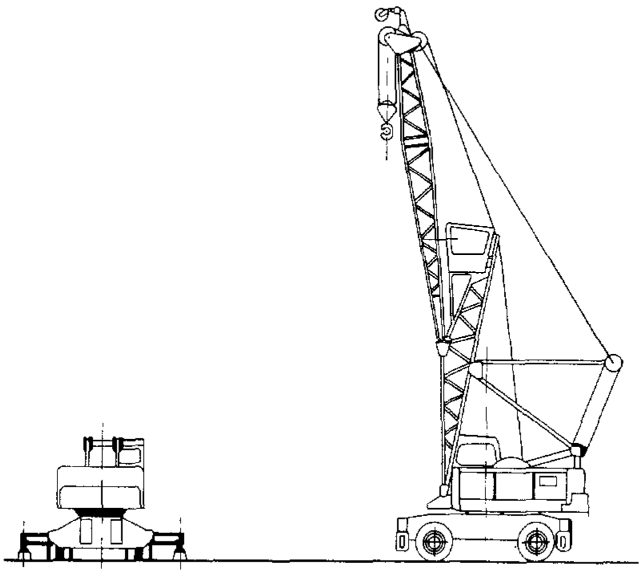
89. With the exception of those ports where there is a large tidal range, the use of quay cranes usually offers little handling advantage over the use of ship's gear while entailing heavy capital expenditure and additional maintenance problems. The difference in productivity between quay cranes and ship's derricks has generally been due to the difficulty of working derricks direct to rail wagons without frequent shunting. If there is no question of direct working to rail wagons, the difference in productivity becomes insignificant. The advent of shipboard electric cranes further sways the argument. The strengthening of the quay edge necessary for quay cranes, and the installation of the requisite crane track and electrical equipment involve further expenses which should be avoided where possible.

90. It may be necessary for port management to accept the idea that the traditional forest of crane masts is no longer the right picture of a break-bulk berth group. A clear, well-surfaced apron for speedy transfer operations is a more appropriate picture. Only in the case where a continuing and large volume of heavy lifts is forecast are rail-mounted quay cranes justified.

91. If conventional rail-mounted quay cranes are not to be provided, a small number of mobile cranes on pneumatic tyres will be needed to lift the heavy items, including containers carried on deck, that will inevitably arrive. Normally, these special cranes will be needed for only a fraction of the ship working time and the number required is small, normally one per berth or one for two berths. When not required, they can supplement the mobile cranes working in open storage areas. These heavy mobile cranes with high towers for ship working are at least as expensive as conventional quay cranes, but they are much more flexible. A typical crane is shown in figure 14.

FIGURE 14

Mobile dockside tower crane



S. Provision of mobile equipment

92. When traditional handling methods are used in conventional break-bulk operations, the equipment allocated for the transfer of cargo to and from the quayside is often insufficient to permit the transfer operation to keep up with the hoisting of loads in or out of the ship's hold. This is demonstrated by the frequent sight of a stationary crane or derrick waiting for a load to be hooked on or off. Careful equipping and planning of the transfer operation will thus often be the most effective single method of raising ship-handling productivity.

93. It is difficult to give clear economic justification for any specific level of equipment for the quayside operation, as can be done for the provision of berths and sheds; the estimate of equipment needs must be based on experience of the type of operation proposed. When the equipment needs have been estimated they must be included, together with the estimates for reserve equipment, spare parts and maintenance services, as an integral part of the investment proposal. No attempt should be made to economize in this area, since without proper equipment the economic and financial success of the whole investment will be jeopardized.

94. In recent years the quantity of mechanical handling equipment needed per berth has increased owing to the greater variety of cargo classes, including a higher proportion of palletized cargoes, and increasing numbers of containers and heavy loads carried on virtually every route, together with a continuation of the traditional break-bulk cargo. Moreover, higher equipment requirements than seem appropriate at first sight must be provided to allow for the time equipment is out of service because of scheduled maintenance, breakdowns and repairs.

95. As described in part one, chapter I, the project plan for a new development should include an operational plan. This plan should describe how ships are to

be discharged and loaded. and goods are to he transferred to and from the ship's side. and how they are to be stacked in the sheds and open storage areas. The equipping and layout of the facilities should be based on this operational plan.

96. Nevertheless, it is often difficult at the time of planning a break-bulk berth to estimate precisely what the proportions of the different traffic will be. In this case a standard equipping policy can be adopted along the lines set forth below.

97. The types of equipment needed for each part of the operation are as follows:

(n) Discharging and loading;
Where ship's gear is appropriate: nil;
For containers and heavy lifts: mobile tower crane at ship's side.

(h) Transfer between quay and storage areas:
Fork-lift truck
or
Tractor/trailer combination.

The tractor/trailer combinations can be used in many ways, according to the transfer distance and how long the tractor would be immobilized either at the ship's side or at the stack if it remained coupled to the trailer. In principle. as suggested in the report of the UNCTAD secretariat on berth throughput[1]. the tractor should be uncoupled at both ends of the journey, working with three sets of trailers (one being loaded, one being unloaded and one being towed). This is often difficult to do and. since the best method of transfer may be to tow either a single trailer or a train of two or three trailers, exact planning is difficult. An overall average for working methods would be in the region of two tractors and eight trailers per gang.

(c) Stacking and sorting in shed or open areas. and delivery from these areas:
Fork-lift truck
or
Mobile yard crane.

98 It is unlikely that equipping decisions will be needed for a single berth in isolation, since to provide for all possibilities will then be very costly. It is preferable to plan the equipping of groups of berths-say, three at a time-with a daily allocation of the three-berth pool of equipment as required. For the three-berth group shown in figure 11, the following would be a suitable scale of equipment for allocation among ten gangs:

(a) For four gangs working ship's derricks to fork-lift trucks:
12 fork-lift trucks:

(b) For four gangs working ship's derricks to tractor/trailers:
8 tractors;
32 trailers;

(c) For two gangs working mobile cranes to tractor/trailers:
2 mobile tower cranes:
4 tractors;
16 trailers:

(d) For transit shed and open storage area operation:
8 fork lift trucks;
4 mobile yard cranes.

99. The three-berth equipment should then be boosted by a reserve for breakdowns and preventive maintenance, as follows:

Mobile cranes	20 per cent (but it will often be necessary to provide one spare crane in any case)
Fork-lift trucks	25 per cent
Tractors ..	20 per cent
Trailers	5 per cent

This gives a total three-berth equipment of:

20-ton mobile tower cranes	3
10-ton mobile yard cranes	5
Fork-lift trucks	25
Tractors	15
Trailers	50

100. This level of equipping can be scaled up or down according to the number of gangs in the operation plan for the port zone. In the absence of local operational statistics, the following number of gangs may be assumed for planning purposes:

Deep-sea ships	3 gangs, occasionally 4 (average 3⅓)
Smaller coastal and short-sea ships	1 or 2 gangs (average 1½)

T. Cargo-handling attachments

101. The correct range of cargo-handling attachments cannot be exactly specified until the detailed composition of the traffic is known. In order to make funds available for their purchase, during and after commissioning of the new facilities. a definite provision should be made in the project budget. If this is not done there can be delays in obtaining authorization for minor purchases that can seriously endanger the operation of the new facilities.

102. A few of the attachments which may be required for fork-lift operations are illustrated in figure 15. Mobile cranes will also need a range of hook gear, including container spreaders as well as standard stevedore's gear. A suitable provision to include in the project budget is a figure related to the number of cranes and fork-lift trucks provided in the following manner:

Equipment	*Budget cost of attachments as a percentage of total purchase price*
Mobile tower crane	10
Heavy fork-lift truck	15
Light fork-lift truck	25

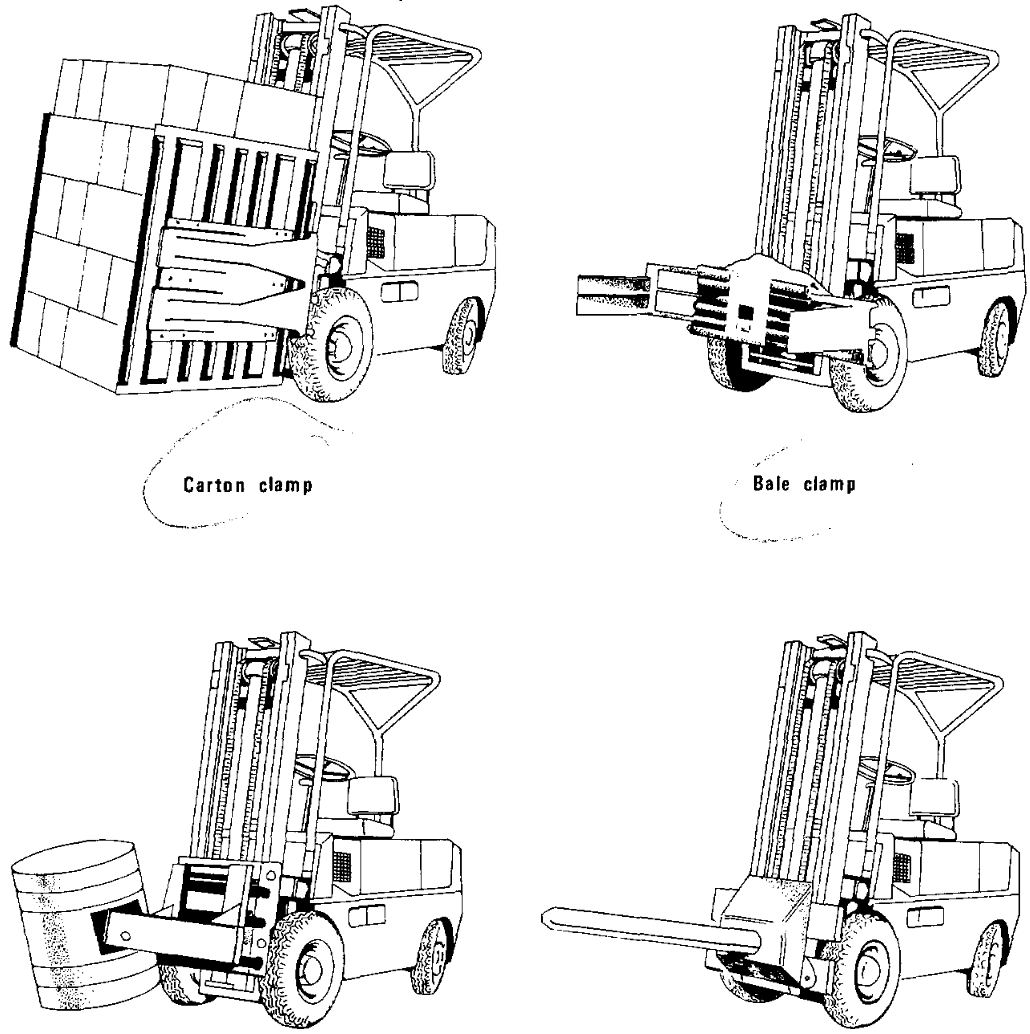
U. Elevators and conveyors

103. There are certain limited roles for elevators and conveyors in break-bulk operations. Pocket eleva-

[1] See *Berth Throughput Systematic Methods for Improving General Cargo Operations* (United Nations publication, Sales No. E.74.11.D.l). part one. chap IV.

FIGURE 15

Examples of fork-lift truck attachments



Carton clamp

Bale clamp

Drum clamp

Port attachment

tors can be used to work in and out of ship's holds for large consignments. They consist essentially of two continuous strands of chain which carry a continuous canvas band arranged in loop pockets. Although theoretically such elevators working continuously can produce substantial outputs, in practice there are frequent interruptions and in general terms it is unlikely that a pocket elevator can reach the speed of a well-planned conventional lift-off operation.

104. Various types of conveyor, such as slat, roller, belt and plate conveyors, can be used wherever the physical dimensions of the ship and quay permit, for example in the side ports of side-loading ships. They may also be used in transport sheds and warehouses. All conveyors, however, form a barrier to other movements and therefore conveyors made up of portable sections are to be preferred to fixed ones when used on the quay apron. Although conveyors are ideal for horizontal transport, they are not cheap, and the scale, speed and flexibility of the operation should be carefully assessed before installing a large conveyor system.

Chapter III

CONTAINER TERMINALS

A. Container ship development

105. Container ships are generally classified into "generations", that is, as having characteristics typical of certain stages in container development and container shipbuilding. The main characteristics of each "generation" are shown in table 1. The term TEU (twenty-foot equivalent unit or equivalent in goods to a container of 20 feet) is a useful standard term for defining the carrying capacity of a container vessel: a 40-foot container therefore counts as two TEUs. The principal dimensions of 20-foot and 40-foot steel containers are given in table 2. The R-foot high 20-foot container has been largely replaced by the X-foot 6-inch unit. and for the 40-foot container the trend is towards units of 9 feet to 9 feet 6 inches.

TABLE 1

Physical characteristics of container ships

	Container capacity (TEUs)	*Dwt*	*Overall length (metres)*	*Overall width (metres)*	*Draught (metres)*
"First-generation" container ships	750	14 000	180	25	9.0
"Second generation" container ships	1 500	30 000	225	29	11.5
"Third generation" container ships	2 500–3 000	4owo	275	32	12.5

106. To keep operating costs to a minimum, the maximum utilization of these large modern vessels must be achieved. Thus there has been a move to reduce the number of ports of call of the mother ships and to introduce feeder vessel services to the ports with smaller volumes of trade. The feeder ships have the task of relieving the long-haul container ships from making the extra calls which greatly increase the total time they spend in ports. Feeder ships vary in size from capacities of 50 to 75 TEUs up to 300 TEUs.

107. The rapid spread of container operations has been very fully documented. A detailed discussion of containerization and its impact on ports in developing countries is given in the UNCTAD publication on the subject" and in a series of reports prepared by the UNCTAD secretariat on the subject of technological change in shipping and its effects on ports.' The last major trade routes between highly industrialized countries have been containerized. At the same time, there is an increasing trend towards containerization of certain specific services linking developing and developed countries.

[2] *Unitization* of Cargo (United Nations publication, Sales No. E.71.11.D.2).

[3] "Technological change in shipping and ifs effects on ports" (TD/B!C 4/129 and Supp.1–6).

TABLE 2

Principal dimensions of typical steel containers

	20 ft × 8 ft × 8 ft		*20 ft × 8 ft × 8ft 6 in.*		*40 ft × 8 ft × 8 ft 6 in.*	
	Corrugated roof	*Flat roof*	*Corrugated roof*	*Flat roof*	*Corrugated roof*	*Flat roof*
Inside (*in millimetres*)						
Length	5 897	5 897	5 897	5 897	12 022	12 022
Width	2 352	2 352	2 352	2 352	2 352	2 352
Height	2 246	2 221.5	2 395.5	2 371	2 395.5	2 371
Door opening (*in millimetres*)						
Width	2 340	2 340	2 340	2 340	2 340	2 340
Height	2 137	2 137	2 280	2 280	2 280	2 280
Inside cubic capacity (in *cubic metres*)	31.5	30.8	33.2	32.9	67.7	67.0
Tare weight (*in kilograms*)	2 230	2 260	2 300	2 330	4 050	4 loo
Stacking capacity	9 high	9 high	9 high	9 high	9 high	9 high

108. Examples of this trend are services between Europe and the Caribbean, between Europe and the Middle East, between Europe and West Africa, between Europe and the Far East, between Europe and South America, between North America and the Far East, between North America and South America and between North America and Central America. Generally the vessels involved are of the first generation or, on the shorter runs, feeder vessels. The basic problems with these services are the imbalance of trade and the labour problems caused by the reduced damage for manpower.

109. At present these and similar container services carry a fraction of the general cargo liner traffic between developed and developing countries, but in developed countries' ports container services already handle between 70 and 80 per cent of the cargo. Therefore port authorities in developing countries must consider the development towards containerization of their countries' trade, and the profound changes in port planning, management and operations which such development brings with it. Thus it is not a question of whether or not to containerize, but rather when to containerize.

110. Both the break-bulk berth group and the multi-purpose terminal must be capable of handling containers-even if, in the former case, only a small number of units are carried (mainly on deck) in a liner operation. This chapter is concerned with the specialized container terminal needed to handle the cellular container ships.

111. These large ships will not normally call at a port without a specialized container terminal offering a specified level of service. By investing in a specialized terminal a port can make calls by container ships possible, but such an investment cannot be financially justified until a satisfactory level of use is guaranteed. The container throughput must be around 50,000 TEUs per year if the investment is to be justified. Below this level, the port should either provide limited facilities for container feeder ships or adopt the transitional multi-purpose terminal described in the next chapter.

B. Planning and organization

112. It is wrong to imagine that the planning, organization and running of a container terminal is a straightforward task. Figure 16 gives an indication of the main factors which have to be taken into consideration in planning a container terminal and can be used as a checklist in order to ensure that none of the most important issues have been overlooked. The complexity of this type of terminal coupled with its newness necessitates a comprehensive training programme of the senior operating staff, often in a well-organized and efficient container terminal.

C. Productivity

113. There has been considerable inaccuracy in predicting container terminal productivity. In the course of its investigations into technological change in shipping and its effects on ports. the UNCTAD secretariat found that the average throughput for a sample of 21 ports was 442 containers per 24 hours in port,[4] a figure significantly below figures which are often quoted.

114. The average productivity per hour per vessel, even averaged over a long period, varies considerably from one terminal to another. from about 10 to 50 containers per hour, even on the same cellular ship operated by two gantries, averaged over a 24-hour period. This figure refers to single units either loaded or discharged and includes any idle time within a working period. The early operating objective of lifting one container off and one container on in a combined cycle is now rarely achieved or even attempted for any significant period.

115. The gross productivity per hour can be converted to a daily figure by using the ratio of working time to berth time. The working time includes any idle time within a working period, such as that due to equipment breakdown, and therefore for ports operating around the clock the ratio could be 100 per cent. A number of reasons prevent ports from achieving this 24-hour per day operation, however, and the ratios usually vary between a peak of 95 per cent and a low of 40 per cent. Clearly this variation in the intensity of working can have a significant effect on the annual throughput of the terminal.

116. The figures for throughput per 24 hours in the sample referred to above varied from a high of approximately 750 containers to a low of approximately 225 containers. The average throughput for these terminals was nearly 450 containers per 24 hours in port, Given that at most terminals 24-hour operation seven days a week is standard practice, the typical throughput was calculated as follows in the early 1970s:

Average output per gantry-crane 20 units per hour
Average number of gantry-cranes allocated to each vessel: 2
Working time/berth time ratio: 0.80

Thus, according to this earlier method,

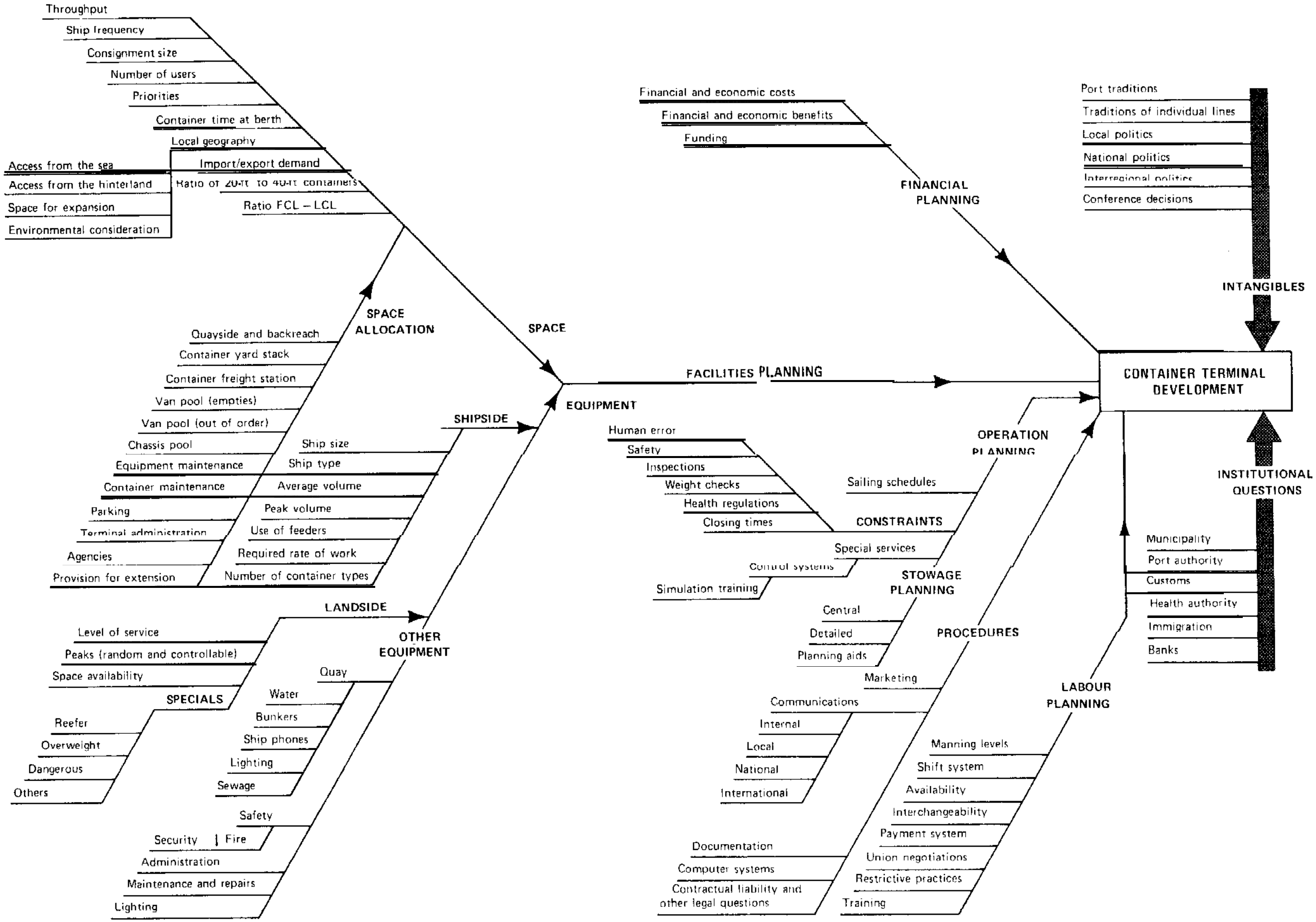
Average throughput per 24 hours = 24 (average output per crane) × (average number of cranes allocated) × (working time/berth time ratio)
= 24 (20 × 2) (0.80)
= about 770 containers.

117. The actual average throughput of the sample is slightly less than 60 per cent of this theoretical figure. Clearly the figures used in this procedure are too optimistic for planning purposes and more realistic figures should be used when calculating ship turn-round time for the economic analysis, especially when one considers that this sample is for major terminals handling second- and third-generation cellular vessels and working three shifts with two cranes on average.

[4] "Technological change in shipping and its effects on ports: the impact of unitization on port operations" (TD/B/C.4/129/Supp.1), para. 90.

FIGURE 16

Dependency tree for container terminal planning



118. There is little doubt among container terminal experts that the present performance of container facilities throughout the world is far from optimum. No doubt part of the difficulty stems from the fact that there is excess capacity at the present time of economic slump and that fewer goods are being moved by this form of transport. However, there are also operational inefficiencies which are due to inappropriate planning decisions, operating procedures, equipment or manpower policies. The main reasons lie in the imbalance between the capacities of the various system parts at a terminal, which results in low hourly productivity per crane, and inadequacies in the inland transport system, which often results in long non-operational periods.

119. In general, the capacity which has been provided for the loading and unloading of containers exceeds the terminal's transfer, stacking, storage and delivery capacity. This has been due primarily to an underestimation of the transfer distances that would have to be covered and of the proportion of time that equipment would be out of service for maintenance purposes. A survey carried out in four ports in the United Kingdom showed that the proportion of time during which straddle-carriers were out of service for maintenance averaged almost 30 per cent.[5] The figure was even higher than this in ports with a high workload. This fact supports the UNCTAD secretariat's view that, for developing countries, tractors and trailers are likely to be the most economic system for the transfer operation and that straddle-carriers should be considered as merely one possibility for the stacking operation.

D. Container handling systems

120. The four most commonly used container handling methods in operation today are the trailer storage system, the heavy-duty fork-lift truck system, the straddle-carrier system, and the gantry-crane system, the gantry-cranes being either rail mounted or rubber tyred. There can also be various combinations of these types of equipment at individual terminals. The essential features of each of the main systems are given in the following paragraphs.

1. TRAILER STORAGE SYSTEM

121. The import containers discharged from a ship by crane are placed on a road trailer, which is towed to an assigned position in the storage area where it remains until collected by a road tractor. Trailers carrying containers for export are placed in the storage area by the road tractors and towed to the ship by port equipment. The containers are thus of necessity stored one high. requiring a large transit storage area (see figure 17). Limited soil improvement is required due to low loading. This is a very efficient system because every container is immediately available for removal by a tractor unit, but in addition to requiring a large area it also requires thousands of trailers, entailing considerable expense. This method is therefore normally used only when a shipping company provides the trailers and either operates at a leased or reserved berth or has access to a special trailer compound. This makes trailer storage generally unsuited for use by multi-user terminals. As a rough rule of thumb for 2,000 TEUs, a container storage area of 100,000 square metres is required.

2. FORK-LIFT TRUCK SYSTEM

122. A heavy-duty fork-lift truck with a capacity of 42 tons and a top-lift spreader is capable of stacking fully loaded 40-foot containers two or three high, with the most common stacking height of two high. A side spreader can be used for 20-foot containers, both full and empty, and for 40-foot empties. Empty containers can be stacked four high. This system places heavy loading on the surface of the terminal and adequate soil improvement and surfacing must therefore be provided. Most port authorities and cargo-handling companies have experience in both the operation and maintenance of fork-lift trucks. Such trucks can transfer containers from the ship's side to the stacking area, or tractor-trailer units can be used which will reduce the number of fork-lift trucks required. Typical aisle widths in the stacking area are 18 metres for 40-foot units and 12 metres for 20-foot units. As a rough rule of thumb for 2,000 TEUs, with an average stacking height of 1.5 boxes, a container storage area of 72,000 square metres would be required.

3. STRADDLE-CARRIER SYSTEM

123. At the present time the straddle-carrier system is the predominant one. Straddle-carriers can stack containers two or three high, move them between quay crane and storage area, and load or unload them to or from road transport (see figure 18). In the past, however, these machines have had a poor reliability record. poor visibility, high maintenance costs and a short life. Leaks from joints in the hydraulic system and oil spillage from damaged pipework caused highly slippery surfaces, broke up asphalt paving and necessitated continual renewal of the white lines and numbers essential in stacking areas. Safe operation demanded that straddle-carriers should operate within a restricted area, and that workers on foot should be kept out of the working area. The fact that despite these drawbacks the straddle-carrier is so widely used is a testimony to its flexibility and its ability to meet peak requirements. Furthermore, major improvements have been made in the design of straddle-carriers, and most of their poor maintenance record resulted from a lack of preventive maintenance and the excessive use of the equipment for transfer operations. A variant of this system is the use of tractor-trailer units for the transfers between quayside and storage area, and the use of straddle-carriers only within the storage area for stacking and selecting containers. Approximately six straddle-carriers are required for each ship-to-shore gantry-

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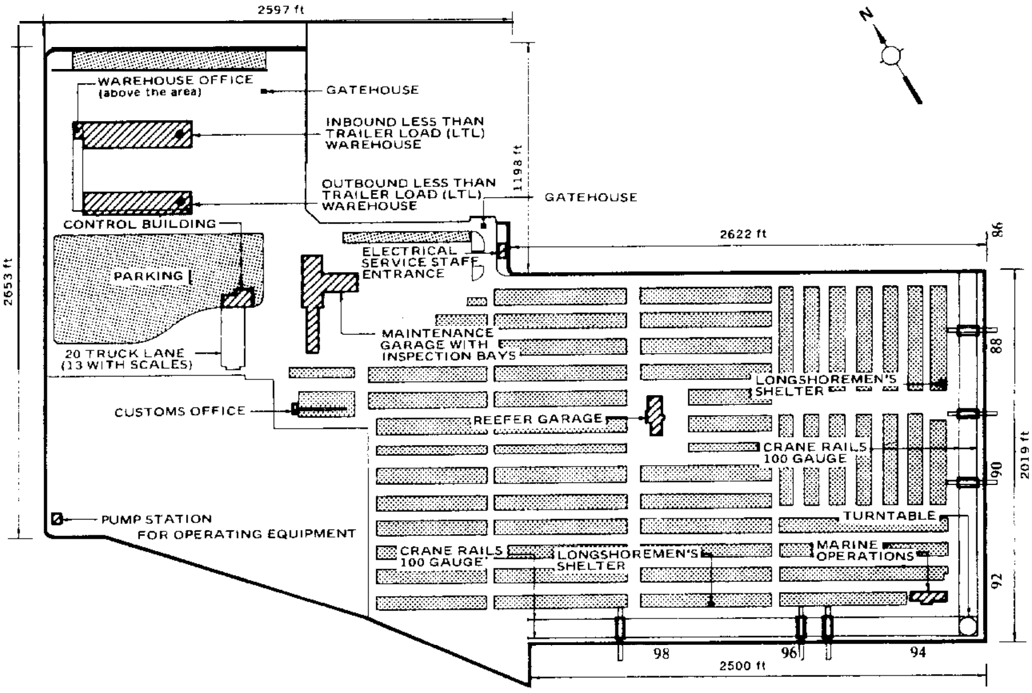
[5] H. K. Dally, "Straddle carrier and container crane evaluation", *National Ports Council Bulletin* (London), No. 3, 1972.

FIGURE 17

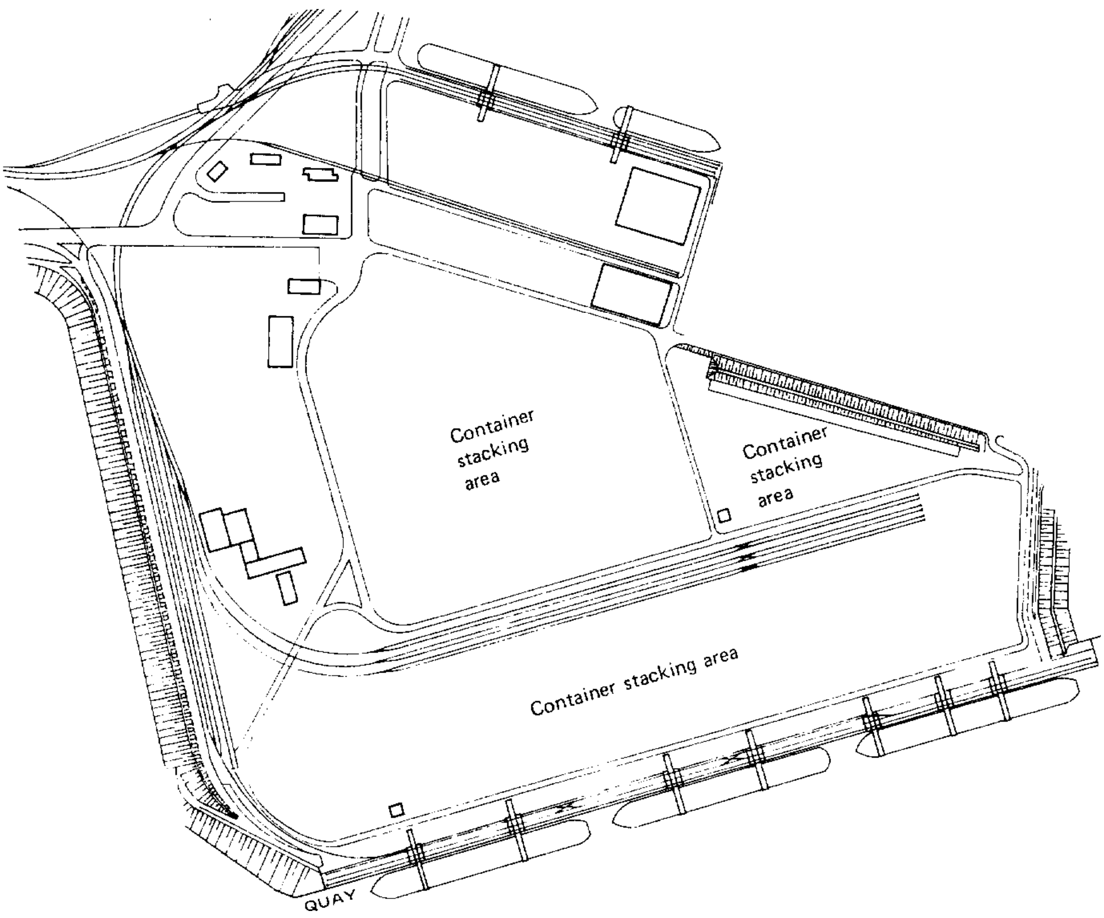
Example of trailer storage container terminal layout



General plan of new sea-land terminal at Elizabeth, New Jersey. (Parking space 3,757 35-ft containers and 2,498 40-ft containers.)

FIGURE 18

Example of straddle-carrier container terminal layout



Container terminal, Bremerhaven (Federal Republic of Germany) crane. As a rough rule of thumb for 2,000 TEUs, a container storage area of 40,000 square metres for 1.5-high stacking, or 30,000 square metres for two-high stacking is required.

4. GANTRY-CRANE SYSTEM

124. In this system, containers in the storage area are stacked by rail-mounted or rubber-tyred gantry-cranes (see figure 19). Rail cranes can stack containers up to five high (although normally containers are stacked no more than four high). Rubber-tyred gantry-cranes can normally stack containers two to three high. Tractor-trailer units make the transfers between quayside and storage area. This system is economical in land because of the high stacking, and is suitable for varying degrees of automation. Gantry-cranes have a good safety record, are reliable and have low maintenance costs and a long life in comparison with straddle-carriers. They are far less flexible but to offset this, gantry-cranes (particularly the rail-mounted type) are better suited for automation. In the longer term, the need to economize in land is likely to be very important, and this favours the use of gantry-cranes. This system is especially useful where exports are a substantial proportion of the total traffic, but perhaps less than optimum where import cargoes constitute the major portion of the traffic. This is because import containers need to be retrieved in a random fashion and, with high-stacking freight, many units need to be shifted. As a rough rule of thumb for 2.000 TEUs, a container storage area of 16,000 square metres is required for 3.5-high stacking.

5. MIXED SYSTEMS

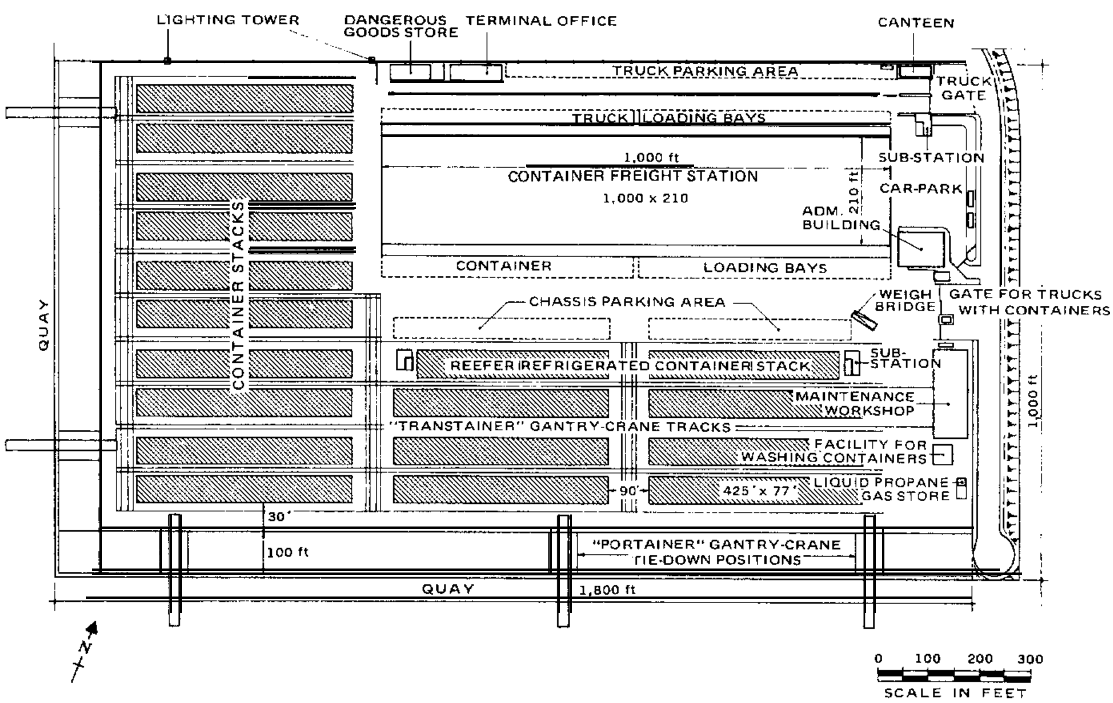
125. Mixed systems employ the best equipment for the particular operation. However, for such systems to be successful, a comprehensive information system and rigid operating policies are required, together with excellent management. For example, straddle-carriers are used for extracting individual import containers and delivering them to road vehicles, but gantry-cranes are used in the container park for feeding exports to the ship where it is possible to work straight off an export stack. Another mixed system is one using straddle-carriers for stacking full containers and fork-lift trucks for empty containers.

E. Area requirements

126. The choice of operating methods and equipment, and thus the area of land needed for a container terminal, depends to a high degree on the availability of local land and on soil conditions. If the terminal is located far from urban agglomerations and land is plentiful and inexpensive, a system of storing containers only one high may be the most economical. For this layout, no costly equipment is needed for stacking containers but transfer distances may become long, resulting in additional transfer equipment being needed. Also, on reclaimed land with relatively soft soil, this one-high method is particularly advantageous since the carrying capacity of the soil does not need to be reinforced as it would for heavy stacking equipment. On the other hand, if land is scarce and expensive, the stacking of containers as high as physical conditions and commercial requirements allow becomes a necessity

FIGURE 19

Example of gantry-crane container terminal layout



127. Lack of container storage space has been another serious constraint on operations. It is true that, since the introduction of containerization on the major trade routes, there is a trend towards larger storage areas for container terminals. but in many. planned developments the space requirements are still under-estimated. Sufficient operational area must be left for interchange areas for both ship-to-shore and stack-to-inland operations, as well as for vehicle parking, maintenance, workshops and administrative buildings.

128. The most frequent error has been to assume that the maximum stacking height can always be attained. In practice the average stacking height is much lower, depending on the amount of shifting of containers necessary in the storage area. and the need for containers to be segregated by destination, weight class. direction of travel (inward or outward). sometimes by type and often by shipping line or service. The need for storage of empty units and of unserviceable containers has also often been overlooked.

129. A further serious mistake is the belief that containers have a shorter terminal transit time than break-bulk cargo. In fact, the same constraints which cause break-bulk cargo to stay in the port will often have a similar effect on container cargo. In practice it is not unusual to find that the transit times for both are very similar. The following are typical delay times for containers at container terminals taken from a number of terminals:

	Days
Containers carrying import cargo	7
Containers carrying export cargo	5
Empty containers	20

130. Planning charts similar to those whose use is explained in section G of chapter II, "The break-bulk berth group", are also helpful in container terminal planning.

131. When sufficient space is set aside for the container park, container freight station (CFS), marshalling and other administrative areas for a terminal operating adjacent to the quay, then there are bound to be enough berths for the traffic. For this reason, the terminal area requirements are calculated first, and then the number of berths checked to see if there is enough berthing capacity.

132. Container terminal, planning chart I (see figure 20) is used to determine the most important dimension of a container terminal, the container park area. The figure for the number of TEUs to be handled across the quay per year is entered on the planning chart. The planner descends vertically to the turning-point where the vertical line meets the line representing the average time the container spends in transit at the terminal. He then moves horizontally to the left to the next turning-point defined by this horizontal and the appropriate line for the area requirement per TEU.

133. The area requirement per TEU depends on the type of container-handling equipment used and the consequent access requirements and maximum stacking height. Typical area requirements are as follows:

	Stacking height (number of containers)	*Square metres per TEU*	
		20-ft container	*40-ft container*
Trailer	1	60	45
Fork-lift truck	1	60	80
	2	30	40
	3	20	27
Straddle-carrier		30	
	2	15	
	3	10	
Gantry-crane	2	15	
	3	10	
	4	7.5	

134. The planner then descends again to the ratio of the average to the maximum stacking height of containers. The average height is the level at which operationally the container park area is considered full. For example. although a straddle-carrier can stack containers three high, it would not be practical for the operator to stack the entire park three high as it would then be impossible to remove individual containers. An adjustment factor must therefore be applied to allow for this fact. The planner now moves horizontally to the right to the reserve capacity safety factor-the factor which allows the park to handle peaks in demand.

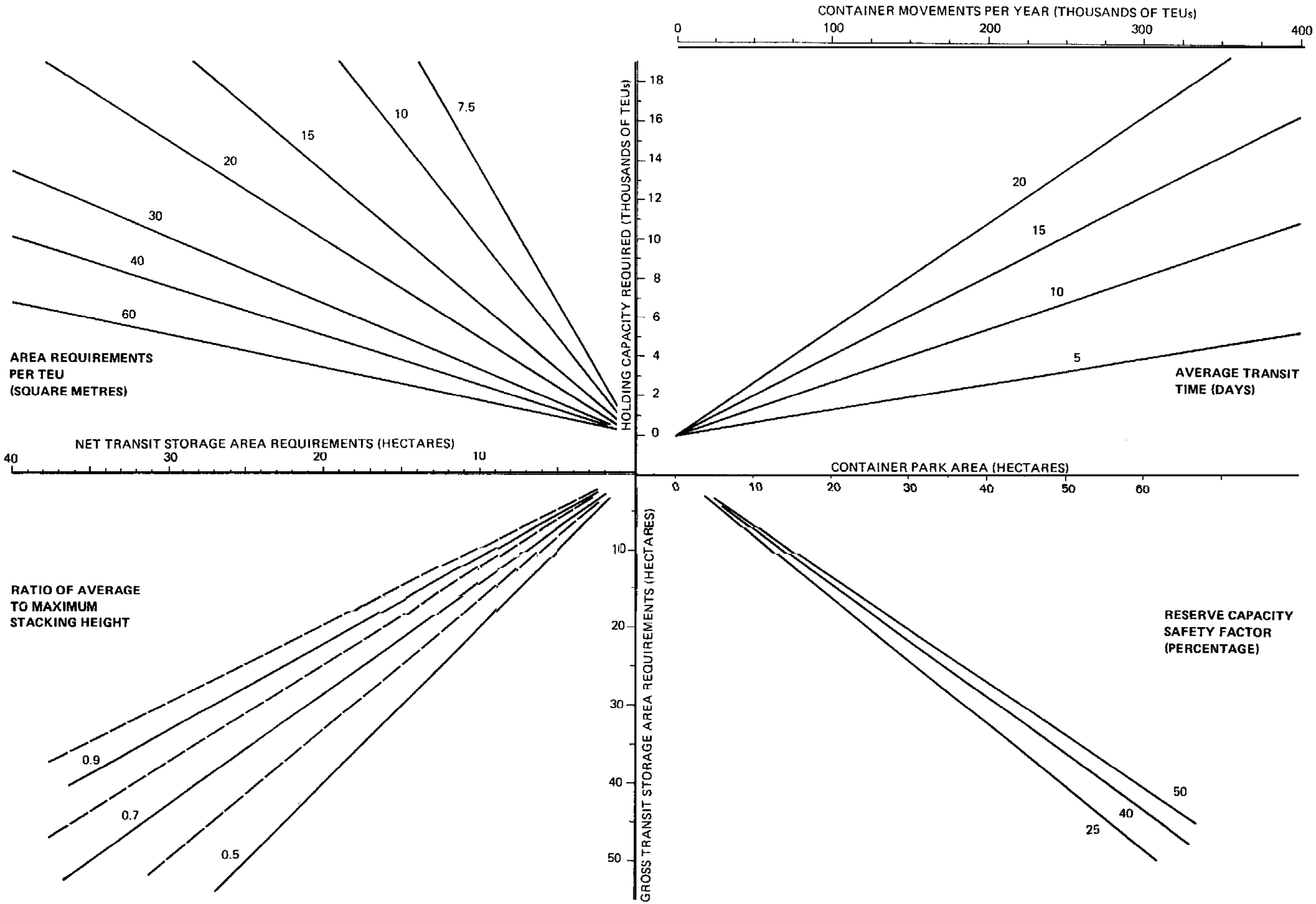
135. Finally he moves upwards to the container park area required. The intersections of the trajectory and the axes give the planner the following information: holding capacity required, in TEUs; net transit storage area requirements; gross transit storage area requirements; and container park area. The chart may be used repeatedly to determine the effect on area requirements of different handling equipment in order to find the most economical solution for local conditions.

136. The planner must now estimate the area requirements for the CFS, the structure used for "stuffing" and "stripping" containers and for consolidating and sorting consignments in the port area. Assuming that each TEU container handled via the CFS requires 29 cubic metres of space, the CFS storage area can be determined by using planning chart II (see figure 21). The following turning-points are used: average transit time of consignment; average stacking height in CFS; access factor to allow for circulation and operational areas in the CFS; and reserve capacity safety factor for periods of peak demand. For example, a terminal at which 20,000 TEUs per year pass through the port CFS, with a mean transit time of 10 days. a stacking height of 2 metres, an access factor of 0.4 and a safety factor of 25 per cent, would require a CFS storage area of 14,500 square metres[6]. The structure should also have a large roof overhang to allow protection of the container loading bays from the weather (see figure 22).

[6] This figure can be compared with other CFS areas at the following container terminals: Guam: 2 berths. CFS 3.066 m^2; Keelung: 5 berths, CFS 2,700 m^2; Port Kelang: 2 berths. CFS 6,771 m^2; Singapore. East Lagoon, 3 berths. CFS 21.000 m^2; Kwai Chung berth 4: 3 berths, CFS 23.241 m^2

FIGURE 20

Container terminal, planning chart I: container park area



Note: 1 hectare = 10,000 m^2.

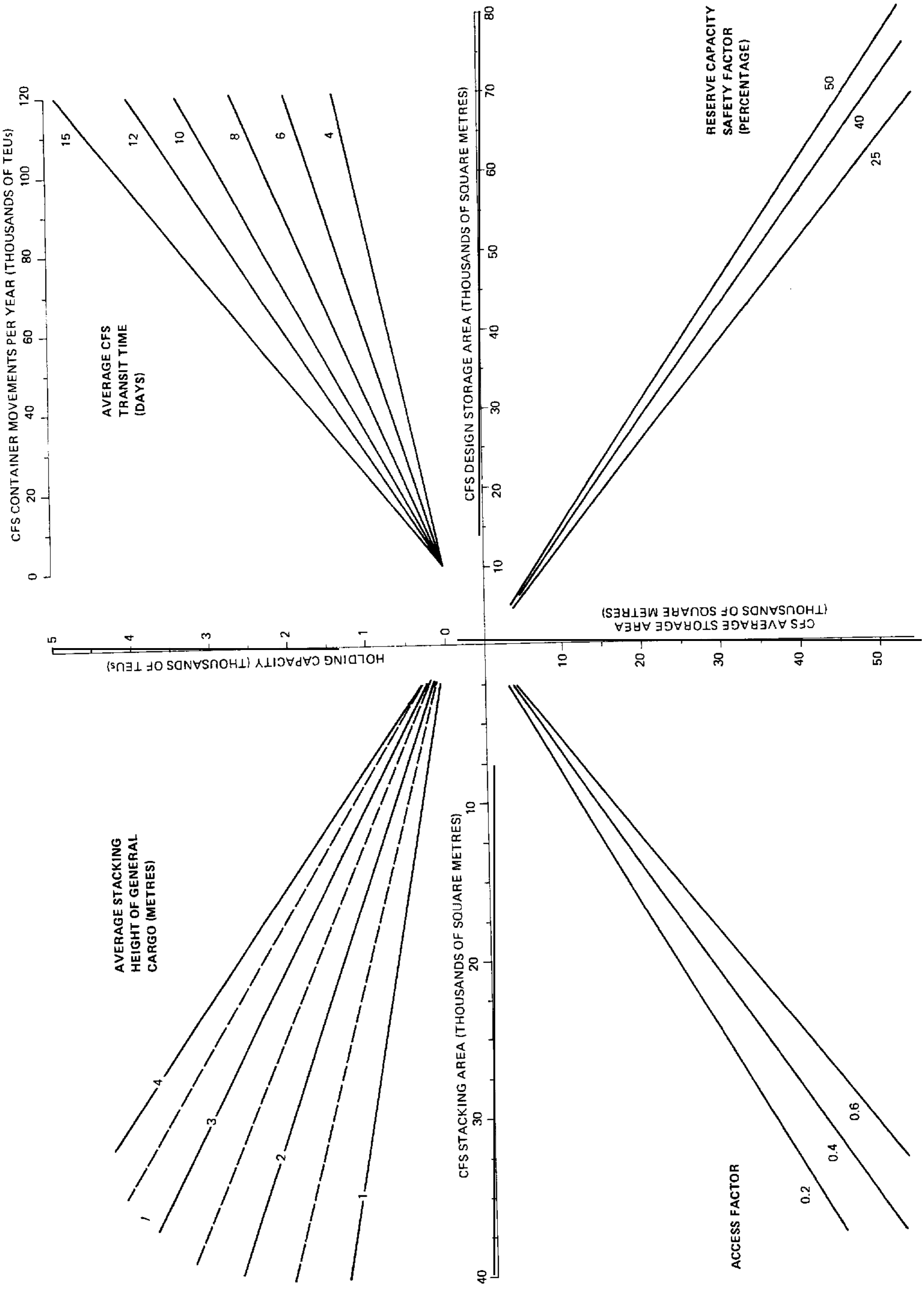
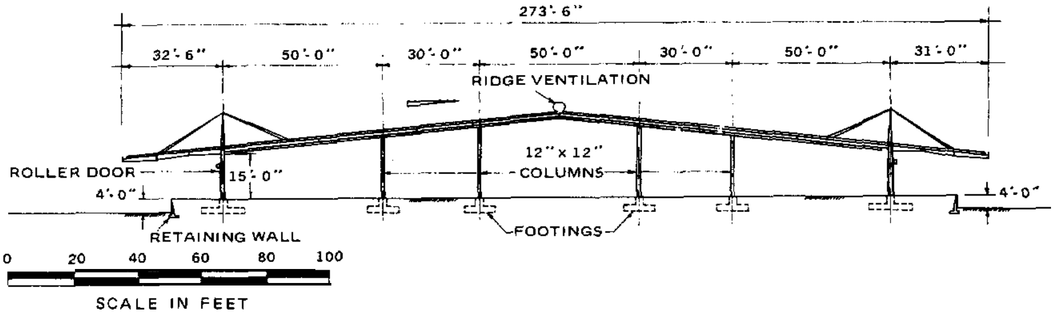

CFS CONTAINER MOVEMENTS PER YEAR (THOUSANDS OF TEUs)
0
20
40
60
80
100
120
AVERAGE CFS TRANSIT TIME (DAYS)
15
12
10
8
6
4
CFS DESIGN STORAGE AREA (THOUSANDS OF SQUARE METRES)
10
20
30
40
50
60
70
80
RESERVE CAPACITY SAFETY FACTOR (PERCENTAGE)
50
40
25
HOLDING CAPACITY (THOUSANDS OF TEUs)
0
1
2
3
4
5
CFS AVERAGE STORAGE AREA (THOUSANDS OF SQUARE METRES)
10
20
30
40
50
AVERAGE STACKING HEIGHT OF GENERAL CARGO (METRES)
4
3
2
1
CFS STACKING AREA (THOUSANDS OF SQUARE METRES)
10
20
30
40
ACCESS FACTOR
0.2
0.4
0.6

FIGURE 22
Cross-section of container freight station



137. As previously mentioned, in addition to the container park and CFS areas, the terminal requires space for marshalling areas, vehicle parking, rail and road access, customs, damaged containers, reefer cargoes, staff, administration, maintenance and dangerous goods storage facilities. Typical additional requirements per berth could be from 20,000 to 30,000 square metres.

F. Berth occupancy at specialized unit terminals

138. Specialized berths such as container terminals can achieve cargo-handling rates five or even ten times higher than conventional berths. In addition, unitization results in a considerable reduction in the number of calls through the pooling of services, with larger consignments per vessel, which further increases the productivity per call. Thus, in unitized form, a given quantity of cargo can be handled at fewer berths, and it will be rare that a container terminal investment decision will involve more than two berths in the initial phase. Therefore the berth occupancies which will be appropriate in order to keep waiting time to an acceptable level will be low. The fact that container ships are much more expensive than general cargo vessels reinforces this need to minimize waiting time. In the planning procedure given below, the basic economic effect of waiting time will be a main factor in the investment decision, but there will in addition be the need to consider other criteria.

139. In the case of any special-purpose or advanced type of installation, the following three criteria should normally be considered:

(a) Whether the resulting berth occupancy will give the right balance between ships waiting for a berth and berths waiting for a ship;

(6) Whether the average ship turn-round time will satisfy the normal user, irrespective of what this implies with regard to berth utilization;

(c) Whether there is sufficient peak capacity to give a satisfactory individual service to the exceptional, more demanding, user and to ensure generally against congestion during periods of exceptional traffic.

140. Performance calculations should be carried out to demonstrate that all three of these criteria are satisfied. There will often be a difference in the capacities which will satisfy the different criteria, and it will be necessary to reach a compromise. In reaching this compromise the port management will often need to take an entrepreneurial decision: there may be no clear cut single solution with an economic justification which at the same time gives a level of service that will satisfy customers. It will be for the decision authority to consider these investment risks, and in order that it may do this the planning team should present separate proposals, according to each of the three criteria, for purposes of comparison. These will be more useful to the decision authority than a single proposal that attempts to meet all three criteria.

141. The container terminal planning chart III (see figure 23) is utilized to determine the berth-day requirement. The method used is similar to that used for the previous charts, starting with the standard working hours per day that ships will be worked when at the terminal, and with the following turning-points: average number of units per hour per crane, which should include an allowance for equipment down-time; number of cranes used per ship (gantry-crane effectiveness factor per crane = 1 crane : 1; 2 cranes: 0.9; 3 cranes: 0.8); average number of moves per ship; and number of ships per year. This path gives the average number of units per day per berth, the average number of units per day per crane, the average berth time per ship (which includes a one-hour period for berthing and deberthing the ship) and the annual berth-day requirement.

142. As we are now considering the performance of the terminal, note that we are using units (i.e. number of containers) rather than TEUs (i.e. twenty-foot equivalent units). When the containers to be worked to and from a ship are estimated in TEUs, this figure must then be converted into units by estimating the proportion of 40-foot units among the total number of units. The number of moves for discharging and reloading hatch covers should also be included.

143. Starting with the berth-day requirement, the following turning-points should be used in planning chart IV (figure 24): number of berths; commission days per year; number of berths; and average daily ship cost. The path traced gives the total time at port and the annual ship cost. Operators of expensive container ships may wish to know, in addition to the average ship time in port, the probability of a ship having to wait before agreeing to use the terminal. For this reason, additional scales are given on the lower left of the chart which show, for one, two or three berths, the probab-

FIGURE 23

Container terminal, planning chart 111: berth-day requirement

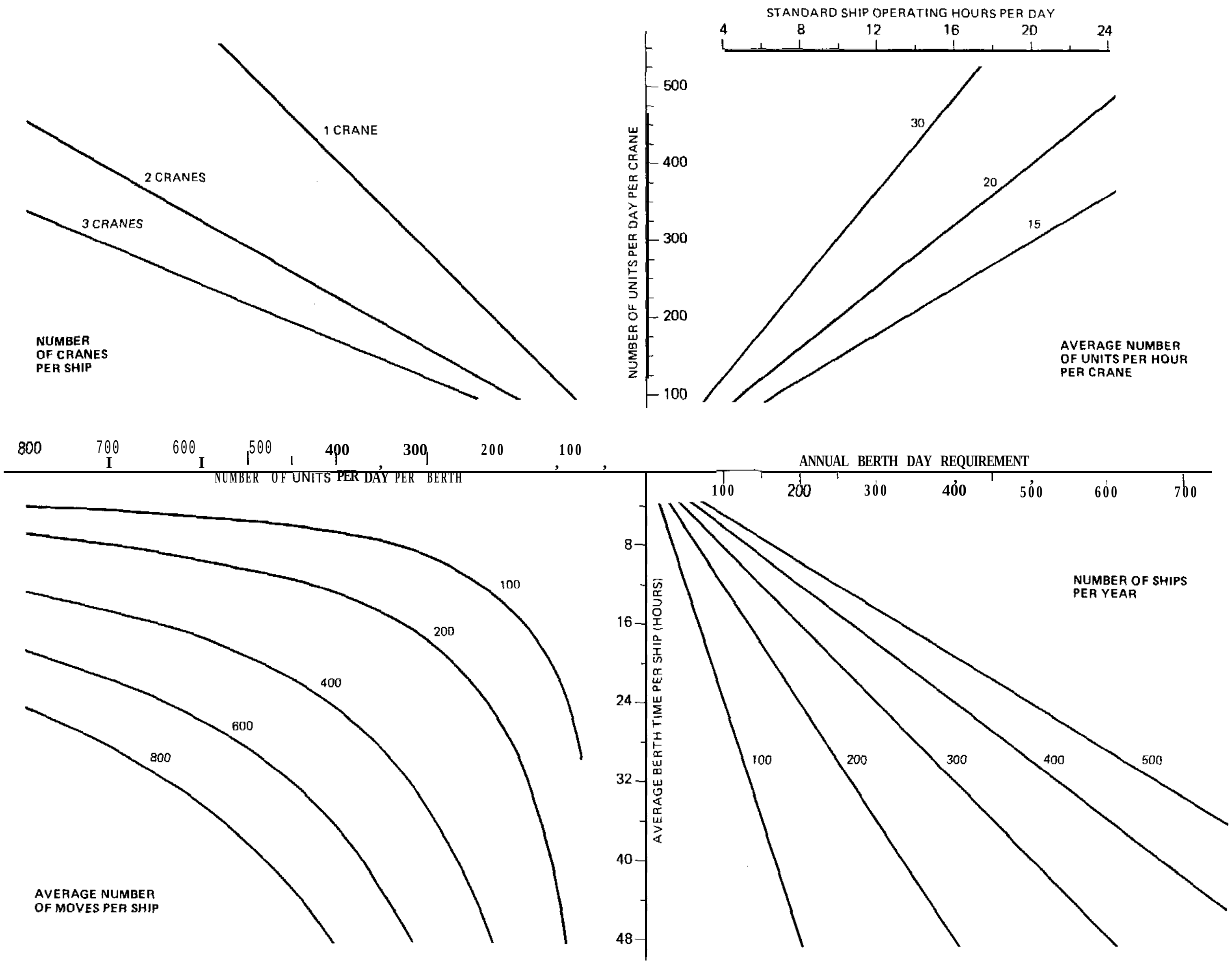
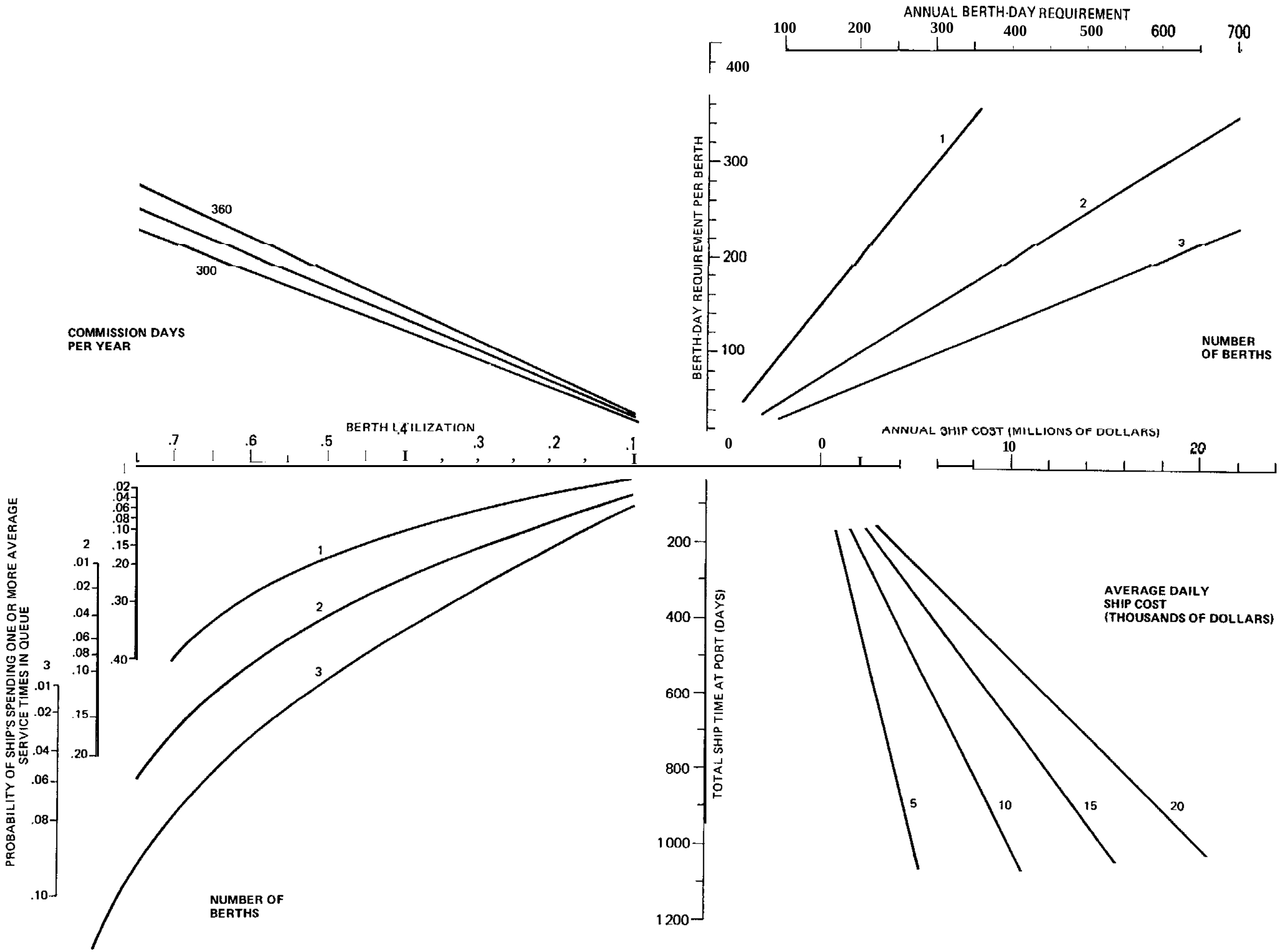


FIGURE 24

Container terminal, planning chart IV: ship cost



ility of a ship having to spend one or more average service times queueing for a berth. For example, if the average time at berth is 12 hours, then the probability shown is the chance of a ship having to wait 12 hours or more for a vacant berth. The probabilities are given as a fraction; thus 0.10 equals a 10 per cent chance. To use these probability scales, draw a line horizontally to the left from the "number of berths" turning-point.

144. The relationship between berth utilization and total time at port is based on queueing theory. The assumption has been used that the service time and the inter-arrival time follow an Erlang 2 distribution. A more detailed discussion is given in annex II, section D. For a terminal servicing a near-sea route for one or two operators, the arrivals would be more regular and the berth waiting time for a given berth utilization would be less. However, these curves can be used with a high degree of confidence for most container terminals.

G. Information systems

145. Many terminal operators have decided to utilize an electronic data processing system to assist in the collection and processing of the required information. It is generally accepted that for terminals handling 100,000 or more containers a year, a manual system, which may have proved very satisfactory up to that point, becomes far less practicable. A computer system can be introduced to handle the large quantity of information. There are, however, cases where efficient manual systems have been successfully used for much larger throughputs.

146. At present, many container terminals have both a manual and a computerized system, but each has a specific function. The manual system serves mainly to assist the terminal operator in the control of all terminal operations (including the location of the containers at the terminal). The computer-assisted system, on the other hand, is used to process invoices, gather statistical data and to present the container operators with detailed information, for example, on the type and number of units at the terminal, the availability of empty units and productivity rates on the ship. The project proposal for a container terminal should include any such data processing equipment as a terminal equipment cost item.

H. Schedule-day agreements

147. The need to achieve a reasonable level of berth occupancy without increasing the probability of ships having to wait has raised the question of the scheduling of arrivals. If vessel arrivals can be scheduled, a much higher berth utilization is possible without significant waiting. It may be possible for agreements to be concluded between container terminal operators and shipping lines for specified schedule-days, particularly with short-sea services. Ships that arrive in the scheduled slot are then guaranteed immediate berthing.

148. Unfortunately. the risk that vessels will be slowed down on deep-sea routes, for example by weather, means that large safety margins normally have to be provided. These destroy much of the advantage of the scheduling, and experience has shown that the ships from several lines arriving at a deep-sea container terminal are only slightly more systematic in their arrival patterns than the traditional liners they replace, The arrival pattern at a terminal is also affected by the hours of work at other ports. For example, if other terminals in the area do not work at the weekend, one that does is likely to find a group of vessels arriving at the end of the week.

149. Faced with this situation, the best that a large container terminal operator may be able to do is to give the fastest turn-round service possible on a first-come first-served basis. The use of a buffer stack of cargo to speed up service is a possibility. There could. for example, be a "post-stack" for import cargoes and a "pre-stack" for export cargoes, the stacks being placed directly on the quay near the vessel.

I. Container feeder services

150. The trend towards concentrating traffic at a small number of pivot or gateway ports is particularly pronounced on the long-distance container routes. The specialized container vessels have become larger and more sophisticated, while the cost of building a modern container terminal is very high. The economics are more and more in favour of unloading and loading all containers at one well-equipped port, and distributing them by coastal feeder vessels to other ports in the region.

151. It is difficult to forecast such developments, and close discussion is needed between the planner and the shipping lines concerned. The attitude of shipping lines is liable to change, and while they may initially wish the mother ships to call at every port, at a later date they may wish to introduce feeder services. Shippers prefer direct calls as this reduces both transport time and the chance of damage to goods.

152. Feeder ships are normally designed for a specific service, with the characteristics of the port in mind. They are relatively small (usually having between 10 and 20 per cent of the capacity of the trunk route vessel), and can be built without ship's gear in order to increase their carrying capacity, to improve their stability and to reduce costs. The majority are probably ro/ro ships, but there are also pure cellular feeder ships and combination ro/ro and lift-off vessels.

153. The load factor of feeder vessels is normally very high, approaching unity. At the ports serviced only by the feeder vessels. however, handling rates—although much higher than with the traditional break-bulk operation-will be lower than at the pivot or gateway specialized terminal because only one gantry-crane can work the feeder vessel. A typical figure of 15 units per hour may be achieved for a feeder ship with a capacity of 100 TEUs. Table 3 gives the principal characteristics of several ships in this class.

TABLE 3

Typical container feeder ships

Type	Dwt	Container capacity (TEUs)	Overall length (metres)	Overall width (metres)	Draught (metres)	Special features
Roll-oniroll-off	4 580	176	130	17	6.25	Catamaran design
Lift-on/lift-off	1 260	106	77	13	3.70	Gearless
Roll-on/roll-off Lift-on/lift-off	6 500	330	115	19	7.40	Equipped with angled stern ramp and one 38-ton gantry-crane
Roll-on/roll-off Lift-on/lift-off	2 080	111	87	14	4.70	Equipped with stern ramp and one 30-ton gantry-crane

J. Types of container handling equipment

154. The large size of IS0 containers necessitates large equipment for handling. The choice of a particular handling method is related to the type of traffic (for example, ship to shore, train to truck or truck to ground), the number of containers to be handled per hour and the distance of travel, which depends on the size and the shape of the site and the number of containers to be stored.

1.55. Ship-to-shore gantry-cranes are specially designed for container traffic. They are capable of substantial cantilever lifting, with spreaders mounted on rotating tables so that containers can be aligned straight into a stack, or on to a vehicle (figure 25). These are expensive pieces of plant, a 35-ton capacity crane for ship-to-shore operation costing approximately $4.5 million (mid-1981 values), including the rail track. The planner must design circulation routes so that any stoppage will not interfere with crane movement. For reliability, a terminal will normally require a minimum of two ship-to-shore gantry-cranes.

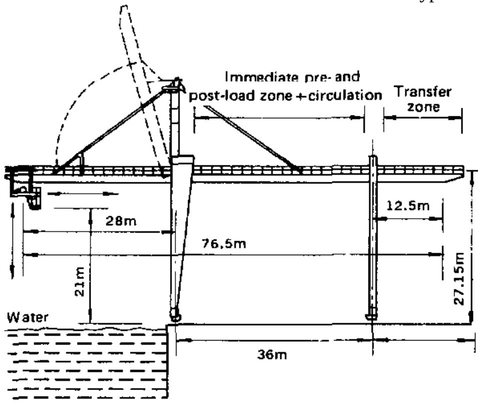
156. Gantry-cranes can also be used in the container yard, where they combine the mobility of straddle-carriers, although slower, with the wide span and height of the ship-to-shore gantry-crane. The yard gantry-cranes may be on rubber tyres, which allows them to move to another task at a different part of the site. The weight of the gantry requires special runways to avoid damage to the terminal surface. Rail-mounted gantries allow wider spans and higher stacking heights. A rubber-tyred gantry crane costs approximately $0.75 million and a rail mounted gantry, including rails, about $1.5 million (mid-1981 values).

157. Straddle-carriers are efficient for linear stacking operations up to a height of three containers. While these carriers are fast and manoeuvrable, they are expensive to buy and operate, with a typical purchase price of $0.5 million (mid-1981 values) for a carrier capable of stacking containers three high. Among the reasons for the high operating costs are maintenance costs and down-time. Modifications are improving the reliability of this type of equipment.

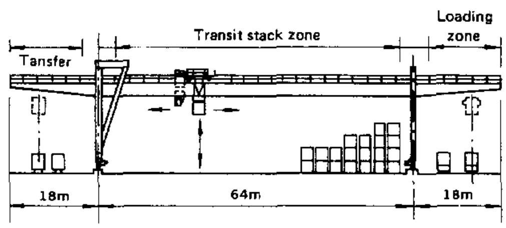
158. Fork-lift trucks can be used for container handling. Operators equip their fork-lift trucks with top-lift or side-lift spreader beams as well. The use of these attachments for container movements by fork-lift truck removes the risk of damage by forks. Normal fork-lift trucks can be used for the handling and stacking of empty containers with fork tunnels, while a special heavy-duty truck is required for full units. The investment for a 35-ton fork-lift truck, including the spreader, is around $300,000 (mid-1981 values). A 3-ton capacity fork-lift truck would cost approximately $30,000 and a 10-ton capacity truck $100,000.

FIGURE 25

Typical gantry-cranes



A. *Ship-loading gantry container crane*



B. Gantry-crane ***for stacking and sorting containers and feeding ship-loading crane***

Chapter IV

THE MULTI-PURPOSE GENERAL CARGO TERMINAL

A. Economics

159. The sequence of changes in the kind of traffic arriving at ports, as a result of growth and transport economics, was discussed in part two. chapter I, "Terminal planning considerations". The need for a multi-purpose terminal to handle both break-bulk cargo and a variety of unit loads during the transitional phase (denoted as phase 4 in part two. figure 1) was pointed out.

160. The role of the multi-purpose terminal is to provide efficient handling facilities for the period—which may last many years-when general cargo ships calling at the port may carry a variety of cargoes transported in modern ways: containers, flats. pre-slung cargoes, large units of iron and steel, large units of packaged timber, as well as cars and heavy machinery, together, of course, with a basic load of break-bulk cargo, increasingly palletized. These modern methods of transporting cargoes were introduced in order to reduce the cost of handling cargoes at ports in developed countries, and the cost of carriage by sea. However, they can actually cause a decrease in cargo-handling productivity and disrupt operations at a port not equipped to handle them efficiently.

161. In order to be able to handle all these cargoes efficiently, the terminal needs to have a greater variety of mechanical equipment than is required for a conventional break-bulk terminal, and a different range of equipment than is normal for a specialized container terminal. The terminal needs a different layout, and modern management. These requirements are summarized below, and are given in more detail in the reports of the UNCTAD secretariat on technological change in shipping and its effects on ports, already referred to several times.[7] Although the initial cost of the terminal is high, a high throughput can be achieved in view of the terminal's flexibility, and furthermore it can be fully utilized soon after commissioning in view of its suitability to handle whatever traffic may come. The resulting cost per ton of cargo handled and the total investment can therefore be significantly lower than the alternative of continuing to build extra conventional berths.

162. For example, a two-berth multi-purpose terminal working two shifts per day and 200 days per year should achieve a throughput of some 650,000 tons per year, assuming a productivity of 800 tons per ship-shift for a typical mix of cargoes with a different productivity for each type of cargo, as follows:

	Tons per shift
Conventional general cargo. palletized and pre-slung cargoes ..	450
Packaged forest products and bundled iron and steel products	I 000
Containers and ro/ro units	I 500

163. Using 1980 cost figures. the UNCTAD secretariat found that such a terminal would cost in the region of $33.3 million and give a handling cost of $20 per ton (including the cost of ship's time in port). If the same cargo were handled over conventional berths, the throughput would probably be no higher than about 175,000 tons per year, and would thus require four conventional berths costing approximately $50 million and giving an effective handling cost per ton of about $33. The figures given for a multi-purpose terminal, which imply very significant savings, are based on typical costs and interest rates in developing countries.

164. The multi-purpose terminal offers full utilization of a high-capacity facility from an early date and offers the possibility of reducing the total port cost for some neo-bulk cargoes. In view of the added long-term advantage that a multi-purpose terminal can more easily be converted later to a specialized unit load terminal, there **is** a strong argument for ports in developing countries to think of general cargo development mainly in terms of multi-purpose facilities.

B. Layout

165. Figure 26 shows a proposed layout for such a two-berth terminal. The following features should be noted: the placing of unit load transit and consolidation sheds at the rear of the quay, so that trucks can be served alongside the sheds without interfering with the transfer operations; the substantial open storage areas closer to the quay for any form of unit load, including containers, or for open storage general cargo; the large quay apron operational areas; the areas for road and rail transport through the terminal; provision of a ro/ro ramp.

166. The concept as shown, adapted to local conditions, has been applied in a number of new port developments for handling semi-bulk and neo-bulk cargoes, although mostly in developed countries. The latest developments in layout are noted and are to be referred to when studying figure 26.

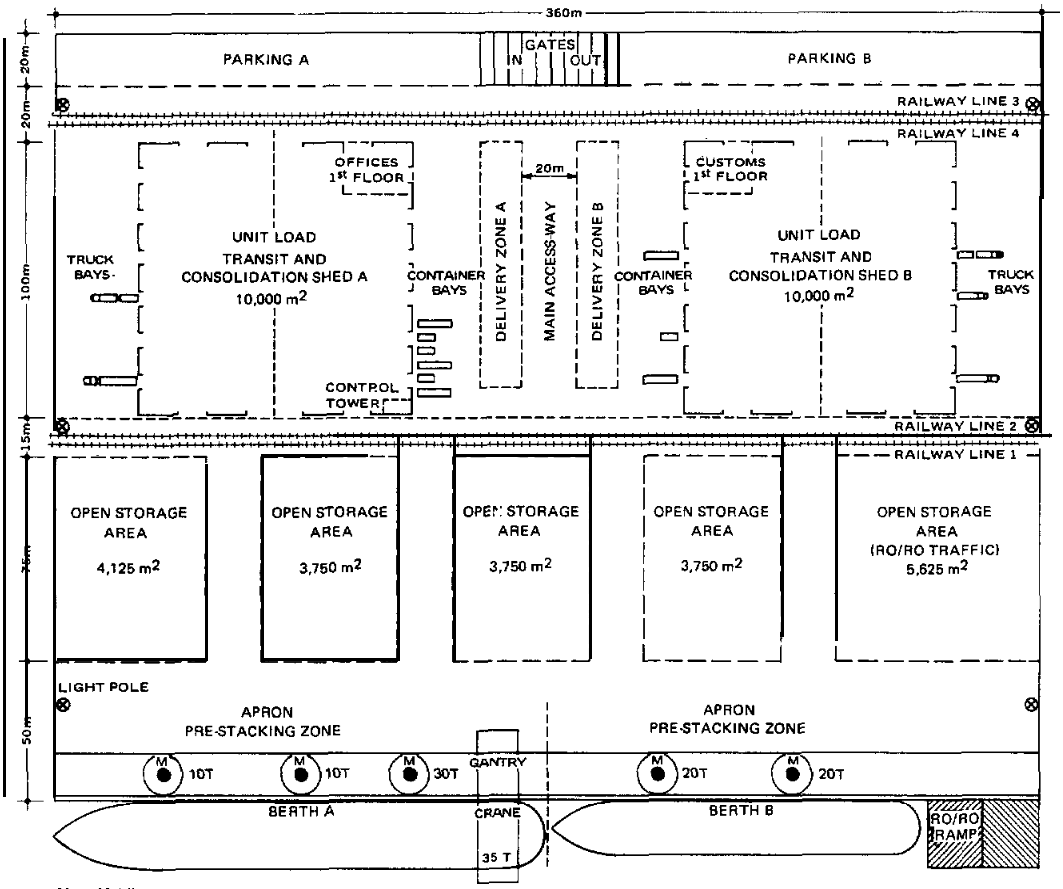
(a) Extension of berth length to 400 or 450 metres to handle larger ships and ship-based ramps;

(b) Increase in storage area to handle larger consignments and longer cargo transit times resulting in total terminal area of 120,000 square metres versus an original area of 100,800 square metres;

[7] TD/B/C.4/129 and Supp.1-6

FIGURE 26

Proposed layout for a two-berth multi-purpose general cargo terminal



M = Mobile crane

(c) Increase in unit-load weight has led to higher-capacity equipment. The flexibility offered by heavy-duty fork-lift trucks with attachments has led to their greater use. Large quantities of homogeneous cargoes have allowed the use of overhead stacking or gantry-cranes.

167. Since such a terminal is designed to serve a transitional phase, it might be advisable-depending on the traffic forecast-to proceed in two stages. Figure 27 shows a layout for a single-berth first phase, in which a single berth can handle the traffic and when the traffic mix demands a higher proportion of open rather than shed storage. Figure 28 shows a layout that is more suitable where there is a higher proportion of shed cargo, where two berths are justified, and where the second-phase development areas have been clearly allocated and partly surfaced. In this version, the transit and consolidation shed must be of a type which can be dismantled and re-used with additional material for the erection of two sheds further back during the second phase.

C. Equipment

168. The main method of ship handling is either by ship's gear or by mobile tower crane. No rail-mounted portal cranes are normally provided and only one gantry-crane in the first instance. A 30-ton mobile tower crane may, however, be on the same rails as the gantry-crane. The standard method of transfer for virtually all classes of cargo is by tractor/trailer combinations, using trailers of a size generally associated with container operations but without corner fixings, of a low profile design, and equipped for easy coupling and uncoupling. While the cost of equipment listed in table 4 is substantial, it can be readily justified. This cost is included in

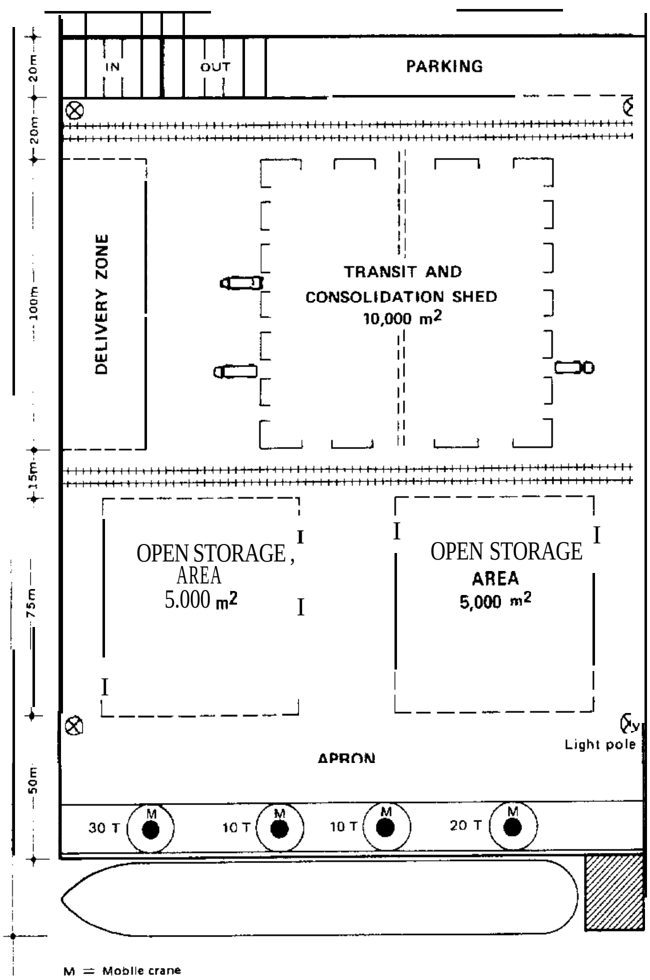
TABLE 4

Handling equipment required for multi-purpose general cargo terminals

	Single berth, first phase, alternative 1 (predominantly open storage)	*Two-berth, first phase, alternative 2 (predominantly shed storage)*	*Two-berth terminal, second phase*
35-ton gantry	—	—	1
30-ton heavy lift crane ,,	1	1	1
20-ton mobile tower crane (for ship working)	1	2	2
10-ton mobile tower cranes (for ship working)	2	2	2
20-ton mobile cranes (for yard working)	1	—	1
J-ton mobile cranes (for yard working)	1	2	2
Straddle-carriers ..	2	—	3
3-ton fork-lift trucks	8	15	15
10-ton fork-lift trucks	2	3	5
Tractors (tugmasters)	3	6	6
Trailers/chassis	9	18	18
Ro/ro ramp	1	1	1

FIGURE 27

Firs1 phase of the multi-purpose terminal, alternative 1



the total terminal cost estimate given above. The list given is for the initial equipping of the terminals illustrated. Perhaps the main reason for difficulties in the operation of unitized cargo terminals has been the failure fully to recognize the need for transfer equipment, and for this reason the quantity of transfer equipment suggested should not be reduced. As a particular traffic develops, the terminal may start to take on a more specialized role and further equipment (such as additional container gantry-cranes and, straddle-carriers) may be justified.

D. Management

169. To take full advantage of the multi-purpose terminal, a modern port management approach is needed. At the planning stage, special consideration should be given to the new status of the dock worker, and to the need for integrated planning of the operation. One of the most sensitive areas in a changing port environment is the status of the dock worker. Early action on the part of management can help to pave the way for a gradual change towards an improved labour management policy. The mangement effort in this respect should include:

(a) Training of specialized personnel (drivers of mechanical equipment, mechanical and electrical technicians for equipment maintenance, traffic controllers);

(*b*) Advance planning of the requirements for manual and office workers, with a regular revision of the quotas required;

(c) Gradual improvement of the status of the dock workers by conversion from a casual to a permanent working force, at least for a substantial proportion of the workforce;

(d) Development of a time-based payment system, incorporating adequate social security provisions.

170. The port management must fully involve the unions in these developments and be willing to accept proposals from both manual and office workers. Changes will always occur more smoothly if there has been extensive consultation.

171. Another area of preliminary action concerns the operational organization of the terminal. Often, the activities on the ship, on the quay apron and in the shed have been considered as separate activities. The net result, even in the case of break-bulk general cargo handling, has been a considerable loss in operating capacity. At a specialized terminal, such separation is completely unacceptable, as a unified responsibility for the overall operation and unity of control of the specialized terminal becomes an increasingly important requirement for its efficiency. On the other hand, it is desirable that the specialized terminal should be operationally independent of the conventional break-bulk berths.

172. Management methods should concentrate on control and continuous monitoring, of the type associated with specialized container operations, for all traffic handled. This will require provision to be made at the planning stage for the following:

(a) Management training;

(h) A supporting administrative organization with planned information flow;

(*c*) The planned preventive maintenance of equipment based on good repair facilities;

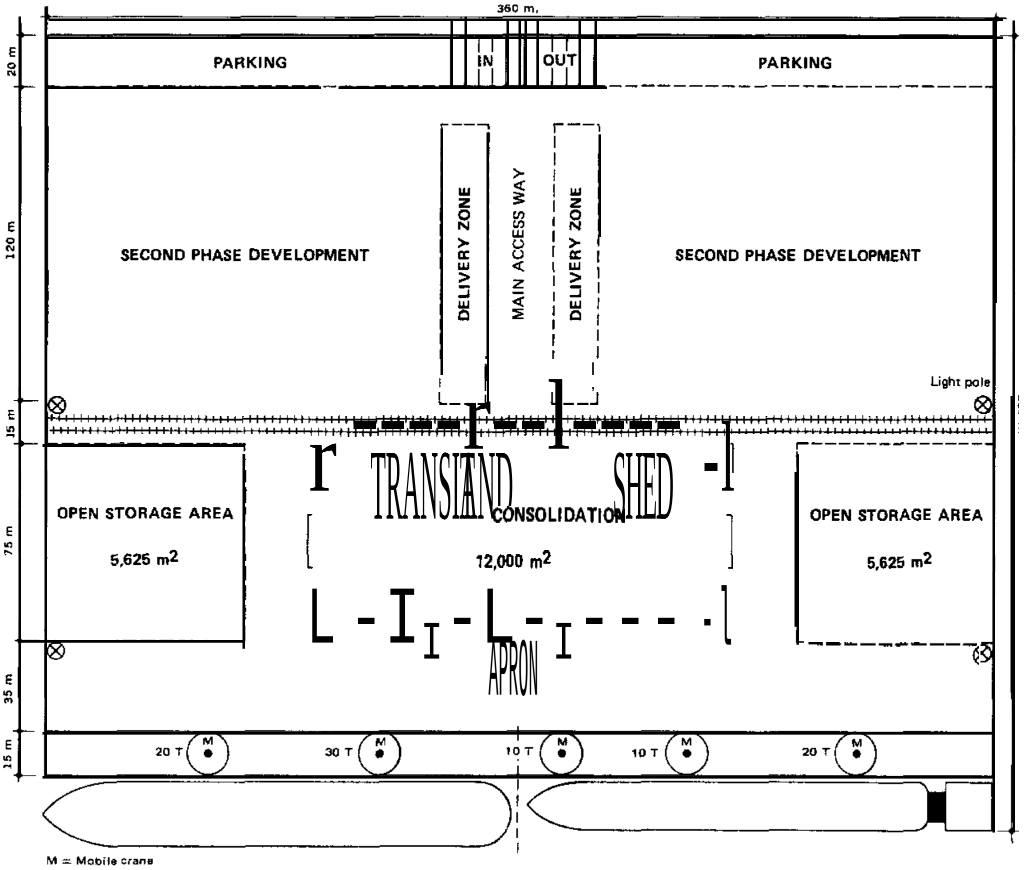
(d) The collection and use by management of statistical performance indicators. as suggested in the UNCTAD publication on the subjects;

(*e*) Close collaboration with shipping agents, forwarding agents and railways, which should have representatives at the terminal.

[8] *Port Performance* ***Indicators*** (United **Nations publication. Sales No.** E.76.II **D.7).**

FIGURE 28

First phase of the multi-purpose terminal, alternative 2



Chapter V

TERMINAL REQUIREMENTS FOR ROLL-ON/ROLL-OFF TRAFFIC

A. The role of roiro services

173. The spread of roiro services to the deep-sea trades is a development which will be of increasing importance to developing countries in view of the great flexibility of the operation. As of mid-1980, the deep-sea roiro fleet consisted of 220 vessels totalling just over 3 million dwt. The deep-sea fleet is predominantly a young fleet, with only 20 ships in existence before 1970, and a total of 125 ships entering service between 1977 and 1979. The most popular type is the pure roiro (55 per cent of total dwt) followed by roiro general cargo (23 per cent) and roiro container ships (20 per cent). By mid-1980 there were 63 vessels of 1.12 million dwt on order that could enter the deep-sea roiro fleet over the next 2 1/2 years, representing an increase of 37 per cent.

174. In mid-1980, 45 per cent of the fleet consisted of vessels up to 9,999 dwt, 31 per cent between 10,000 and 19,999 dwt and 24 per cent over 20,000 dwt. The trend towards increasing vessel size can be expected to continue in the long term as roiro operations extend to more long-haul trades and those high-throughput trades where larger vessels will be used for larger loading per sailing.

175. As listed in part one, chapter III ("Traffic forecasting"), the variety of cargo types which can be carried on roiro vessels-in various combinations-include vehicles, loaded road trailers or semi-trailers and containers on chassis, as well as any general cargo on pallets or flats which can be carried on and off the ship by fork-lift trucks. In addition, roiro vessels are often used to carry passengers. Moreover, the majority of ro/ro ships are equipped for a percentage of lift-off operations for containers and heavy lifts, and in some cases also for bulk cargo. Because of the priority berthing which is often given to this type of service, it can bypass port congestion ship delays. Furthermore, where quays have a suitable load-bearing capacity, large, long, heavy or awkward loads can be worked without special heavy-lift cranes, and in certain cases with less berth length.

176. Several types of vessel of varying sizes are in operation. Vessel design differs with respect to the ramp facility, which may be placed at the stern, in the bow or on the side. The ship itself may dock either alongside a quay or at right angles, for access through the bow or the stern. Cargo is carried on several decks, and access is often provided between these decks by ramps or elevators within the vessel. In some cases, connections can be made to the shore at each separate deck level.

177. In general, for liner deep-sea trades, three main types of ship can be identified:

(a) Type 1: roll-on/roll-off ships with multiple decks and/or holds with side-ports requiring a quay ramp;

(b) Type 2: roll-on/roll-off ships with a ship-based angled stern ramp;

(c) Type 3: mixed roll-on/roll-off, lift-on/lift-off ships requiring a quay ramp.'

178. Ships of the second type, with a ship-based angled stern ramp and multiple decks connected by ramps, are of particular promise for developing countries. The need for sophisticated and relatively expensive port-based link spans is avoided, while a large variety of cargoes can be handled. Moreover, these ships often employ their own fleet of straddle-carriers, fork-lift trucks and other mechanical handling equipment. Hence the investment cost for the port is considerably reduced.

179. An examination of the development of cellular container services and ro/ro services shows that, because of local conditions and differences of approach, the two modes of carriage are in competition on a number of trade routes. However. the true economics of the situation are likely to show that there is room for both on the major routes where there is at present competition. The economics of container services are such that they will usually capture all substantial containerizable cargoes, leaving non-containerizable general cargo to be carried by conventional means. As traffic grows, a point is reached where this residue becomes sufficiently substantial, or cargo-handling cost and ship waiting-time cost sufficiently great, for this merchandise to be divided into the "cream" cargo, cargo of higher value needing rapid handling, and the remainder. The "cream" cargo will tend to be carried on roiro service vessels.

180. Often, the more important factors are flexibility and the cutting-down of port investment, particularly where there are smaller traffic volumes, as in many ports in developing countries. Here, there is no competition between cellular container services and ro/ro services, and the roiro ships will therefore be equipped to carry whatever container traffic there may be.

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[9] Further information is given in an ICHCA Survey of 1978 entitled *Ro-Ro Shore and Ship Romp Characteristics* and in a 1978 report of the PIANC International Study Commission on the Standardisation of Roll-on/Roll-off Ships and Berths (Supplement to Bulletin No. 33 (Vol. 1111979)).

181. It is also interesting to note that operators choose the roll-on/roll-off vessel for a specific commodity and not for the more diversified cargo-mix of the traditional liner trade. For example, automobiles may be carried on the outward voyage and forest products on the return voyage; or, say, steel products may be transported by roiro vessel between ports of the same country. In such cases, cargo flexibility is a less critical factor than cargo-handling productivity and the ease with which changes can be made in ports of call.

B. Ro/ro demand forecasting

182. In any attempt to forecast the extent to which roiro services will penetrate a given route, the following two principal characteristics of the roiro service as opposed to the container service should be borne in mind:

(a) The ability of a ro/ro service to attain high cargo-handling speeds in a highly developed port at one end of the route and satisfactory speeds in a conventional port at the other end;

(b) The ability of a roiro service to switch its ports of call easily in an area of changing trading patterns because it requires the minimum in the way of special port equipment.

183. At the same time, when a route capacity builds up to the point where a cellular container service is introduced, a roiro service will in general be phased out. This will happen because the carrying capacity of a specialized container vessel can be more fully used than that of a ro/ro ship. In broad terms, the nature of roiro cargo is that it is the high-value portion of the miscellaneous cargoes left over after containerization.

C. Berth requirements

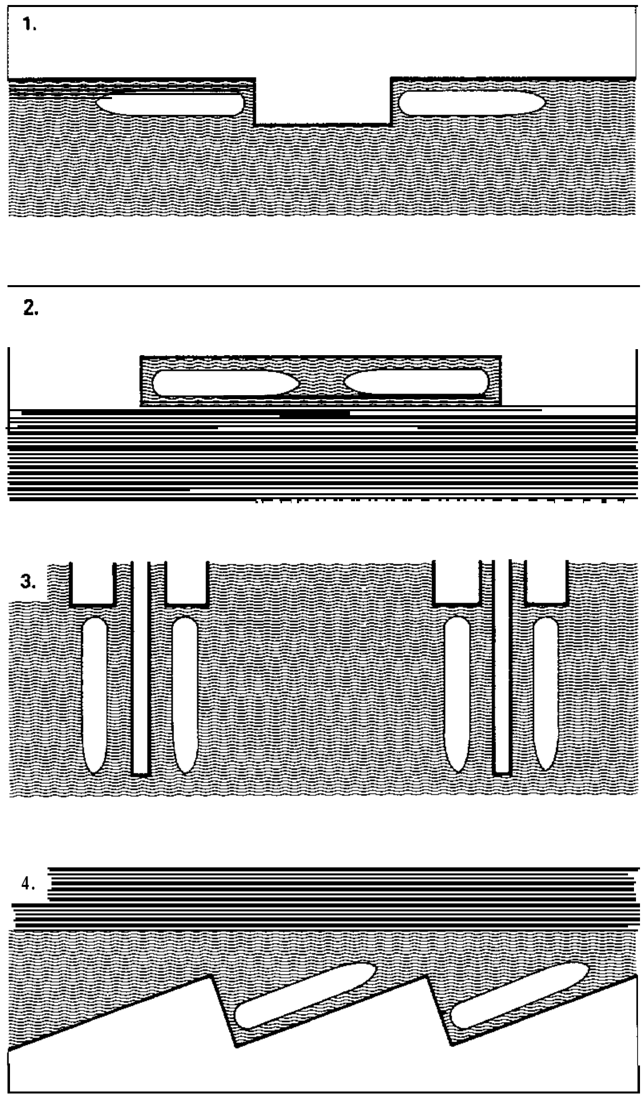
184. Thus, apart from the need for good access and suitable storage areas, roiro operations place little demand on ports for speciahzed facilities and can be fully self supporting in smaller ports. However, this very flexibility means that it is difficult to forecast which class of ro/ro ship, carrying what cargo mix, will use any particular port.

185. Since a ro/ro berth can be prepared and equipped more quickly than most other kinds of berth and since, in many cases, the ship design will be known, the shore facilities should be designed to meet the ship's needs. But it is important to recognize that a berth will outlast most ships and that ships may be moved to other routes if traffic patterns make it desirable to do so. Therefore berth planning should be as flexible as possible, even though only one vessel type is expected at the outset.

186. Four alternative fixed layouts are shown in figure 29. Alternative 1 offers a high degree of flexibility for the future, since it is easily converted to the handling of other types of ship, but a portion of the quay length is lost (usually about 60 metres). The total quay length necessary is large and represents a costly investment.

FIGURE 29

Alternative layouts for a ro/ro quay



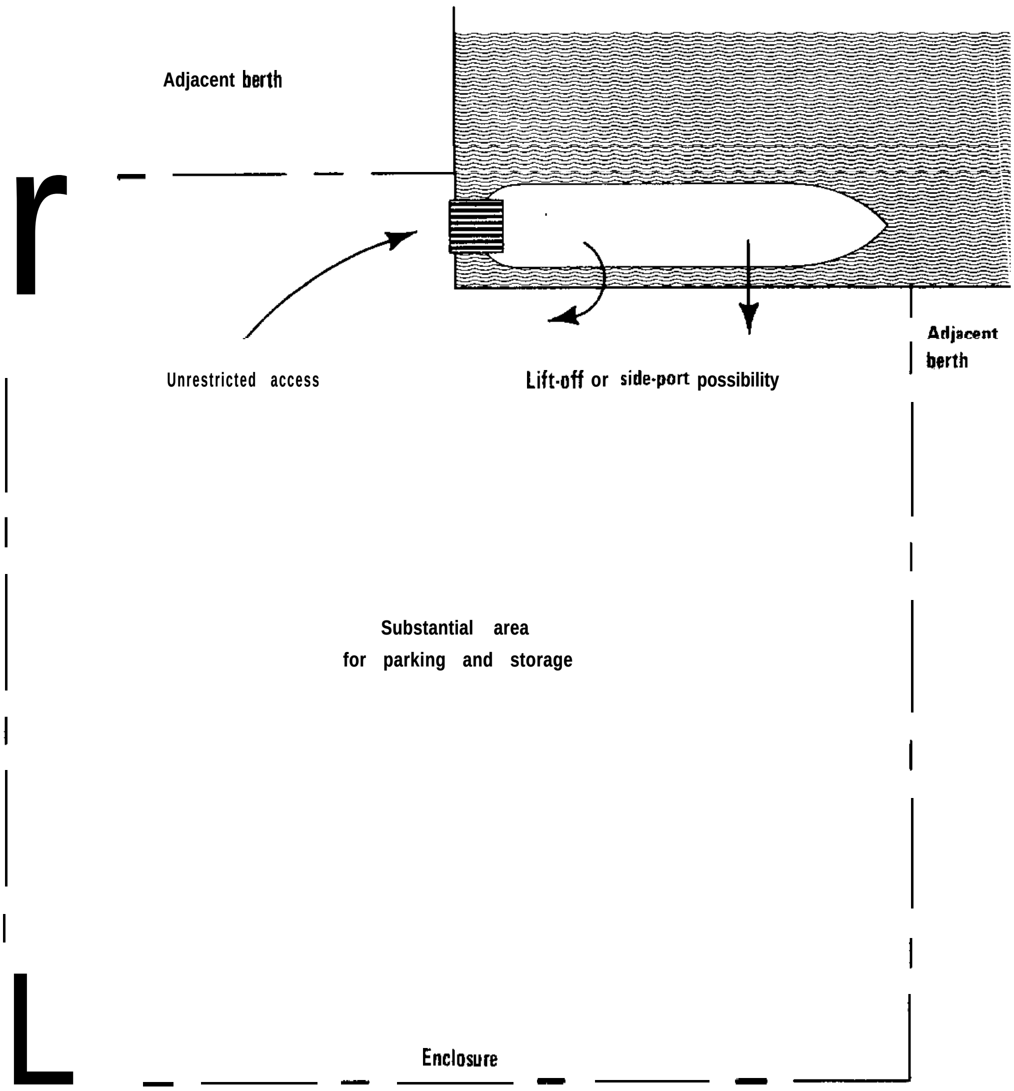
187. Alternative 2 is feasible only if the length of the vessels calling at the port remains unchanged during the lifetime of the facility (30-40 years). In general, this cannot be guaranteed, and, given the trend towards larger ships, few ports may be prepared to take the risk of building a quay which might become inadequate within a time span of five to ten years. However, its advantage is that it separates traffic flows on the quay.

188. Alternative 3, although the least expensive in cost terms, is not generally appropriate since it can be used only for roiro vessels with stern or bow cargo-handling arrangements. This eliminates a large number of ships and any lift-off operation.

189. Alternative 4 has a number of advantages. It combines the flexibility required to handle different types of ships with the possibility of receiving vessels of increasing length. This staggered layout for two berths is a natural development of the single roiro corner berth, which is the preferred layout when only one ro/ro ship at a time is to be handled. The typical layout of the single corner berth is shown in figure 30.

FIGURE 30

Preferred layout of a single roiro corner berth



190. A roiro berth needs to be in a well-protected location in a port. Although some down-time can be accepted at any berth in a port, roiro traffic is, more than any other, dependent for its overall transport economy on rapid turn-round times and it can be more seriously affected by swell and by tides than a lift-off operation.

191. In a location where there is no tide, roiro facilities can dispense with adjustable ramps and are very cheap to construct. The simplest form of roiro berth comprises a surface on to which the stern or bow ramp of a ship is lowered during loading/unloading. A slewing or fixed quarter ramp allows a roiro ship to use a normal berth and can be supported by a system of tension cables, with an automatic winch which limits pressure on the wharf. Figure 31 illustrates the typical design for a slewing ramp, which gives the ship a greater flexibility in berthing choice. In high tidal ranges, the necessary adjustable bridge ramp and supports add considerably to the cost of the basic facility. With a tidal range of 5 metres, a bridge ramp from 25 to 50 metres long[10] would be needed, capable of carrying the heaviest trucks and trailers. Under such conditions, the economic and operational possibility of an enclosed dock should be examined, as discussed in part one, chapter VII, "Civil engineering aspects".

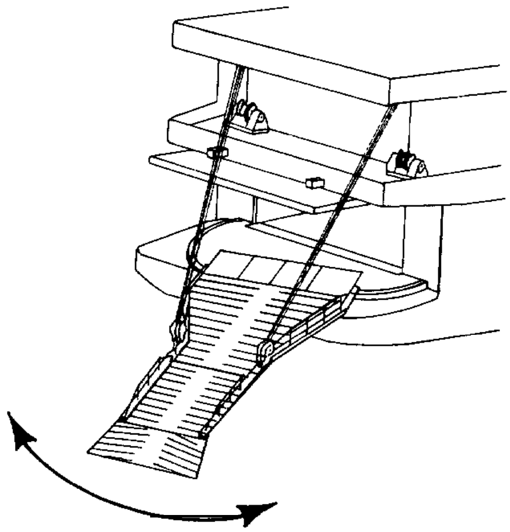
192. In more sophisticated systems, an adjustable bridge ramp forms a suspended roadway hinged at the inshore end and supported near the outer end to provide a connection between the shore approach and the ship. The outer end may have a telescopic or hinged connection. There is, therefore, a much greater interaction between ship design and berth design than for many other maritime facilities.

193. Several basic designs have been put forward for the bridge ramp, which differ essentially in the method adopted for the adjustment of the ship end of the bridge ramp to accommodate changes in level due to loading and discharging and tidal fluctuations. Two alternatives are normally considered. The first consists of a floating pontoon or bridge ramp which automatically rises and falls with the change of tide. Figure 32 illustrates one form of this bridge ramp. The second possibility is for the ship end of the bridge ramp to be

[10] The exact length depends on the maximum difference in elevation between the ship's exit and the quay surface.

FIGURE 31

Example of slewing ramp for ro/ro service



connected to a fixed gantry structure either by cables or by hydraulic means, which provide the necessary adjustment.

194. An important feature of a floating bridge ramp is its capability of being moved from one part of the quay wall to another. This is desirable in many cases, to increase berthing flexibility. It is usually possible to tow pontoons to other locations fairly quickly.

D. Terminal area requirements

195. One characteristic of the ro/ro terminal is the need for adequately fenced, protected and surfaced storage areas with a wide, well-paved access way. The transit storage area needed for a ro/ro terminal may be even larger than that needed for a container terminal, which is normally 10 hectares per berth. To determine the storage area requirements, the ro/ro cargo forecasts should be grouped under the following four headings:"

(a) Containers;

(b) Cargo carried by intermediate methods;

(c) General cargo;

(d) Wheeled cargo.

196. The container forecast is in TEU units and therefore the container terminal planning chart I, for the container park area, can be used. The appropriate area requirement per TEU factor, together with other factors such as transit time, will allow the planner to calculate the corresponding area requirements for the ro/ro terminal.

[11] See part one, chapter III. section F, on forecasting cargoes carried by ro/ro ship.

FIGURE 32

Example of adjustable bridge ramp for ro/ro service

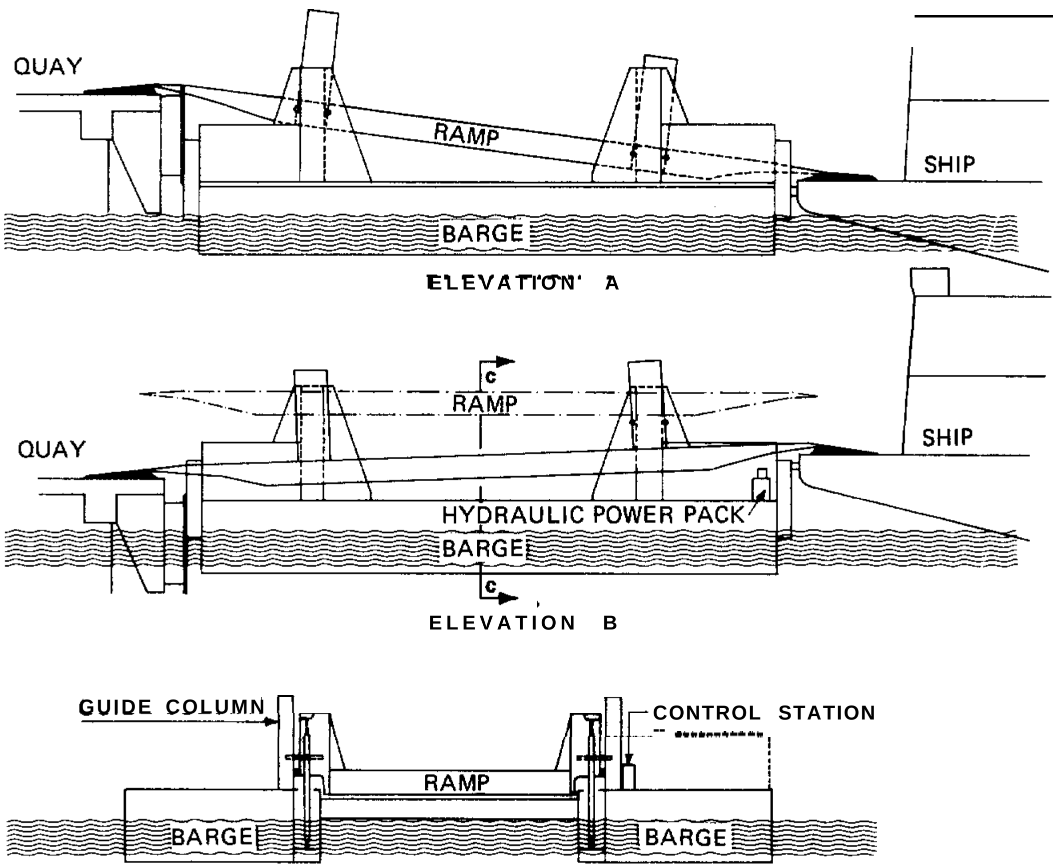
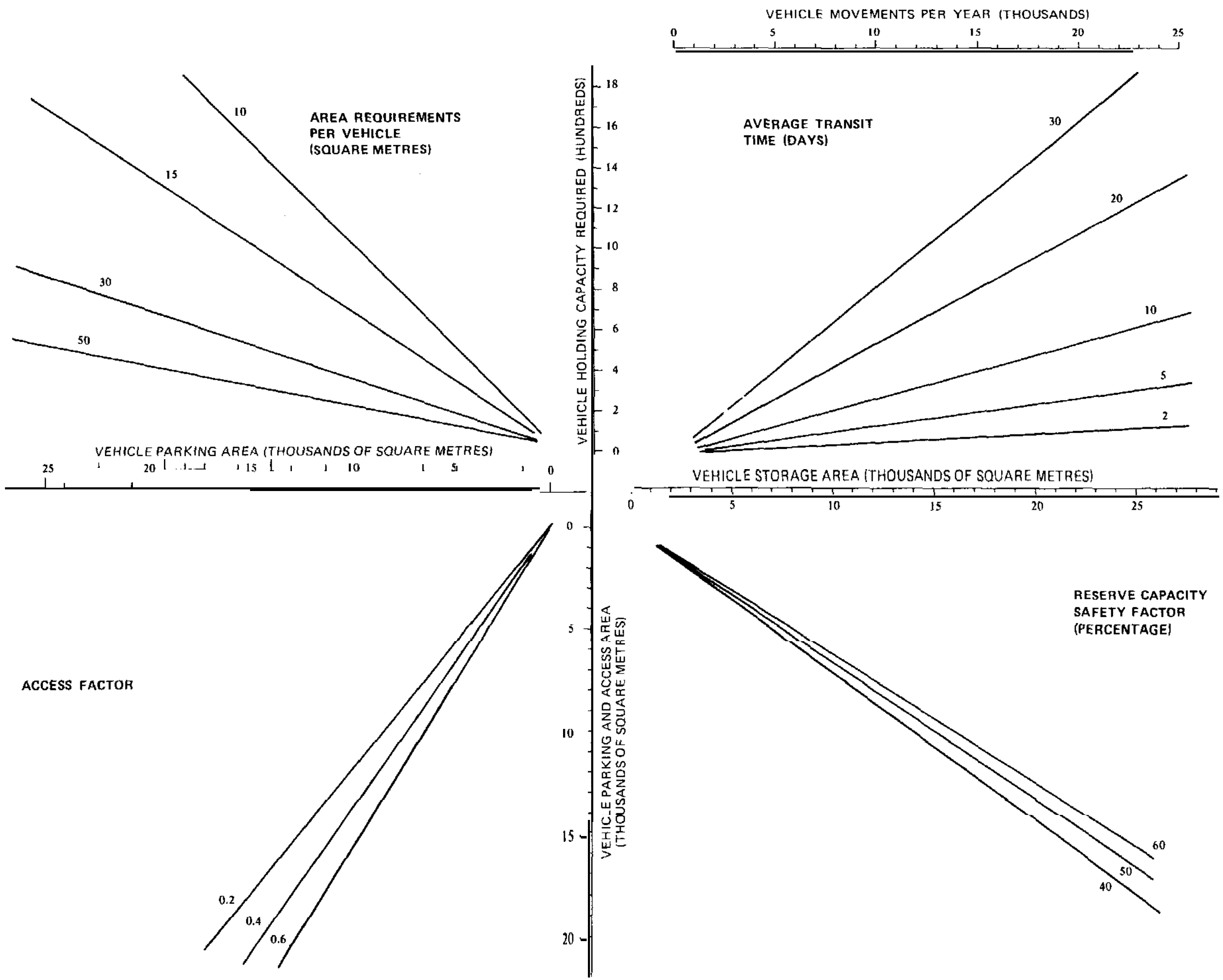


FIGURE 33

Ro/ro terminal planning chart: vehicle storage area



197. The storage area requirements for the second and third categories of roiro cargo can be determined by using the break-bulk terminal planning chart III for storage area requirements. The appropriate stowage factor, stacking height and transit time must be used for each category.

198. The area requirement for roiro wheeled cargo can be determined from the roiro terminal planning chart for vehicle storage area, illustrated in figure 33. Typical area requirements, excluding access area, for various road transport vehicles are as follows:

	Square metres
Articulated truck, 15-metre	46.5
Rigid truck, 16-ton	26.5
Automobile	
large	11.0
small	7.0

A sufficiently large area should be allocated to this category of cargo to accommodate the largest shipment of vehicles envisaged. For example, a shipment of 500 small automobiles would require a minimum area of approximately 4,500 square metres, assuming a 2.5 per cent allowance for access.

E. Ro/ro terminal equipment

199. Transfer and stacking operations are carried out with a large variety of equipment on one terminal. For transfer operations, the main piece of equipment will be the port terminal tractor. The tractor will have the ability to haul a fixed load up a specified gradient at a certain speed, as well as a port-adapted, heavy-duty fifth wheel to allow crossing ramp connections. This fifth wheel will have lateral inclination allowance and a locking device to reduce torsional stress. The cab of the tractor will have swivelling controls or dual seats for forward and reverse manoeuvring.

200. Other equipment used for both transfer and stacking would be low-profile straddle-carriers and heavy-duty fork-lift trucks with a low-profile cab and triplex mast.

201. For working in the ship's hold via side ports, an electric fork-lift truck is preferable to a diesel-driven vehicle. Slopes and cambers can reduce fork-lift performance seriously. The gradient should never exceed 1 in 10. For example, where there is a slope both to the ship's deck and to the shed or stack, battery-driven fork-lift trucks may need recharging three times in one shift, and diesel lift trucks are more appropriate.

Chapter VI

TERMINAL REQUIREMENTS FOR BARGE-CARRYING VESSELS

A. Barge-carrier systems

202. The impact of barge-carrying vessels on port operations in developing countries is discussed in more detail in the reports of the UNCTAD secretariat on technological change in shipping and its effect on ports, which have already been referred to several times.[12] Five types of barge carriers are in commercial service: BACAT, LASH, BACO, SEABEE and Danube Sea Lighter. The LASH system is the one chosen by the majority of lines. The principal dimensions of the barge carriers and their barges are given in tables 5 and 6.

203. The barge carrier requires few, if any, port facilities and is designed to discharge offshore its cargo of loaded barges, which are then moved by tug either into port or into an inland waterway system. The carrier is then free to accept pre-loaded barges for the return trip. The great advantage is that the carrier spends most of its time at sea and is not penalized by inadequate facilities or congestion.

204. In practice, however, these systems have not proved themselves, largely because few barge carriers have been operated on the type of routes for which they were designed. In addition, the almost parallel development of containerized and ro/ro handling systems have proved more versatile and, in the long run, cheaper to operate.

205. The most successful barge-carrying operations to date have tended to be between highly industrialized regions, namely between the United States (region of the Gulf of Mexico) and northern Europe. Other routes are between Europe or the Gulf of Mexico and the Middle East. A new operator is the Soviet Interlighter joint venture, which has a service linking the Danube river ports via the Black Sea to India, Pakistan, Malaysia, Viet Nam and Kampuchea. Two new barge carriers will provide, with two tug units, feeder services for the existing ships.

206. The other barge carrier operator is the Baco-Liner company. The ships utilize opening bow doors to float on and off BACO barges 24 metres long, each capable of loading 800 tons. The free upper decks can be used to stack TEUs in three tiers.

207. As table 5 shows, barge carriers may be equipped to carry containers or may be pure barge carriers. The former vessels are provided either with cellular holds or special frames for the carriage of containers on deck and they have a ship-based gantry-crane for handling the containers.

[12] TD/B/C 4/129 and Supp 1-6.

B. Barge-carrier handling requirements

208. The initial idea of barge carriers was that the barges should be loaded and discharged from the mother ship while the latter was at anchor outside the port, and that the cargo carried by the barges should be loaded and discharged at any shallow-draught berth, tugs being used for towing the barges to the berth. Thus, aside from tugs, the port facilities required would be minimal.

209. In practice, more sheltered water has been found desirable for the purpose of loading and unloading the barges, and the mother-ship operation normally takes place inside the port area-at moorings, alongside container or break-bulk berths, or even at a special T-shaped jetty. In either case, a deep entrance channel is required; in addition to the operating draught of the vessel, a minimum of 1 metre must be allowed for trim changes during the operation. The water areas required for the manoeuvring of such large vessels are also substantial, as is the area needed around the mother vessel for manoeuvring the barges.

210. Furthermore, barge carriers with a cellular container complement must call at a terminal with facilities for handling containers.

C. Barge-handling requirements

211. Handling the barges within the port requires "barge park areas" which are large water surfaces, well separated from the other water-based traffic in the port, where laden export barges await shipment, laden import barges stay until such time as they are sent inland or can be discharged, and empty barges are kept in stock. The area needs careful attention from the point of view of port security.

212. The requisite size of a park area can be considerable, since the inland penetration of the barges is at present low, and thus the great majority are destined for port loading and discharge. Although large water areas may be available in river ports, in breakwater ports the lack of water area proves a major impediment to the smooth functioning of the barge-carrier service. As a rule of thumb, a minimum barge park area of 10,000 square metres should be provided, this area allowing for an average discharge of eight barges per call and a peak of 25 barges.

213. In ports where the necessary areas have been provided. significant investment costs have been involved. At Bremerhaven, 31 pontoons have been constructed, offering mooring space for 140 barges. The

TABLE 5

Principal barge-carrier dimensions

Operator and vessel	Dwt	Overall length (metres)	Overall width (metres)	Maximum draught (metres)	Barge-carrying capacity	Container capacity (TEUs)	
						With barges	Without barges
BACAT SYSTEM:							
Mackinnon-Mackenzie & Co.							
Bacat 1	2 682	103.5	18.8	5.4	13	—	
LASH SYSTEM:							
Central Gulf Lines Inc.							
Acadia Forest	48 303	261.4	32.6	12.1	80	—	—
Atlantic Forest	48 327	261.4	32.6	12.1	80	—	
Bilderdyk	44799	261.4	32.3	11.3	83	—	—
William Hooper	46 892	272.3	30.5	12.4	89		—
Button Gwinnett	46 892	212.6	30.5	12.4	89	—	
George Wythe	46 890	272.3	30.5	12.4	89	—	—
Spruce (non-propelled)	2 600	112.7	34.2	3.4	15	—	—
Oak	11550	134.5	34.2	4.8	18		108
Willow	11496	134.5	34.2	4.8	18	—	108
Condock Rederei							
Condock I	3 170	92.4	19.6	4.6	3	—	383
Condock II	3 170	92.4	19.6	4.6	3	—	383
Delta Steamship Lines							
Delta Caribe	30 292	249.9	30.5	10.7	70	—	840
Delta Mar	41048	272.3	30.6	11.6	85	72	1728
Delta Norte	41 048	272.3	30.6	11.6	85	72	1 728
Delta Sud	41 048	272.3	30.6	11.6	85	72	1728
Prudential Lines Inc.							
LASH Italia	30 298	249.9	30.5	12.4	70	—	840
LASH Atlantico	30298	249.9	30.5	12.4	70		840
LASH Pacifico	30 298	249.9	30.5	12.4	70	—	840
Waterman Steamship Corp.							
Robert E. Lee	41 578	212.3	30.6	11.6	89	—	—
Sam Houston	41 578	272.3	30.6	11.6	89	—	
Stonewall Jackson	41578	272.3	30.6	11.6	89		—
Benjamin Harrison	21 500	272.3	30.5	11.6	80		665
Edward Routledge	21 500	257.6	30.5	11.6	80	—	655
Navilash							
One on order	9 640	n.a.	n.a.	n.a.	22	—	
BACO SYSTEM:							
Baco-Liner GmbH							
Baco-Liner 1	21 801	204.1	28.5	6.7	12	501	501
Baco-Liner 2	21 801	204.1	28.5	6.1	12	501	501
Baco-Liner 3 (on order)	21 800	204.1	28.5	6.1	12	501	501
SEABEE SYSTEM:							
Lykes Bros. Steamship Co.							
Doctor Lykes	39 026	267.0	32.3	11.9	38	400	1 800
Almeria Lykes	39026	267.0	32.3	11.9	38	400	1 800
Tillie Lykes	39 026	267.0	32.3	11.9	38	400	1 800
DANUBE SEA LIGHTER SYSTEM:							
Interlighter							
Juluis Fucik	31850	266.5	35.1	11.0	26	720	1 552
Tibor Szamueli	31850	266.5	35.1	11.0	26	720	1 552
Two on order	8 563	n.a.	n.a.	n.a.	6	—	513

Source: Lloyds Shipping Economist (London), October 1982.

total length of the pontoons exceeds 650 metres, and the total cost of the project was almost $4 million. The basin and barge park areas are illustrated in figure 34.

214. Barges can be handled at existing break-bulk and lighterage berths, even of old-fashioned design. However, it might be advisable to provide special handling facilities for the barges where:

(a) Existing facilities are inadequate because they do not provide weather protection or sufficient space for assembling cargo and loading it on to barges;

(6) Existing facilities are fully utilized and the handling of additional barges would lead to congestion;

(c) The distance between the barge park area and the existing break-bulk berths is excessive;

(d) A combined terminal for handling containers and barges is preferred from a cost-effectiveness and operational point of view.

215. The higher the cost of labour in a port, the greater will be the need to build well-equipped and suitable barge-handling facilities. Only then can the operations be expected to achieve the considerable increase in productivity which is an essential requirement in ports with high labour costs if port cargo-handling charges are not to become prohibitive. Similar reasoning provides an incentive for the increased use of pal-

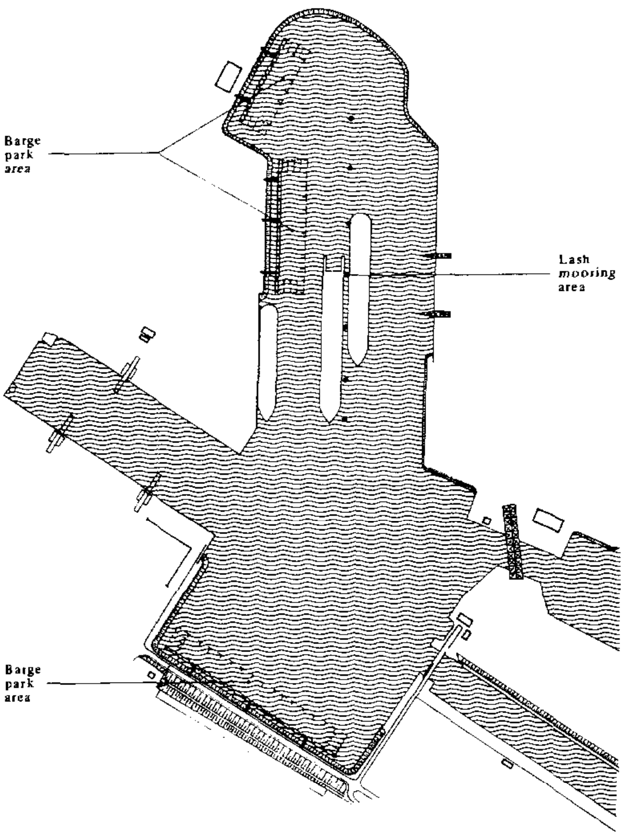
TABLE 6

Barge dimensions

Type	*Length (metres)*	*Breadth (metres)*	*Maximum draught (metres)*	*Carrying capacity (tons)*	*Bale capacity (m^3)*
BACAT	16.82	4.65	2.5	140	164
LASH	18.76	9.50	2.1	370	554
BACO	24.00	9.50	4.1	800	1 020
SEABEE	29.72	111.67	3 2	844	1 108
DANUBE SEA LIGHTER	38.25	11.40	3.3	1 070	1 300

FIGURE 34

LASH facilities at Bremerhaven



lets, bundled units and pre-slung units in a barge-carrier operation.

216. In Singapore. a large warehousing complex (providing 200,000 square metres of covered storage space) at Pasir Panjang, which was built independently from the barge-carrier development, has now been partly set aside for the receipt of cargo from barge carriers. This development has made it necessary for the Port of Singapore Authority to install in the Pasir Panjang area six mooring buoys, which will permit the safe anchorage of 120 barges. The buoys are approximately 700 metres apart and are all in line, thus stretching out over 3,500 metres.

217. Although there is thus a variety of alternatives in providing facilities for barge-carrying vessels, combined with or indepedent of break-bulk or unitized berths, indicative planning figures for an annual throughput of 250,000 tons made up of 1,000 barge units with an average cargo load of 250 tons per barge would be as follows:

Number of mooring areas	1
Number of mooring buoys	4
Required barge park area (assuming a peak of 50 barges at one time)	20,000 m^2
Number of tugs required to tow barges between the mother-vessel and the barge park area (depending on the distance between them) ...	3
Number of pontoons (assummg an inland penetration of less than 10 per cent)	20
Length of quay and area required to load and discharge the cargo of the barges in port	As for two break-bulk berths

Chapter VII

DRY BULK CARGO TERMINALS

A. Introduction

218. This chapter is concerned with dry bulk cargoes, but it is necessary first to note that the word "bulk" can be used in two different senses. Traditionally, the expression has been used to indicate that a commodity was loaded or discharged in loose or fluid form, for example, grain or petroleum. More recently, however, there has been a tendency to talk about "bulk shipments" in the sense of shipments by the full shipload or substantial part-load, whether or not the commodity in question is handled by bulk cargo methods in the traditional sense. Thus it is now common to speak of "bulk shipments" of steel plates or bundled timber. The term "semi-bulk" is also used, for example, with reference to large shipments of bagged cargo. This chapter considers dry bulk cargoes in the traditional sense only.

219. Dry bulk cargo is customarily divided into two groups, the "major bulk cargoes" and the "minor bulk cargoes". The major bulk cargoes consist of a group of five commodities which almost invariably move by non-liner methods in full shiploads. In 1980, the traffic in these products was as follows:

	World sea borne trade (millions of tons)	*Percentage carried by bulk and combined carriers greater than 40,000 dwt*
Iron ore	314	91
Grain	207	43
Coal	206	65
Bauxite	48	40
Phosphate ...	48	17

Source: *World Bulk Trades 1980*, Fearnleys

The majority of shipments of these commodities are made by specialized bulk carriers and combined carriers (over 40,000 dwt), but general cargo vessels are also used to a certain extent. When a traditional 'tween-deck vessel is used, however, a severe reduction in handling speed results. Separate descriptions of a typical coal import terminal and a typical phosphate rock export terminal are given later in this chapter.

B. Main characteristics of a major bulk cargo terminal

220. A radical difference exists between the character of a major bulk cargo terminal, especially one for the export of mineral ores, and the average all-purpose commercial port. The requirements with respect to location, depth of water, type of infrastructure, layout, equipment, storage facilities and auxiliary services are basically different from those in a typical general cargo port. Also, the administrative, operating and labour problems must be approached in a different way.

221. Unlike a general cargo port, a terminal for the export of mineral ores does not need to be located close to the main centres of commercial and industrial activities of the country. The nearest possible distance from the mining area, with good land communication, is the most desirable place, subject, of course, to there being favourable natural conditions at that sector of the coast. Depth of water requirements are more stringent, as the trend is towards the transport of most ores in the largest possible vessels with a draft often in excess of 15 metres.

222. Vessels of this size require huge stocks of ore at the terminal and therefore extensive storage facilities. In order to minimize expensive ship time at port, it is necessary to ensure a relatively low berth occupancy to avoid the risk of ships having to wait for a berth, and a very high rate of loading while they are at berth. To achieve the required speeds of loading, a network of belt conveyors is needed, linking powerful reclaimers to ship-loaders. The mechanization of cargo handling has eliminated the need for a large labour force, and the uniformity and simplicity of the material handled at a dry bulk cargo terminal means that the many commercial services needed at a general cargo berth are not required.

223. The handling techniques used allow vessels to be berthed up to a kilometre or more away from shore, if necessary, with the ores being carried to the ship by belt conveyors placed on a light structure. A typical ore berth consists of at least two berthing dolphins, two mooring dolphins and some buoys. In-shore of the berthing dolphins, an independent structure supports the loading equipment, composed of a ship-loader connected to land by belt conveyors. The storage area on land requires the proper equipment for unloading vehicles from the mines, for stacking the ores on the stockpiles and for reclaiming ore for delivery by belt conveyor to the ship-loader. In addition, facilities for direct transport from unloading hoppers to the ship-loader should be provided.

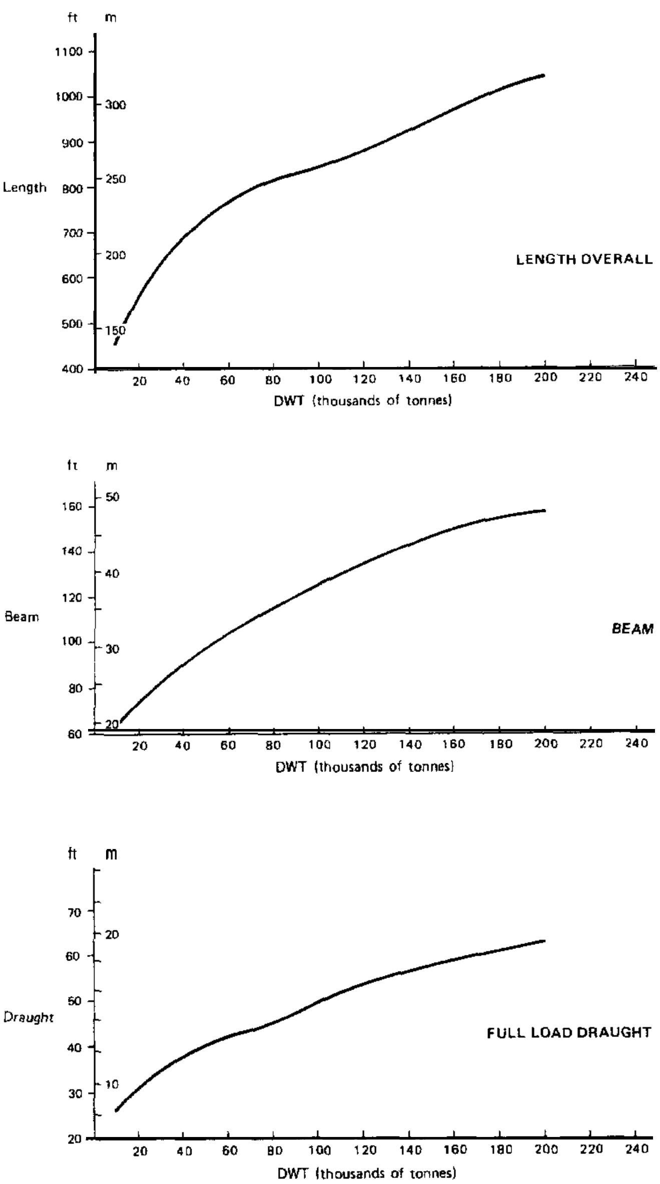
224. Although the basic elements will remain approximately the same from one terminal to another, the particulars of the design will vary considerably, according to local conditions, the nature of the material and the scope of the operation. Normally each installation will have to be designed and built to suit the particular circumstances.

C. Bulk carriers

225. Wherever possible, bulk cargo installations should be designed for specific ships known to be call-

FIGURE 35

Principal dimensions of dry bulk cargo carriers



Source: University of Liverpool, Marine Transport Centre, *The Principal Dimensions and Operating Draughts of Bulk Carriers*.

ing. Detailed discussions with the shipowners and shippers should therefore be held to agree on the requirements for ship-loaders and unloaders. However, other ships will call and the specifications will need to take account of both maximum and minimum ship sizes.

226. The phenomenal growth of the dry bulk cargo fleet in recent years is comparable to the growth, in both numbers and size, of oil tankers. In the mid-60s there began a trend towards combination carriers able to transport two or more different types of commodities. Most of the larger vessels are capable of transporting both dry and liquid bulk commodities. Bulk carriers are classified into six types, designated as follows: B (bulk), 0 (ore), B/O (bulk/ore). O/O (ore/oil), OBO (ore/bulk/oil) and OSO (ore/slurry/oil).

227. Figure 35 gives curves showing the relationship between the length overall, beam and full load draught. and the dwt, for the majority of dry bulk carriers. Where information on specific vessels to be employed is not available, these curves are sufficiently accurate for preliminary planning purposes.

228. Ideally, all water areas which ships may have to pass through or lie in should be designed for their maximum (fully-loaded) draught. even though the occasions when ships will enter or leave port at this draught will be few in number. However, substantial economies can sometimes be made by providing less depth than this when there is certainty as to the loadings to be expected. A rough general relationship between load factor and draught for dry bulk carriers is given in figure 36.

229. It is possible for there to be certainty as to the dry bulk cargo loadings to be expected when there is an integrated transport service, for example, bulk carriers chartered by a chemical works. In such a case. the maximum load factor and hence the draught can be determined from the known stowage factor of the commodity in question and the specification of the ships to be chartered. Planning for a limited draught may also be justified when the draught of ships arriving or departing is linked to and limited by draught restrictions elsewhere.

230. The planner should thus be aware that facilities designed for a fully loaded 100,000-dwt carrier may also have to handle a partially loaded 200,000-dwt carrier. While the draught limitation of the entrance channel is overcome by the reduced load factor of the vessel, the beam and length may prevent the vessel working at the terminal. This factor should be borne in mind when specifying mechanical handling equipment. The facilities may also be required to handle smaller vessels and appropriate steps would be necessary; for example, fendering may need modification.

D. Bulk handling equipment performance specifications

231. The exact meaning of the manufacturer's performance specification for a piece of bulk handling equipment must be understood by the planner of a terminal. In fact, the various items of equipment for bulk cargo handling are subject to wide variations in performance. This applies particularly to ship unloaders and reclaimers.

232. In the case of a grab unloader, for example, the discharge rate depends on all of the following factors:

(a) Volumetric capacity of the grab;

(b) Density and nature of the material;

(c) Grab hoisting speed and acceleration;

(d) Trolley travelling speed. acceleration and braking;

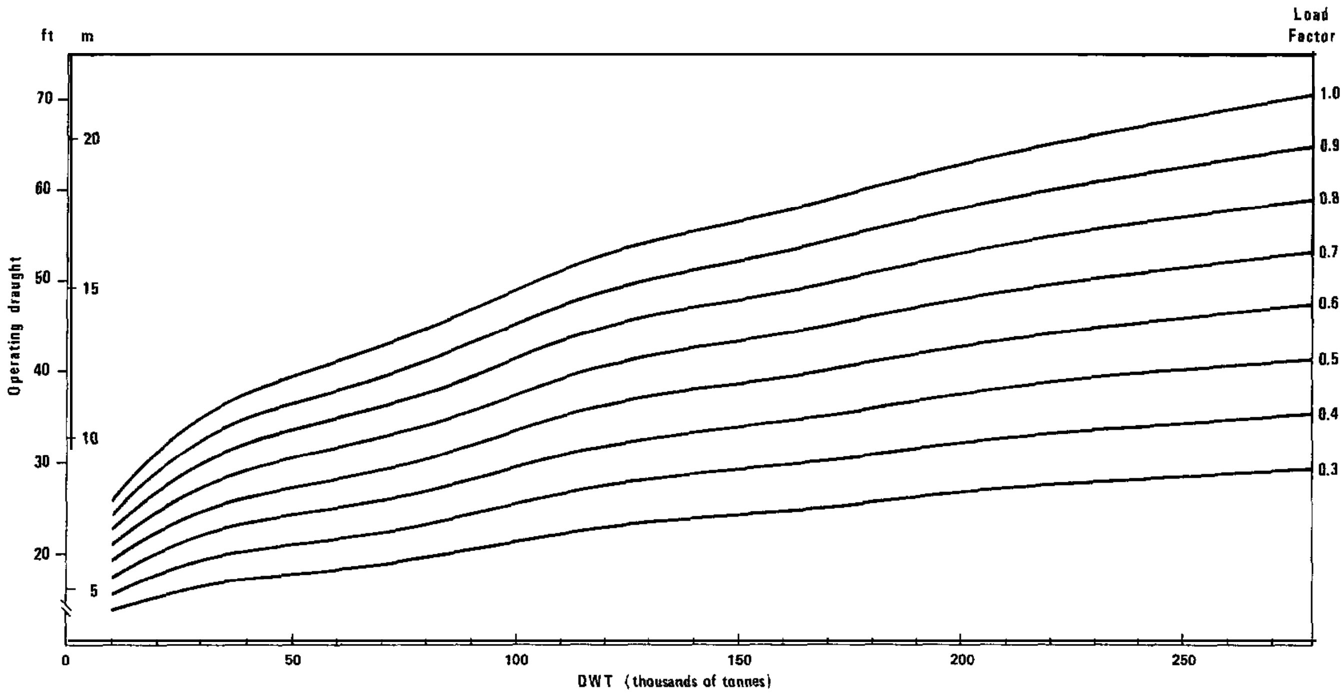
(e) Skill of unloader operator;

(*f*) Shape of hold and hatch opening;

(*g*) Method of trimming in the hold;

FIGURE 36

Operating draughts for different load factors against dwt for dry bulk cargo carriers



Source: University of Liverpool, Marine Transport Centre, *The Principal Dimensions and Operating Draughts of Bulk Carriers.*

(h) Ship's beam and unloader outreach;

(i) Depth of hold and tidal height;

(*j*) Travel distance from ship's rail to hopper.

233. Thus there is little meaning to a capacity figure for an unloader taken in isolation from the ship and the layout of the installation. The following three capacities should be defined in proposals, tender requests and design specifications: (a) peak capacity; (b) rated capacity; (c) effective capacity.

234. The peak capacity is defined as the maximum hourly unloading rate which can be achieved by the unloader when the cross traverse and hoisting distances in the unloading cycle are the absolute minimum, for example, when a full ship at the highest tide is discharging to a full hopper, and when the operator can exploit the maximum capacity of the hoisting and traverse speeds with a full grab. This rate is the capacity to which the connecting belt conveyors and weighers should be designed in the absence of other overriding economic factors.

235. The rated capacity differs from the peak capacity: it is the unloading rate during unloading from a specific point in a vessel. This point is generally located, horizontally, at the centre of the vessel to be unloaded, and vertically, at mean low water level for the port. The payload of the bucket divided by the time taken to perform one cycle from the digging point to the receiving hopper on the quay and back gives the rated capacity. This figure is a useful definition for the comparison of equipment proposals and the classification of alternative solutions to a specific requirement.

236. The effective capacity is the average hourly rate of tonnage discharged during the unloading of the entire cargo of one ship, taking into account the time lost in trimming, cleaning up, moving between holds and the requisite breaks during the working periods, but excluding scheduled non-working periods, for example night-time and weekends. The effective rate is the figure used for port planning. The ratio of the effective capacity to the rated capacity gives the through-ship efficiency factor which for grabs is usually about 50 per cent. The effective rate and the factor for the fraction of time berthed ships are worked per day are used to determine the daily throughput and then the average ship service time.

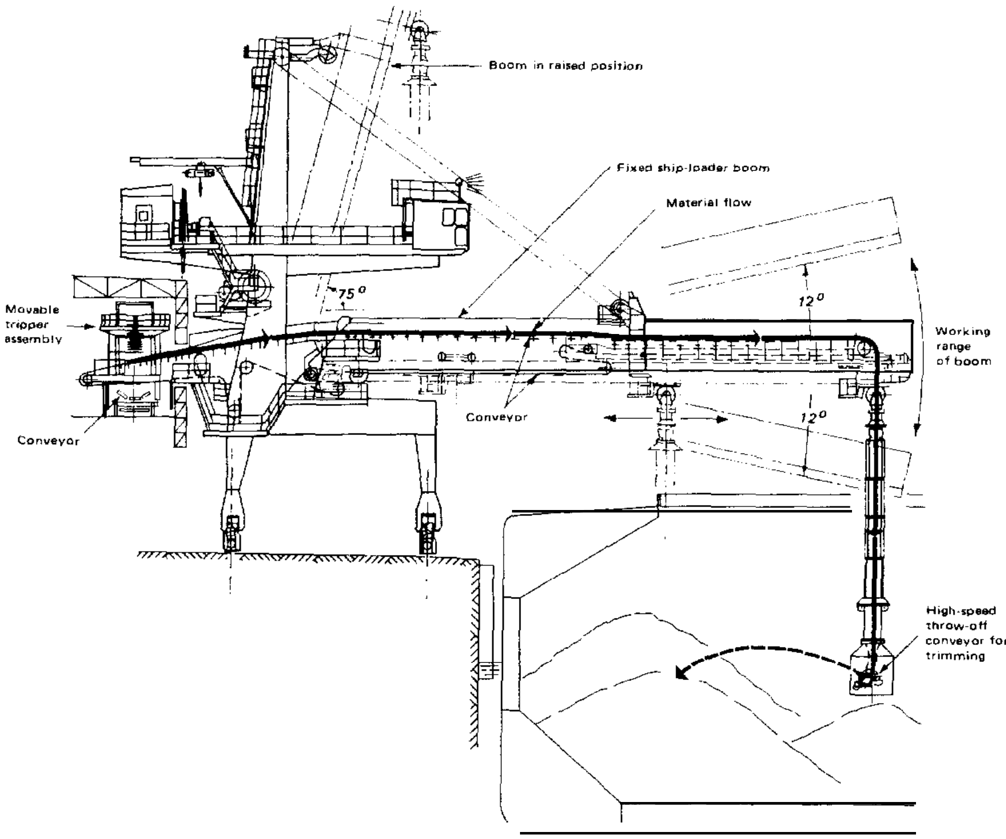
237. The "peak capacity" and "rated capacity" are also known as the "cream digging rate" and the "free digging rate" respectively. In a typical case, where the peak capacity is 2,500 tons per hour, the rated capacity may be 2,000 tons per hour and the effective capacity not more than 1,000 tons per hour. The effective unloading capacity can be even lower than 40 per cent of the peak capacity if the ship has unsuitable holds, narrow hatches and bad conditions for trimming.

E. Ship loading

238. Ship-loading systems are simple in comparison with ship-discharging systems. They normally require only a feed elevator or conveyor, a loading chute and the force of gravity. With such technically simple systems, phenomenal rates can be achieved. Other loaders are fitted with flight conveyors or spiral chutes to reduce the degradation of friable materials, or with telescopic tubes fitted with chutes or centrifugal slinger belts for distributing the material in the hold. Shiploaders can normally be positioned adjacent to the hatch to be loaded, and they receive the material from high-capacity belt conveyors. The loading boom can be

FIGURE 37

Example of travelling ship-loader with material from high-level conveyor



hoisted or lowered to suit the height of the vessel being loaded. In addition to continuous loading with a ship-loader, grabs can also be used for loading bulk cargoes.

239. Ship-loader capacities are usually limited by the other parts of the installation such as the conveyors or reclaimers, but normal capacity ranges are between 1,000 and 7,000 tons an hour. In special cases, 16,000 tons per hour handling ship-loaders are possible for very large bulk vessels. At higher loading speeds, the limit may be imposed by the rate at which the ship can be de-ballasted.

240. Ship-loaders are designed to permit the holds to be loaded in a definite sequence to avoid putting structural stresses on the vessel. Telescoping spouts at the end of the boom are frequently provided to direct the discharge into specific parts of the vessel. The boom can be raised to pass clear of a vessel's superstructure when changing from hatch to hatch, but this may require the conveying system to be stopped in order to prevent spillage of material. To avoid this, the material can be conveyed into a surge hopper at a point before the loader and returned to the normal flow when loading is resumed. The loader belts must then run faster than the supporting conveyors to handle the additional flow.

F. Types of ship-loaders

241. The travelling loader (see figure 37) is on a gantry running parallel to the quay. The ship-loader is usually fed by a conveyor with a movable tripper. The tripper feeds the material from the conveyor to the ship-loader boom conveyor. The ship-loader consists of a mast superstructure from which a hinged boom is suspended. The boom is raised or lowered to suit the vessel and to clear the vessel's superstructure when moving from hatch to hatch. The vessel end of the boom can be constructed to telescope or a shuttle section can be arranged to travel inside the fixed boom. A take-up system must compensate for variations in belt length due to the boom movements. A design feature of this type of loader is that there is only a slight shift of the centre of gravity within the structure for all the jib and boom movements, and the loader can therefore be placed on somewhat narrower rails than other types.

242. The radial loader was developed for use as an offshore unit and consists of a pivoted boom which can rotate or slew through an angle of approximately 90 degrees about one end, whilst the other end is carried on a curved track supported on suitable piles. The boom supports a conveyor which extends over the vessel. This section, in addition to travelling backwards and forwards, can also be made to luff. Material is discharged from the approach arm conveyor at the pivoted end of the boom conveyor, where. if required, a surge hopper can be located.

243. The main advantage of slewing bridge-loaders as compared with the travelling loaders is the lower capital cost of the total installation, that is, of the loader and related conveyors, together with the marine structures. Another favourable feature is that it is

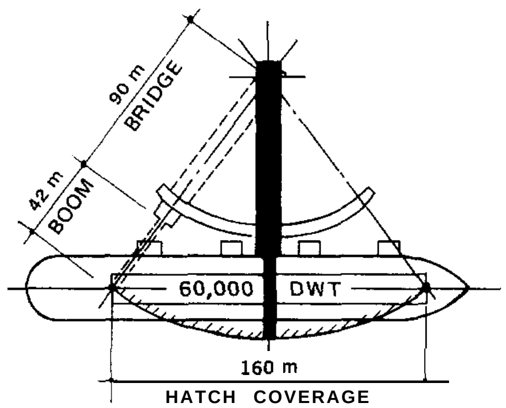
easier to enclose the conveyor belts and transfers and to install dust control systems. A disadvantage is that this type of loader can completely fill, without final trimming, only a modern bulk carrier with no intermediate masts and derricks. This prevents carriers which are so equipped from using the terminal.

244. The liner loader achieves the same purpose by a combination of translation and rotation (the two methods are shown in figure 38); when the front turntable travels on a linear runway parallel to the ship, the turntable pivot is allowed to slide as well as rotate. Construction is usually simpler and less expensive with a straight runway rather than a curved one, and ship coverage is increased.

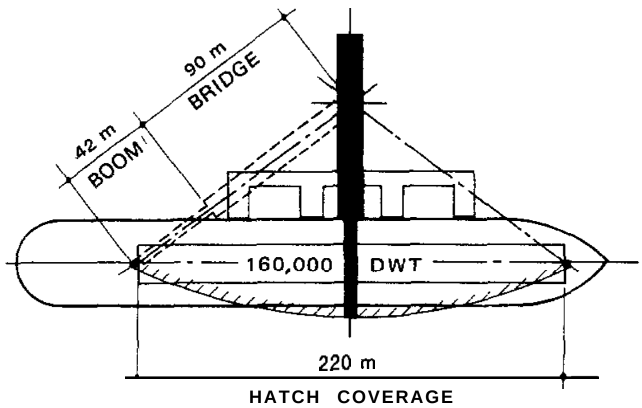
245. The travelling and slewing type of loader is a combination of a radial and travelling unit. It is particularly suited for use on both sides of a "finger" jetty, i.e. one extending out to sea with berthing facilities on either side. A travelling gantry with a rotating superstructure has a luffing boom conveyor which is fed from a jetty conveyor centrally located between the travelling gantry rails. By means of a tripper, the material is transferred from the jetty conveyor to a receiving hopper located over the pivoted **end** of the boom. Although only one vessel can be loaded at a time, the fact that vessels can be berthed on both sides of the jetty can eliminate delays in operating due to berthing and de-berthing. This may be important under conditions of high berth occupancy and tight scheduling.

FIGURE 38

Radial and linear loader comparison



Radial loader



Linear loader

246. The fixed ship-loader is generally used for smaller installations. As the vessel size is usually small, the output rarely exceeds 500 tons per hour. The movement of the loading boom between hatches is either non-existent or restricted, and it is therefore necessary to move the vessel. This may not present any problems with the smaller type of vessel having two or three holds only, and has been used extensively for the export of raw sugar.

247. The approach conveyor from the land is carried to the berth on a series of trestles and terminates with a tower structure. The conveyor is either extended in a short sliding section terminating with a telescopic chute or is carried in a luffing boom fitted with a telescopic chute. In some cases a limited amount of radial movement is provided to enable the whole area of the hatch opening to be covered and so reduce the amount of final trimming.

G. Ship unloading

248. There are four basic systems available to the terminal operator for the discharge of dry bulk material: grabs, pneumatic systems, vertical conveyors and bucket elevators. For a throughput per unit of between 50 and 1,000 tons per hour, pneumatic or vertical conveyor systems are adequate. For throughputs from 1,000 up to 5,000 tons per hour, grabs or bucket elevators are the only alternative. Grabs are the most widely used methods of loading and discharging bulk cargoes.

1. GRABS

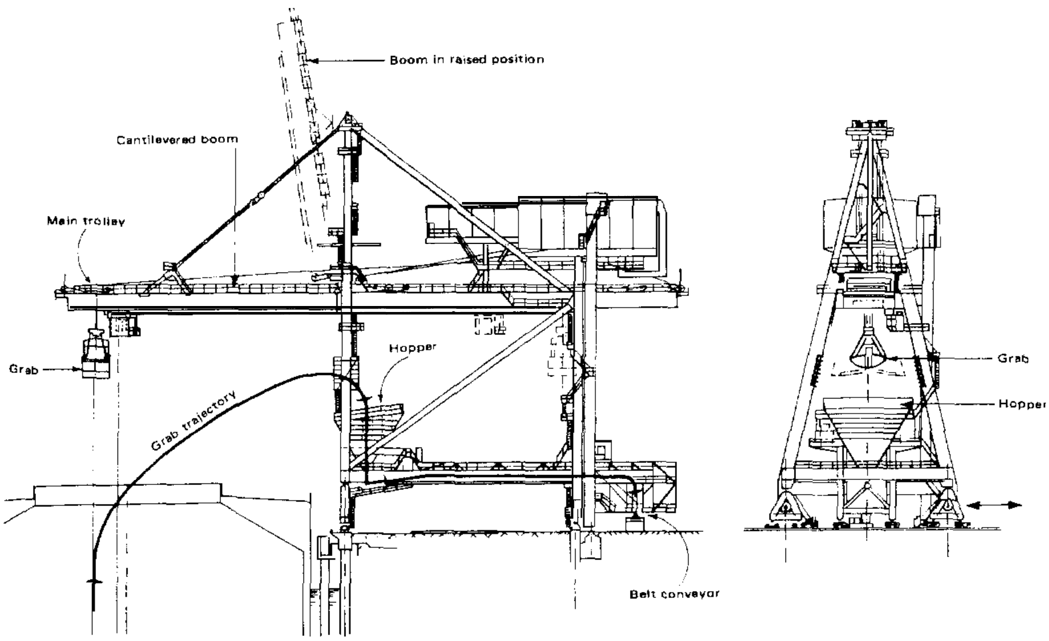
249. The main principle of unloading bulk commodities by grab has not undergone any change in the past 50 years. However, the grab is now normally used only for picking material up from the vessel hold and discharging it into a hopper located at the quay edge feeding on to a belt conveyor, as illustrated in figure 39. In previous practice the grab trolley travelled further, discharging to the stockpile.

250. The attainable handling rate for each grab is determined by the number of handling cycles per hour and the average grab payload. The time of a handling cycle is a function of the hoisting speed and acceleration of the grab bucket, the travelling speed and acceleration of the trolley, the horizontal and vertical distances and the closing time of the grab. Further factors affecting it are the skill of the operator, the properties of the material being handled, the shape of the hatches and cargo holds and the degree of cleaning required at the end of each hold-emptying. Operator fatigue in any case places a limit of about 60 cycles per hour. Two operators can be provided, each working alternately for one hour.

251. For a given lift capacity, the main method of increasing productivity is increasing the payload/deadweight ratio of the grab bucket. The normal ratio is 1:1,

FIGURE 39

Travelling overhead trolley unloader grabbing crane



but newer high-capacity designs are approaching 2:1. A bulk cargo terminal handling a range of commodities will require a set of two or three grab buckets for each crane (one on the hook, one on standby and/or one in repair), plus a set of grabs for each commodity which has significantly different physical characteristics. The number of available designs is very large, ranging from the light grabs for handling products such as animal feedstuffs and grain, to the massive 50-ton-lift ore handlers. Specialist advice should therefore be sought to allow the choice of the correct unit for a specific material and crane type, and for specific working conditions

252. To achieve the desired rate of unloading, it is often necessary for a single vessel to be served by two unloaders. This has an important advantage in providing operating capacity during the failure of one of the units.

253. The principal materials for which the grabbing bulk unloader is used are the main bulk products, namely, iron ore, coal, bauxite, alumina and phosphate rock. Other commodities handled by smaller mobile grabbing cranes include raw sugar, bulk fertilizers, petroleum coke and various varieties of bean and nut kernels.

254. There are three main forms of grabbing crane. The travelling overhead trolley unloader (see figure 39) has a cantilevered boom which projects over the hatch. The trolley transfers the bucket from the hold to the hopper on the quay, The structure travels parallel to the quay to allow working the full length of the ship. Typical free digging rates for these units range from 500 to 2,000 tons per hour.

255. The revolving grabbing crane, as shown in figure 40, is generally of the level luffing type and is probably the most commonly used type for unloading. The crane grabs and lifts the material and discharges it into a hopper, generally at the front to eliminate slewing during operation. The hopper feeds a jetty conveyor in the usual way or it can discharge directly to trucks or rail wagons. These cranes can attain a free digging rate of between 500 and 700 tons per hour. When a normal general cargo crane is being used for grab unloading, the hopper must be located on the same track as the crane. The 90-degree slewing movement for each grab cycle limits the free digging rate to 250 tons per hour, a good average rate being about 180 tons per hour.

256. The third form of grabbing crane is the mobile port tower crane which is useful in smaller ports handling a wide range of mixed cargoes to and from smaller vessels. This unit comprises a standard mobile crane with an additional tower structure fitted with an elevated cab to allow the operator to look down into the ship's hold. Productivities are similar to those achieved with the revolving grabbing crane.

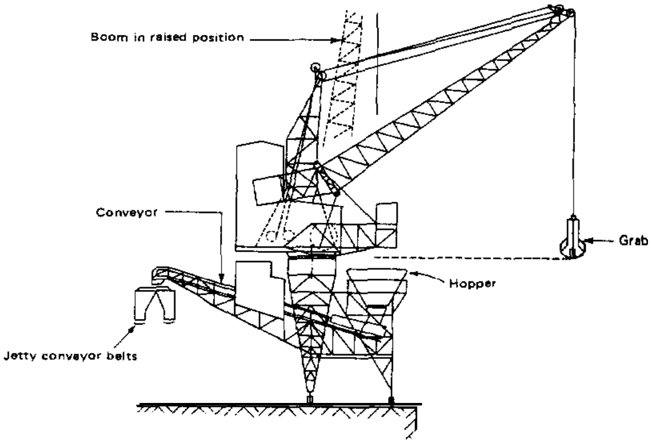
2. PNELJMATICSYSTEMS

257. Pneumatic systems are suitable for handling bulk cargo of comparatively low specific gravity and viscosity such as grains, cement and powdered coal. Pneumatic equipment is classified into vacuum, or suction types and pressure, or blowing types. The former are suitable for collecting materials from several places to one spot while the latter are suitable for delivering cargo from one spot to several places. However, the blow type tends to create dust problems. A combination of the two systems is also used, but it is generally restricted to portable equipment. Typical uses of this equipment are shown in figure 41.

258. Vacuum pneumatic conveyors are simple in construction and materials are not lost through spillage during transportation. However, the power consump-

FIGURE 40

Revolving grabbing crane

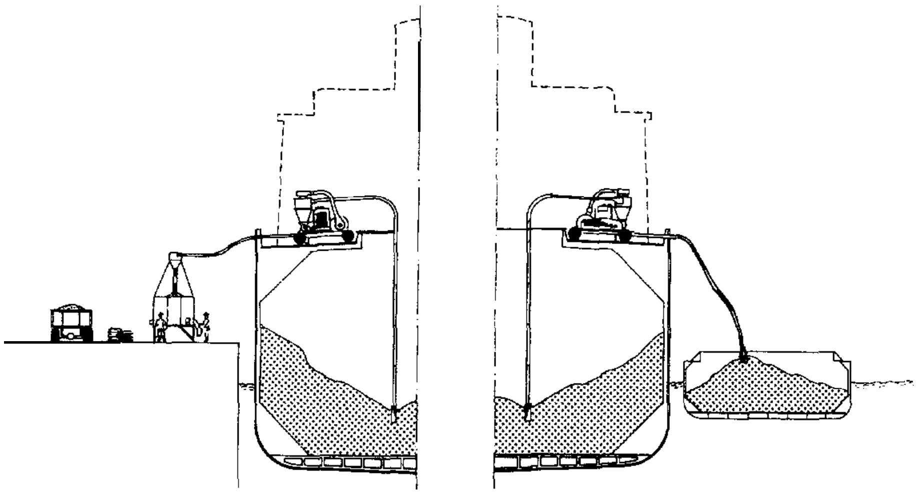


tion is high compared with other transporting media. Before a decision is taken whether to adopt a pneumatic handling system or a conventional mechanical handling system, not only must the capital, maintenance and operating costs be considered, but also health, cleanliness and other factors which cannot be directly evaluated.

259. Certain materials are potentially dangerous and should be handled carefully to ensure the health of the operators. Some hazards to health can be overcome by the wearing of face masks and protective clothing. The adoption of a fully enclosed pneumatic handling system, although initially more expensive, often improves working conditions and reduces material loss as well. Cleaner conditions improve morale, facilitate plant maintenance and reduce health hazards.

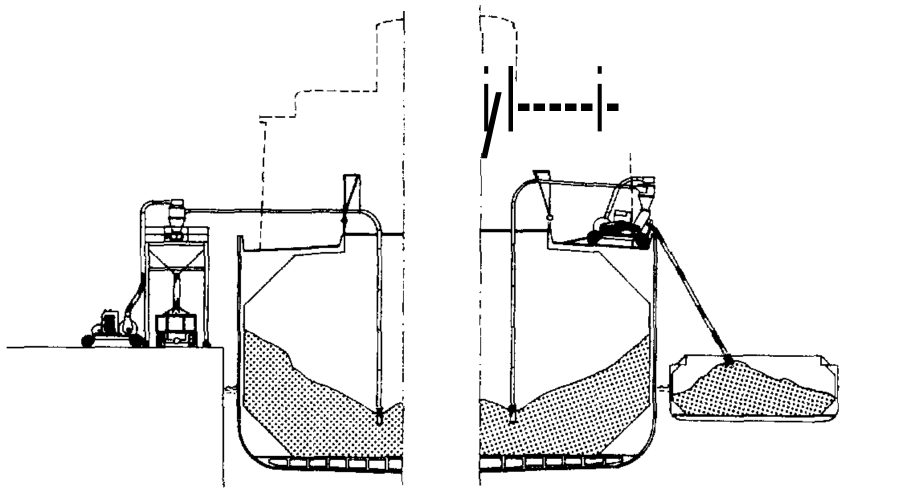
FIGURE 41

Portable pneumatic handling equipment



1. Combination vacuum/pressure system; conveying grain from ship into bagging hopper.

2. Combination vacuum/pressure system; conveying from ship to barge.



3. Vacuum-only system : transferring grain from ship into truck or rail wagon loading hopper.

4. Vacuuming grain from ship; loading grain by gravity into barge.

260. The travelling pneumatic elevator consists of a rail-mounted gantry with a total enclosed superstructure for housing the major items of equipment. Generally, two units are housed in one gantry, and the usual limit of unloading rates is about 200 tons per hour per unit. The unloading arms terminate in flexible intake tubes which allow very efficient cleanup of the hold. Material sucked through the nozzle is collected by cyclone-type separators and discharged on to the onward conveying system, very often a belt conveyor.

261. There exist also waterborne versions of the travelling pneumatic elevator. They are self-contained and self-propelled machines, with a throughput similar to that of the rail-mounted kind. They can be used for discharging directly to shore storage or, in the case of onward transport, to barges. They can also be arranged to operate in reverse, from barge to vessel for export.

262. In addition, there are portable pneumatic units on wheeled trailers which can be positioned on the quay or aboard the vessel, as shown in figure 41. The handling rates of this light portable equipment are low, usually about 50 tons per hour.

3. VERTICAL CONVEYORS

263. The chain conveyor unloader (see figure 42) is a self-contained unit working on the en *masse* principle. The free digging rate is generally limited to 150 tons per hour. The conveying chain is carried inside a rectangular casing and its motion carries material from the hold. A second unit can be used as a connection to hinterland transport as the unit can be adapted for inclined and horizontal conveying. The units are restricted to dry, friable materials that are compatible with direct contact with moving parts. For intermittent use, it may be more economical to employ this type of unit rather than the grab ship unloader, in spite of its high maintenance cost.

264. The vertical screw conveyor is a full blade screw contained in a tubular casing. The unit can be used at any angle from the horizontal to the vertical. Screw conveyors can efficiently deal with all fine powdered and granular materials, lumpy (provided the lumps do not exceed a specified size in relation to the screw diameter), semi-liquid and fibrous materials. Free digging rates of up to 600 tons per hour have been achieved. The throughput is restricted to the rate at which material can freely flow into the feed aperture. A proprietary type of screw auger has an independently driven spiral around the feed intake to combat this feed problem.

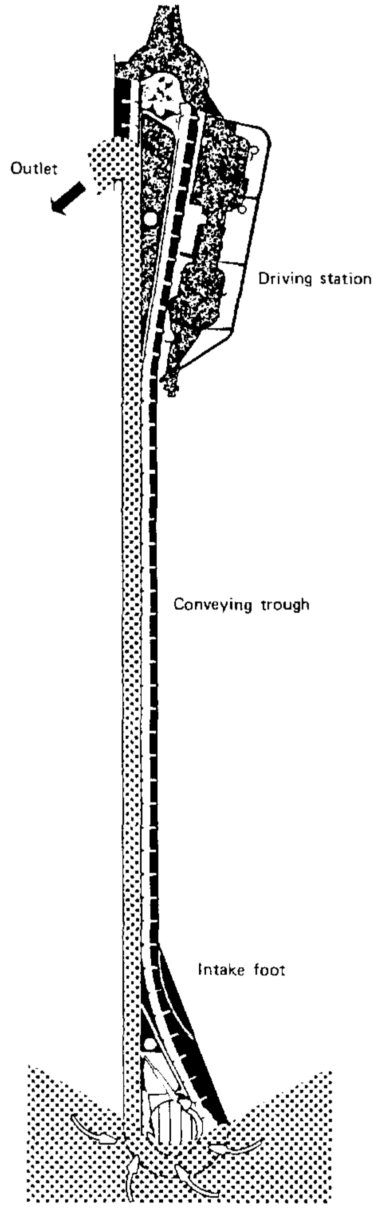
4. BUCKET ELEVATORS

265. Bucket elevators are another alternative for handling rates in the 1,000–5,000 tons per hour range. At present these continuous unloaders appear less efficient in terms of cost per ton unloaded than grabs, taking account of total capital expenditure and operating costs. However, the free digging rates for these units will approach 5,000 tons per hour, while grabs have a maximum rate of 2,500 tons per hour. Developments in this matter should be watched in view of the high theoretical handling rates.

266. One concept involves a continuously rotating bucket wheel suspended from the luffing boom of the travelling unloader. This bucket wheel digs up the material and feeds a continuous bucket elevator. The weight of the structure plus the dynamic digging forces require a heavier and more expensive quay than for the usual grab cranes.

267. An alternative approach uses a bucket chain elevator with the buckets acting as digging scoops. As in the case of the wheel and elevator, the bucket elevator is suspended from the luffing boom. A heavy foundation is again required to absorb the digging forces, and maintenance costs may be considerable. At smaller installations, for example, those for the unloading of coal and phosphate from barges, purpose-built facilities utilizing the bucket chain elevator can be very useful.

FIGURE 42
Chain conveyor unloader



5. Slurry system

268. Certain materials, such as iron ore, salt, bauxite, heavy mineral sands and certain coals may be suitable for transportation via the slurry method. This method basically consists of making a slurry-water mixture with 70 per cent ore and 30 per cent water at a mine site, and then pumping it aboard specially equipped mineral tankers. Excess water is decanted prior to ship departure, leaving a concentrate with over 90 per cent solids. At the discharge port, rotating water jets in the bottom of the holds undercut and liquefy the ore concentrate so that it can be pumped ashore. This system eliminates loading and discharge cranes, elaborate docking arrangements and other facilities.

269. The slurry process is a clean one which minimizes material loss that occurs with other, dust-inducing ore-handling procedures. Decanted liquid during the loading process may have to be returned to a settling pond to avoid pollution and to recover ultra-fine particles. The slurry form of the cargo makes it economic to locate the storage area some distance from the port area. The rate of discharge will be dependent upon the size of ship and the installed pumps, but for large vessels it will normally be 6,000–8,000 dry tons per hour. Material can be loaded dry by conventional systems and unloaded using the slurry process.

6. Self-discharging vessels

270. At the beginning of 1982, 56 per cent of the bulk carriers were equipped with gear for self-discharge, while only 12 per cent of the ore carriers were so equipped. The average size of vessels so equipped was markedly smaller than that of vessels without gear. The gear usually consists of bucket cranes or derricks with a safe working load varying from 3 to 30 tons.

271. A limited number of carriers have been built which utilize gravity reclaiming on to a belt, chain, or screw conveyor in the bottom of the holds to feed an elevator system within the ship. These vessels require only a hopper and conveyor arrangement at the discharging terminal to transfer material from the ship's system to the storage area.

H. Horizontal transport

272. Conveyors are the most extensively used piece of equipment in dry bulk handling and reappear in a variety of forms in elevators, ship-loaders, packers and reclaimers, as well as purely for horizontal transport. For horizontal transport, unlimited distances can theoretically be covered by conveyor, although transport economics will usually limit conveyor systems to a few kilometres before rail or road transport becomes more appropriate.

273. The conveyor system layout has a major effect on the whole terminal area requirements, and on its flexibility. The routes taken, and the choice between raised, ground-level or underground systems should be given a similar degree of attention to the layout of a road system in a built-up area. On long runs, design for ease of maintenance is paramount.

274. The general adoption of the belt conveyor as a mechanical carrier for bulk materials has been due to its inherent merits:

(a) Simplicity of construction;

(b) Dependability and economy of upkeep;

(c) Efficiency, with small driving power requirements.

(d) Complete discharge of the material handled;

(e) Adaptability.

The material is received directly on to the belt and is carried with a minimum of friction and noise to its destination. There are no joints or other projections to break or wear, and abrasion or friction between the material and the belt exists only at transfer points.

275. The limited vertical angle at which belt conveyors can carry materials necessitates a considerable amount of space to enable the material to be lifted to the required height. The supporting structure for long conveyors also requires routine maintenance work such as painting. These disadvantages have to be considered.

276. Belt conveyors are either flat or troughed, with the former used for packaged material. Two flat belt conveyors with their carrying surfaces located in a vertical plane at an appropriate distance apart can form a "pinch" belt elevator suitable for the unloading and loading of bagged material. Peak rates of 4,000 bags per hour have been achieved.

277. Developments have made possible the production of stronger and wider rubber belts with canvas plies. In addition to these belts with canvas plies, belts with steel wire to increase tensile strength have been produced. In combination with improvements in the associated belt idlers, belt conveyors are capable of transferring several thousands of tons per hour.

278. The chain conveyor has a flighted chain which moves around inside a totally enclosed casing with a dividing partition. Material can be introduced at any point in the top of the casing; it falls through an opening in the partition plate to the bottom of the casing, and is then conveyed by the chain until it reaches a discharge opening. The conveyor can be used up to an angle limited by the characteristics of the material. Any free-flowing material can be handled by this means, and the process is dust free. Grain is the most common material handled, and rates up to 500 tons per hour are possible. For small port installations, in combination with chain-type unloaders, this type of equipment is very useful.

279. The en ***masse*** conveyor is similar to the chain conveyor but is different in operating principle and has a casing of smaller cross-section. The unit works on the principle that the friction between the material and the specially designed chain is greater than the friction between the material and the casing. The material shifts as one body, en masse. This method permits vertical as well as horizontal conveying, and multiple inlets and outlets can be used. The construction can be made dust-tight. One disadvantage is that a certain amount of product degradation occurs.

280. Screw conveyors are a very compact form of handling with a totally enclosed casing, either U-shaped or tubular. The selection of the correct type of screw and trough cross section for the material to be handled is essential if maximum efficiency is to be obtained. Generally, capacities do not exceed 500 tons per hour. The power required is much higher than for other conveyors. Provision has to be made to accommodate end thrust due to the reaction of material along the casing. These conveyors can be inclined from the horizontal.

281. The powder pump can be used for the onward transport of dry pulverized free-flowing materials. Capacities of up to 200 tons per hour at distances up to 1,200 metres have been obtained. A high-speed screw feeds material through a non-return valve into a chamber fed with compressed air which conveys the material to the receiving vessel. Powders composed of fragile aggregates are unsuitable for this technique.

282. The fluidizing gravity conveyor can be used for horizontal transport, particularly for powders. The principle of the conveyor is that when air is passed upward through the material, the mass expands and behaves as a fluid. The conveyor consists of a sloping trough with a porous medium extending across its width. Powder fed into the conveyor flows freely down it.

283. The mono-cableway is the simplest form of aerial ropeway and is the cheapest to install and maintain. A single endless cable serves both to support and transport the load, which is carried in buckets. A single section rarely exceeds 8 kilometres in length but multiple sections can be used. Buckets are disengaged from the cable at transfer stations and are pushed or run automatically on to the next section. At the terminals the loading and unloading can be either manual or automatic. The maximum capacity is generally taken at 150 tons per hour with a typical bucket capacity of 0.5 tons.

284. The bi-cable system separates the supporting and hauling functions of the cables. Two parallel carrying cables are provided on each side of the ropeway centre line. Each cable is anchored at one end and is provided with a tensioning device at the other. An endless hauling cable is used to move the buckets supported on the carrying cables. The relatively heavy single loads which can be supported permit handling rates of up to 500 tons per hour.

I. Weighing and sampling

285. Material must often be weighed immediately prior to loading or after unloading for payment purposes, or for checking against shipping documents. A simple method is to weigh the material continuously while it is being conveyed. and according to the type of equipment used, varying degrees of accuracy are obtainable. Essentially, the loaded side of the belt is carried over an independently supported section of conveyor structure. The weight of material on this section of the belt is instantaneously recorded. and in conjunction with the speed of the belt the quantity conveyed at any flow rate can be calculated automatically. Various forms of obtaining weights give different degrees of accuracy, and range from simple mechanical/electrical devices to electronic strain gauge units. Two standard levels of accuracy may be provided: an accuracy to within 1-2 per cent of the actual weight, and an accuracy to within 2-4 per cent. The degree of accuracy attained is dependent on the placing of the weigher, which is a skilled task.

286. Batch weighing methods are also employed, normally through the use of a weighing bin in conjunction with a surge hopper. Material is temporarily diverted to the hopper while the full bin is automatically weighed and dumped. Weighing towers are often incorporated into the conveyor network, an inclined conveyor being used to feed the top of the tower.

287. Sampling is sometimes a requtrement in a transfer of material, generally to satisfy the purchaser that the material is in accordance with specifications. Any attempt to take a sample by hand could result in incorrect representation of a particular batch. It is therefore essential to take a series of samples automatically at timed intervals. In order to obtain a representative sample from the whole series of primary samples, they can be mixed together and a further sample taken. This procedure can be repeated until a very representative sample of the batch is obtained.

288. Several methods of obtaining samples are available according to the characteristics of the material and the accuracy required. A usual type of sampler consists of a scoop which is quickly swung through the material either on the belt or through the falling stream of material, and deposits its contents either into a sample box or into a mixing hopper for further sampling. The decision as to the best method of sampling and type of sampler to use should be left to the specialist.

J. Stackers and reclaimers

289. The stacker is a specialized machine designed for the continuous stacking up of various kinds of bulk materials in storage areas, and comprises a tripper (see figure 43) and a stacking-out conveyor. Material is discharged by means of a tripper which allows the stacker to be positioned anywhere along the whole length of the belt conveyor in the storage area. The material is then fed on to the stacking-out conveyor carried in a boom which is capable of being slewed and/or derricked, or may be fixed. Figure 44 shows a typical stacker arrangement. Sometimes, material can be discharged direct from the tripper to allow the area adjacent to the tripper to be used for storage. The capacities of stackers are constantly being increased. and outputs up to 6,000 tons per hour or more are possible, the limiting factor normally being the rate of feed from the unloading equipment. Blending is achieved by the right mode of stacking.

290. The modern reclaimer is a machine that can continuously reclaim and discharge the stored material from the storage area. and consists of the reclaiming mechanism and the intermediate belt conveyor. The reclaiming mechanism may be a revolving wheel on

which buckets or gathering arms are attached. Reclaimers are high in efficiency provided that care is taken in stockpile planning. Typical rated capacities of individual units vary from 1,000 to 3,000 tons per hour. Peak capacities must be used for designing conveyor systems. There is a limitation on the order in which piles of different grades of material can be reclaimed according to their accessibility. It may also be necessary to use a bulldozer to push the farthest parts of the pile into positions accessible to the reclaimer arm. Large-capacity machines are very heavy and require substantial track foundations, so that the existing ground conditions could be the limiting factor.

291. Stacker reclaimers, as illustrated in figure 45, have the two functions of stacking and reclaiming in a single unit. The belt conveyor on the boom travels in the discharge direction with the reclaim wheel stationary when discharging, and in the reverse direction with the reclaim wheel in operation when reclaiming.

292. When the storage area is small, stacker reclaimers have proved to be extremely useful. In a small area, the installation of a separate stacker and a reclaimer will sometimes limit the working area of each machine and cause areas of inaccessible material. If the need for stacking and reclaiming at the same time does not arise, for example, when for a single material the

FIGURE 43

Principle of belt loop or tripper

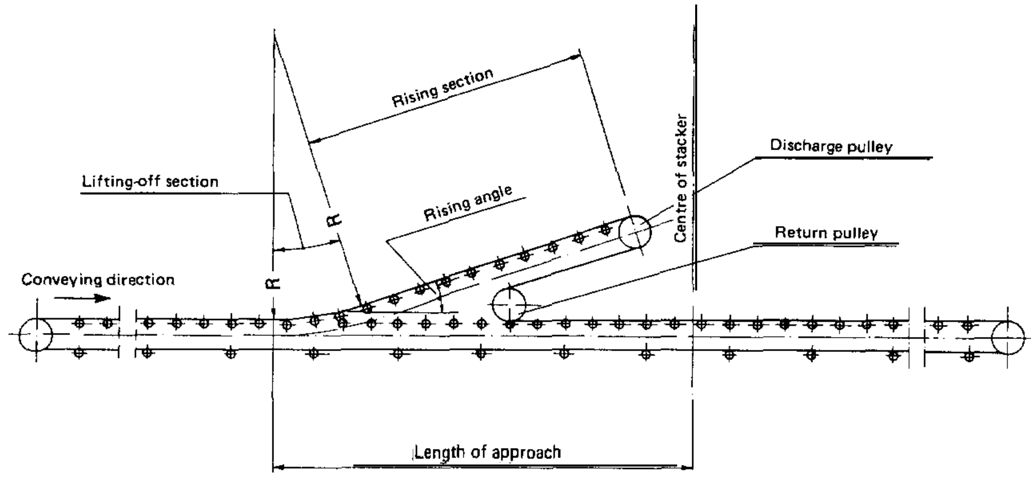


FIGURE 44

Arrangement of stacker for feeding stockpiles

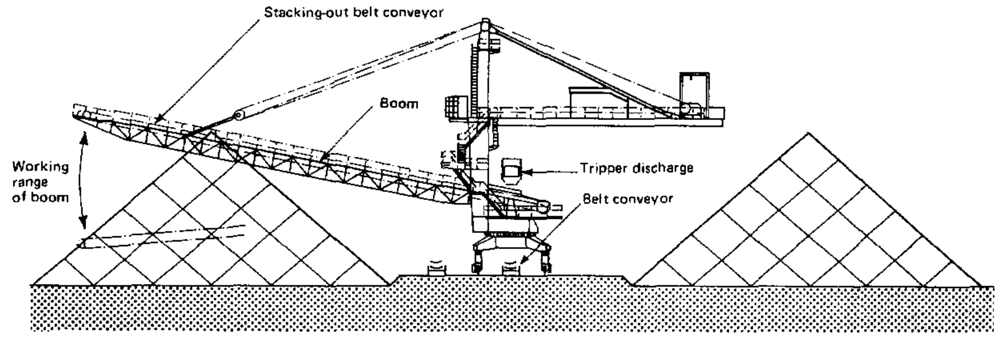
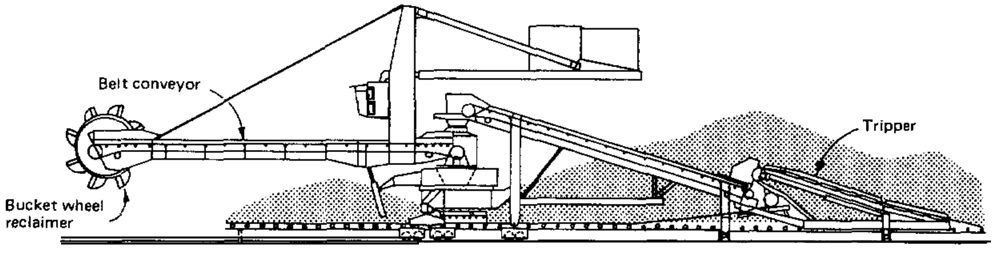


FIGURE 45

Typical stacker/reclaimer



arriving flow can be routed direct to the ship-loader in addition to the reclaimed flow, then it is recommended that a stacker/reclaimer should be used. with reduced initial investment. On the other hand, if both operations are required simultaneously, then separate-function machines are required.

293. An alternative to the bucket wheel stacker/reclaimer is a scraper/reclaimer, also known as a "back-stacker" reclaimer. Here the boom conveyor consists of two heavy-duty chains with flights of substantial proportions at regular intervals. For stacking, the boom conveyor flights scrape the material into the stack from the hopper feed. and for reclaiming, the chain conveyor is reversed and the material is scraped down the pile into a trough to a normal conveyor. This system is lower in maintenance costs and raises less dust. The method has been successfully used at a phosphate rock terminal.

294. A further alternative stacker/reclaimer arrangement, which in the past was used extensively, is the overhead travelling transporter. Here a travelling gantry spans the storage area and contains a belt conveyor at high level with travelling tripper. Also mounted in the gantry are usually two travelling bucket elevators which can discharge on to the belt conveyor.

295. In the stacking operation, material from the store yard conveyor is elevated to the gantry belt conveyor for discharge direct to store by the travelling tripper. For reclaim, the elevators, of open-frame construction, are lowered into the material which is reclaimed in the buckets and discharged on to the reversed gantry conveyor. This discharges into the store yard conveyor which is also reversed. The reclaim rate of the elevators is limited to about 500 tons per hour and considering the extensive steel-work required to carry this equipment, with the subsequent high maintenance costs, this type of unit has generally been superseded by the other forms of reclaiming.

296. There is another scraper/reclaimer type of machine which is usually installed in a storage building, although it can be used outside for materials that do not require weather protection. Capacities of up to 1,000 tons per hour are available. In this unit the material pile is reclaimed by a scraper chain conveyor suspended from a portal frame and pivoted at its lower end. The frame is mounted on travelling bogies running on rails throughout the whole length of the building. A belt conveyor in the terminal receives material from the pivoted end of the chain conveyor, whilst an additional chain scraper is sometimes suspended from the other leg of the portal frame to push the material into the path of the main chain conveyor.

297. This approach has several advantages:

(a) Fully automatic operation of the machine is possible, although it is usually operator controlled;

(b) Reclaiming is continuous;

(c) Reclaiming output is independent of the skill of the operator.

A disadvantage is that the substantial space required for the plant causes loss of storage space inside the building.

298. The underground reclaim system can be used for either covered or open storage, and it is probably one of the most common, although it has certain disadvantages. It normally consists of one or more underground conveyors running the whole length of the storage and enclosed in tunnels, as shown in figure 46. The system relies on gravity for the discharging of the material on to the underground conveyors. The shape of the tunnels is dictated by the method used for controlling the rate of discharge.

299. In one example of the system, there is a series of feed openings in the floor of the store, each fitted with a chute and an adjustable cut-off gate. The flow of material through an opening can reach a speed of up to 1.000 tons per hour, and the total reclaim rate will be dictated by the number of openings which it is feasible to control. Normally, three or four openings can be discharging at any one time on to each conveyor.

300. The main advantage of this system is that the capital costs are relatively low, but these mav be outweighed by the operating costs and the inefficiency of the reclaim. Each feed opening will be able to reclaim only a limited amount of material, depending on its angle of repose. Moreover. the rate of flow through each feed opening will decrease throughout the discharge, requiring constant attention from an operator to ensure that the total reclaim rate is maintained. As it is usually necessary to have more than one outlet in operation at any one time, the extract rate will be dependent upon the skill of the operator, and some loss in output is inevitable. Another disadvantage is that it will not be possible to empty the store completely without resort to the use of bulldozers, and this may not be acceptable when handling dusty or dangerous materials. It can also be difficult to avoid severe dust levels underground and arduous working conditions for the feed operators. Another important consideration to be borne in mind in the designing of underground reclaiming systems is that of drainage.

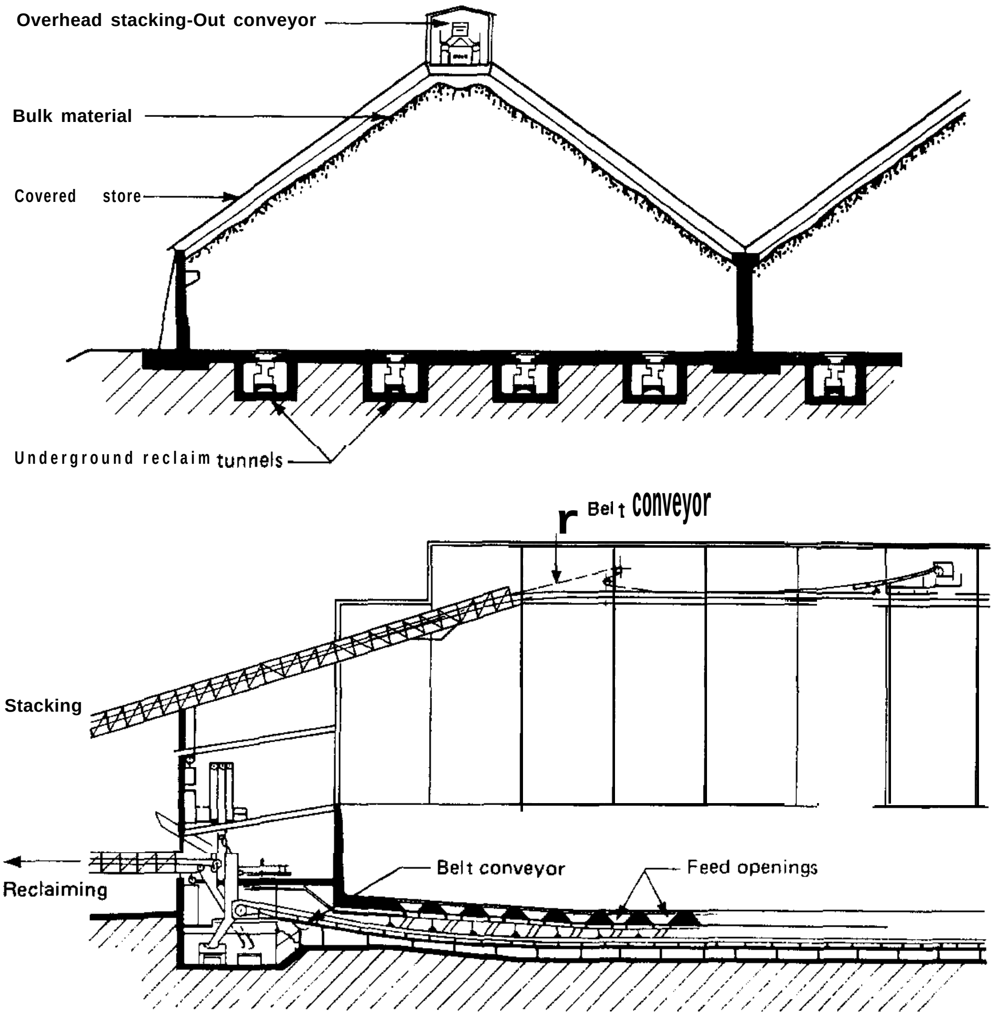
301. A form of extraction which overcomes the operational disadvantages is the provision of a paddle wheel extractor to feed on to the belt conveyor. Here a specially formed base to the store is required, having hopper sides and a continuous slot running the whole length of the store. The paddle wheel extractor, which has slowly revolving arms moving in a horizontal plane, is mounted in a travelling carriage which travels backwards and forwards along the slot. Material is therefore continuously taken equally from the whole store, and the whole operation can be carried out automatically by an operator from an isolated control room, which could be advantageous when dusty material is handled. The main disadvantage of this system is in the cost of construction of the special slot opening, which can be high.

302. The dragline scraper has been used quite successfully in the past. but has been superseded to a large extent by the mobile bulldozer and large-capacity front-end loading shovel. It is, however, still useful where very dusty materials are handled and the use of mobile equipment in an enclosed store would be undesirable.

303. The equipment consists of a winch house. generally situated in a tower superstructure. which has a reception hopper at its base, and a pair of hauling ropes

FIGURE 46

Underground reclaim with gravity feed to belt conveyor



which extend from the tower to a travelling frame. This frame is power driven and moves around in an arc on the outside of the stockpile. A travelling scoop, attached to the ropes, can be moved backwards and forwards across the stockpile. During its forward motion, it moves material into the receiving hopper, whence it passes on to the conveying system.

304. For very small installations having an appropriately sized storage area adjacent to the quayside or to a reclaim conveyor system, it may be convenient to use a front-end loader and a mobile belt conveyor having a suitably sized feed hopper. In some installations, a small feeder conveyor below the surface must be used with a wide ground-level hopper having an open side through which material may be directly pushed. With a front-end loader, capacities up to 100 tons per hour are within the capabilities of each driver. The mobile belt conveyors can also be used for direct loading into barges and lighters from tipping trucks. The rate of loading is determined by the vehicle tipping speeds.

305. A scraper is standard equipment used in civil engineering for site preparation, and for the open pit working of certain minerals. It has been used very successfully for emergency stock reclamation, when a machine with a capacity of up to 20 cubic metres can be used. When the bowl is full, the clam-shell gate is closed and the bowl raised clear of the ground; the machine then travels to the discharge point. It is only possible to discharge into a suitably sized ground hopper, which will add to the civil engineering capital costs. This type of reclaim can be used only when degradation of the material, due to the heavy machine travelling over the storage area, is acceptable.

K. Storage

306. The availability of land for the stockpile is limited either by the natural conditions or by the cost of acquisition. The stockpile must therefore be planned so that a maximum amount of material can be stored in a minimum area. The volume of material which can be stored in a given area will depend, not only on the bearing capacity of the ground and the characteristics of the material but also on the outreach and height of stackers and reclaimers. The function of the stockpile is to enable transportation facilities with different times

and rates of working to function independently of each other, so as to avoid delays caused by one facility having to wait for another.

307. The most common form of bulk storage is the wind-row arrangement (see figure 47). where material is arranged in an elongated pile, the width of which is determined by the height of discharge and the angle of repose of the material. On smaller sites. a circular pile may he arranged, with stacking out and reclaim from a central rotating stacker/reclaimer. The storage area may he open to the elements or completely covered, according to the material and the prevailing weather.

308. For material affected by weather, a covered store. normally a portal-framed structure spanning the width of the pile and extending for the whole length, is used. Feed-in is generally from a high belt conveyor situated along the apex of the building and reclaim is by means either of a scraper/reclaimer or of an underground conveyor. When dusty materials are being handled, it may not be possible to reclaim with a scraper/reclaimer at the same time that material is being fed into the store. The two options are then either to erect a second storage building. or to use an underground reclaim system.

309. When unloading a vessel it may be necessary to use road vehicles or rail trucks for onward transport. In this case it may be convenient to use a storage bunker or truck silo in conjunction with the open storage. The bunker takes the form of an elevated store of limited quantity that can be fed at the same time as the main flow to the stockpile. The onward loading of transport vehicles is carried out from bottom-opening doors. Control is usually effected from raised platforms giving an unobstructed view of the loading operarion and of the traffic movements. Bunkers may be constructed from reinforced concrete or structural steel and plating, and arranged to be fed from overhead conveyor systems or pneumatically.

310. When storage bunkers are empty, material entering could have a considerable distance of free fall, which would result in segregation and in degradation of friable materials. One device to prevent this degradation is a specially designed chute in the form of a spiral which arrests the fall of material by friction in the chute sides. Segregation occurs when particles of a well-mixed material. being delivered from a single point. fall on to the cone of material. Fine particles tend to lodge in gaps, while large particles tend to roll down the surface of the cone and collect near the walls. Where segregation is to be avoided. care must be taken to ensure that material is withdrawn evenly from the whole cross-sectional area of the bunker. This can be achieved through careful design by specialists.

311. A silo may be a single unit or a multiple unit in which various grades of material may be stored. Silos are generally used for the storage of grain and animal feeds where provision must be made for sealing against the ingress of moisture and vermin. Construction materials used can be reinforced concrete or steel, in which case the steel wall plates should preferably be coated with vitreous enamel to provide a surface which is virtually impervious to corrosion. This protection is important. as a silo unit in close proximity to the sea would be adversely affected by salt sea spray. Internally, any corrosion would adversely affect the quality of grain. The silo is fed from an overhead system and discharged through bottom doors.

312. The tote bin system has been developed in recent years for the handling of minor bulk cargoes. especially where a sealed container is required. The bin is both a shipping container and an intermediate storage unit which becomes a discharge hopper when mounted on special tipping equipment. Thus the material remains in a single container throughout the process of transportation.

313. The usual material used for the bin construction is aluminium, which is light in weight, resistant to corrosion and capable of being stacked. Unfortunately. as in the case of all bulk bins. the return journey of the empty bin adds considerably to the cost of transportation, and this becomes a serious constraint for long journeys and for export materials. If the bin can be reduced in volume for the return journey, this disadvantage is minimized. Alternatively. a cheap throw-away container can be used.

314. A surge hopper is often necessary to act as temporary storage during a certain phase of a conveying operation. For example, during a loading operation a ship-loader will need to be moved from hatch to hatch. While it moves, the material flow from the ship-loader must be stopped to prevent spillage on the deck of the vessel. The conveyor system from the stockpile can be kept in motion if the material flow to the jetty conveyor is bypassed into a surge hopper.

315. When the ship-loader is in position again, the ship-loader and jetty conveyor are restarted, taking material from the approach conveyor plus the material temporarily stored in the surge hopper. The ship-loader and the jetty conveyor are sized to suit this increased flow of material.

316. This method can give considerable improvements in throughput, but for smaller throughputs the installation of a surge hopper may not be justified. The size of the hopper depends on the rate at which material flows along the approach conveyor and the time taken for the ship-loader to travel between the hatches furthest apart.

L. Vehicle reception

317. There are four main ways of discharging bulk cargo from rail wagons:

(a) Bottom discharge;

(b) Rotary tipping;

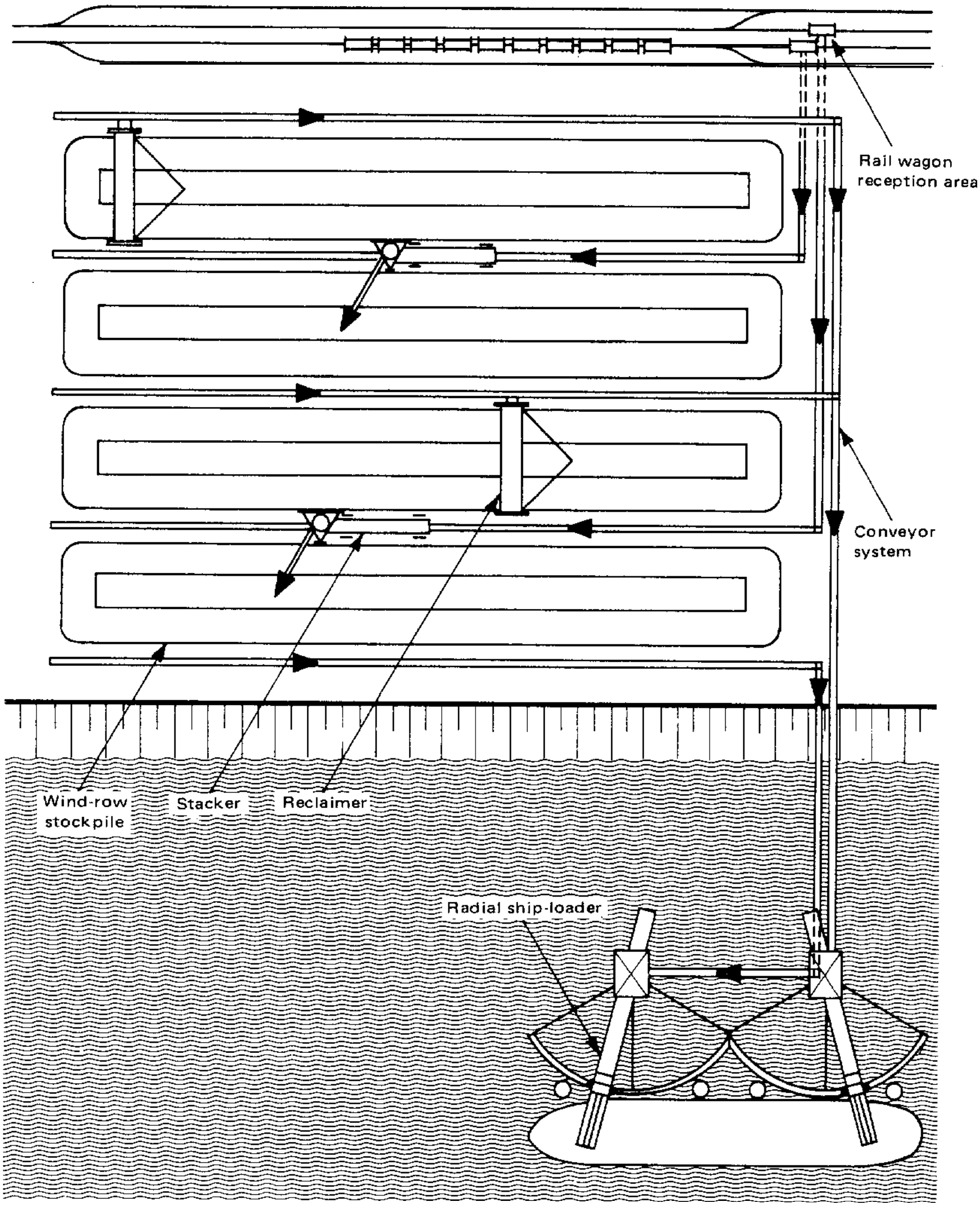
(c) End tipping;

(d) Pneumatic discharge.

In the first three methods, the material is discharged into a hopper which is emptied via a transfer conveyor. Bottom-discharge wagons are fitted with bottom doors which open to empty the vehicle. For the rotary and end-tipping facilities the rail car is physically rotated or tipped to discharge the wagon. With the rotary tipper, the rail wagons do not have to be uncoupled if they are fitted with rotating couples.

FIGURE 47

Export port showing arrangement of wind-row stockpiles



318. For powdery free-flowing materials, a combination of compressed air and gravity can be used to discharge the wagon. The wagon consists of a pressure vessel and is discharged via hoses to the receiving store.

319. Road trucks have the same method of discharge as rail, but can often be self-tipping. High-capacity tippers have a gross weight of over 32 tons, while smaller tippers have gross weights of 24 and 16 tons. Trucks with pressure vessels for pneumatic discharge can be fitted with a diesel-engined blower unit to make deliveries independent of an external air supply. Self-tipper trucks can discharge directly to stockpiles via a mobile belt conveyor with a hopper.

M. Stand-by facilities

320. The high cost of the vessel's time makes it essential that equipment should be available at all times while the vessel is alongside the jetty. A plant breakdown during unloading/loading operations can result in high demurrage payments. Preventive maintenance will go a long way to reduce this down-time, but stoppages through plant breakdown will still occur. In addition to a skilled maintenance force to repair the fault quickly, provision must be made for the duplication of certain conveyors and for the necessary rerouting of material flows. The provision of other stand-by equipment for unloading/loading should also be considered. This

could take several forms; for example, either two reclaimers can be arranged to cover one stockpile, or the use of high-capacity mobile front-end loaders can be resorted to. Stand-by mobile front-end loaders can also supplement the normal rate of reclaim during seasonal peaks, using emergency reclaim hoppers which are mounted on tracks alongside the reclaim conveyors.

321. The grab bucket has high reliability, with only few components subject to wear, and any necessary repairs to the digging lips, shells and bearings can easily be effected at low cost in a workshop. Several sets of grab buckets for a single bulk unloader are normally purchased so that the correct type is available for each of the different bulk commodities and vessels, and reserve buckets are available for each commodity. Where two unloaders are in operation, one machine can continue operatmg during the short period needed to change the bucket on the other. Adequate provision for storage and for transportation of grabs to the workshops for repair should be provided in the jetty design.

N. Environmental considerations

322. Pollution prevention is a major cost item and at the outset of any scheme it will be necessary first to establish an environmental policy. It will be necessary for the appropriate authority to specify the importance it attaches to the local environment. and how much extra it is prepared to pay to maintain it. In order to take a decision. the planner will need to prepare a statement on the probable effects of the installation on the local environment in the absence of any special precautions. In addition, a study of working conditions within the terminal will have to be made. At this stage, experts should be called in and proper specifications agreed upon satisfying the policy laid down.

323. The characteristics of the material handled may be that it is very dusty. or dangerous to health, or even liable to form explosive mixtures with air or moisture. Several problems arise with respect to dust suppression or extraction. First, the degree of pollution tolerated must be clearly specified, the minimum requirements being stated quantitatively, for example, that the area within a specified distance from the installation should not contain more than a specific number of grams of material per cubic metre. Imprecise statements such as “nearly dustless” or “to the satisfaction of the engineer” should be avoided. A large amount of dust will emanate from a poorly maintained plant; thus simplicity of design and easy maintenance should be sought when a choice of equipment is being made.

324. A study should be made of equipment actually in use for the handling of similar material in order to determine the environmental effects. For example, many attempts have been made to seal the receiving hopper of a grab unloader effectively when material is being discharged from the grab into the hopper. The use of an air curtain will prevent dust spreading on discharge, but it should be remembered that the grab has to pass through this curtain to its discharge position and that a certain amount of material will be blown off the surface in the process. A more effective method may be to put the hopper into a chamber sealed with rubber curtains.

325. Often the prevailing wind will assist in preventing dust pollution by blowing the dust out to sea-a condition that may be acceptable. However, a port installation sited upwind of a community could find itself in serious trouble at times of high wind when a dusty product is being handled without effective dust control. Operations might have to cease at such times, with resultant high costs for ship delay. For certain cargoes, a water spray system may be used to prevent dust, or an enclosed storage area may he used to contain it.

326. Attention must be paid to the risk of corrosion, and all structures should be adequately treated to protect them from the effects of the moist, salt-laden atmosphere and of the materials being handled. Specialist advice should be obtained as experience can be drawn on from existing installations. Should protective sheeting be fitted to structures, this should receive the same consideration. High daytime temperatures in hot climates produce extensive condensation during the hours of darkness. This is especially apparent on the insides of silos.

327. Wind can also blow dusty material off a belt if it is not protected by wind boards, a simple housing, or a totally enclosed gantry. In addition, wind forces can cause the belt to track very badly and, under extreme conditions, to lift off the idlers completely, especially when unloaded.

328. In the case of ship-loaders and unloaders, full account must be taken of needs for operating under wind conditions. The power applied to each operation must be adopted accordingly. especially when loaders or unloaders are being moved along the quay. Due allowance must he made for the opposing wind forces when the equipment is travelling into wind and, likewise, when it is travelling with the wind, due allowance must be made for the wind in determining the braking force required to arrest travel within the specified distance. Under storm wind conditions, special anchoring positions must be provided where the equipment can be positively secured.

0. Planning tasks

329. The argument is sometimes advanced that the planning of a bulk cargo port terminal should be done entirely by the industry planners for the bulk commodity concerned, as part of the total physical distribution system from, say, up-country mine to overseas customer. A coherent overall plan, based on through-transport economic principles, should certainly be drawn up by the industry planners at the appropriate time. There are often large gains to be made by coordinating the production rate, land transport, port stockpiling and handling, and maritime transport. However, the work done by the industry sector planner does not relieve the port management of the need to plan and control the main design parameters of all dry bulk cargo installations within the port area.

330. The port planner will need to know at an early stage of the planning the genera1 implications for land and water areas of long-term developments in the

sphere of dry bulk cargo transport. Also, during the stage of the preparation of detailed designs by the industry sector planner, there is a need for close consultation with the port planner to ensure that the main design parameters of the terminal are correct.

331. In addition, there are often common users of a dry bulk cargo terminal, and as far as they are concerned the design responsibility is clearly that of the port authority. There will be common parts of an installation that are used by several different bulk cargo carriers, for commodities that are to a varying extent compatible. It will be necessary for compromises to be reached between the demands of a number of different users.

332. For these reasons the port planner should carry out his own calculations for each of the following points, procedures for which are given in this handbook:

(a) The effective hourly capacity of each handling installation and the combined capacities of all the handling installations;

(b) The number of berths and the number of ship-loaders at each berth;

(c) The capacity and location of surge storage installations, stores and stockpiles;

(d) The capacity of the inland transport vehicle fleet.

333. Ideally, the industry sector planner should be able to give the port the specifications of the service the port should provide, and a target port cost per ton, based, in the case of exports, on the acceptable f.o.b. export selling price. Where the service specifications and a target cost are not provided, the planner may have to make broad estimates of the acceptable levels of cost and ship service.

334. From the point of view of port interests, one high-capacity dry bulk cargo terminal is preferable to two or more terminals with moderate yearly capacity. When growth in exports seems possible but uncertain, it may be advisable to start with modest and not too expensive facilities. Allowance should, however, be made for the possibility of installing additional ship-loaders and higher-capacity conveyors and increasing the stockpile area, if necessary, at a later stage, without any serious interruption of operations. With careful planning, expansion in this way should prove more economical than the construction of a second terminal for the same kind of material.

335. The whole terminal operation must be systematically set out showing the rate of tonnage per hour for each piece of equipment, and for each situation that may arise during the sequence of loading or discharging. Special buffer arrangements will be required when one part of the installation has to be halted.

336. Often there will be alternative operating modes and routes for the flow of the commodity. The matching of flows will need to be calculated for each of these modes. The design must be carried out by a specialist for the installation concerned, but the port planner can however check on the part of the design concerning the ship operation by using the following planning charts.

337. The ship-handling capacity of the terminal is determined by a joint analysis of the number of berths and the number and handling rates of the ship-loaders or discharging installations at each berth. The handling rates of ship-loaders are governed largely by the reclaiming rate. Planning charts I and II, illustrated in figures 48 and 49, should be used for this analysis. Where seasonal effects are important, special attention must be given to the investment advantages and disadvantages involved, as discussed in part one, chapter II, on planning principles.

338. The planning charts for the dry bulk cargo terminal have been developed to assist the port planner in his economic analysis of the effects of various handling rates on ship turn-round time. In addition to the economics, the planner is also interested in the service times that various sizes of shipment will entail. These charts can be used for either an import or an export dry bulk cargo terminal.

339. As has already been made clear, the productivity of each ship-loader or unloader varies according to the characteristics of the ship and the cargo, and the position of the cargo in the ship. Manufacturers often publish rated capacities for a particular commodity which are based on near-optimum operating conditions. However, to obtain the effective hourly capacity when working, an efficiency factor covering the total ship working time (through-ship efficiency factor) should be applied. This factor should be determined by a specialist, but as a rough check it could be taken as not more than 0.5 for unloading and 0.7 for loading.

340. The law of diminishing returns applies as regards the number of ship-loaders or unloaders which can work one ship. That is to say, doubling the number of facilities at a berth will not necessarily double the throughput of the berth. For the purposes of the planning chart, the following throughput factors have been assumed for two., three, four and five ship-loaders/unloaders per berth respectively: 1.75; 2.25; 2.60; and *2.85.*

341. Dry bulk cargo terminal planning charts I and II are used in the same way as break-bulk cargo terminal planning charts I and II. The planner needs the following basic information in order to be able to utilize these charts: ship-loader/unloader rated capacities; average shipment size; number of ships per year; average ship cost per day; and number of berth commission days per year.

342. The planner enters planning chart I with the figure indicating the rated capacity; he then draws a vertical line to make a turning-point where it meets the through-ship efficiency factor. He then moves horizontally to the left to the next turning-point with the appropriate line for the number of ship-loaders/unloaders employed per berth. He descends again to the standard number of ship operating hours per day, then moves horizontally to the right to the turning-point with the curve indicating average shipment size and finally draws a vertical line up to the average berth time for individual ships. A typical two-hour delay for berthing and deberthing ships has been added to this average time. When the actual delay differs from this, the average berth time can be adjusted accordingly.

FIGURE 48

Dry bulk cargo terminal, planning chart I: berth time

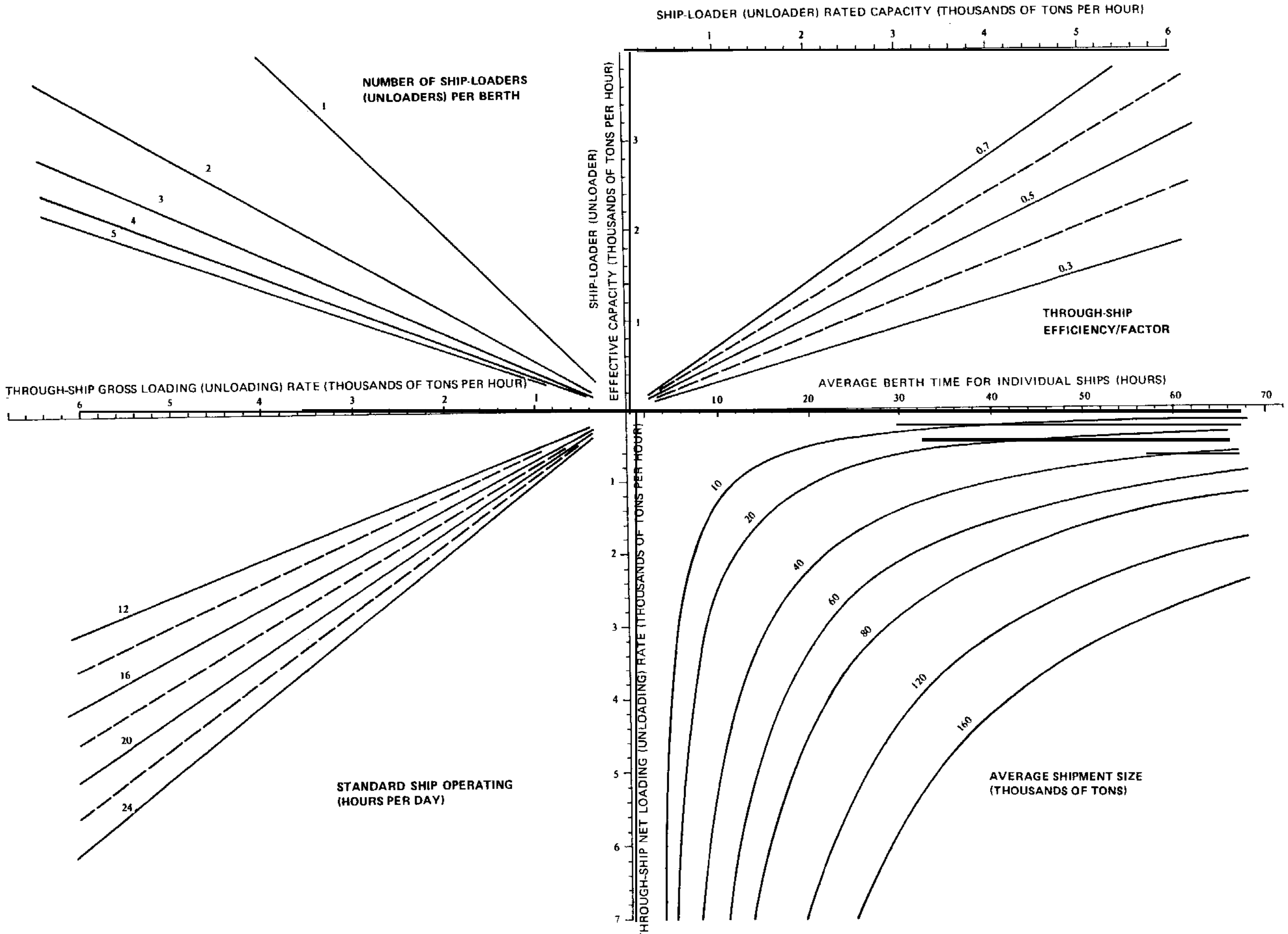
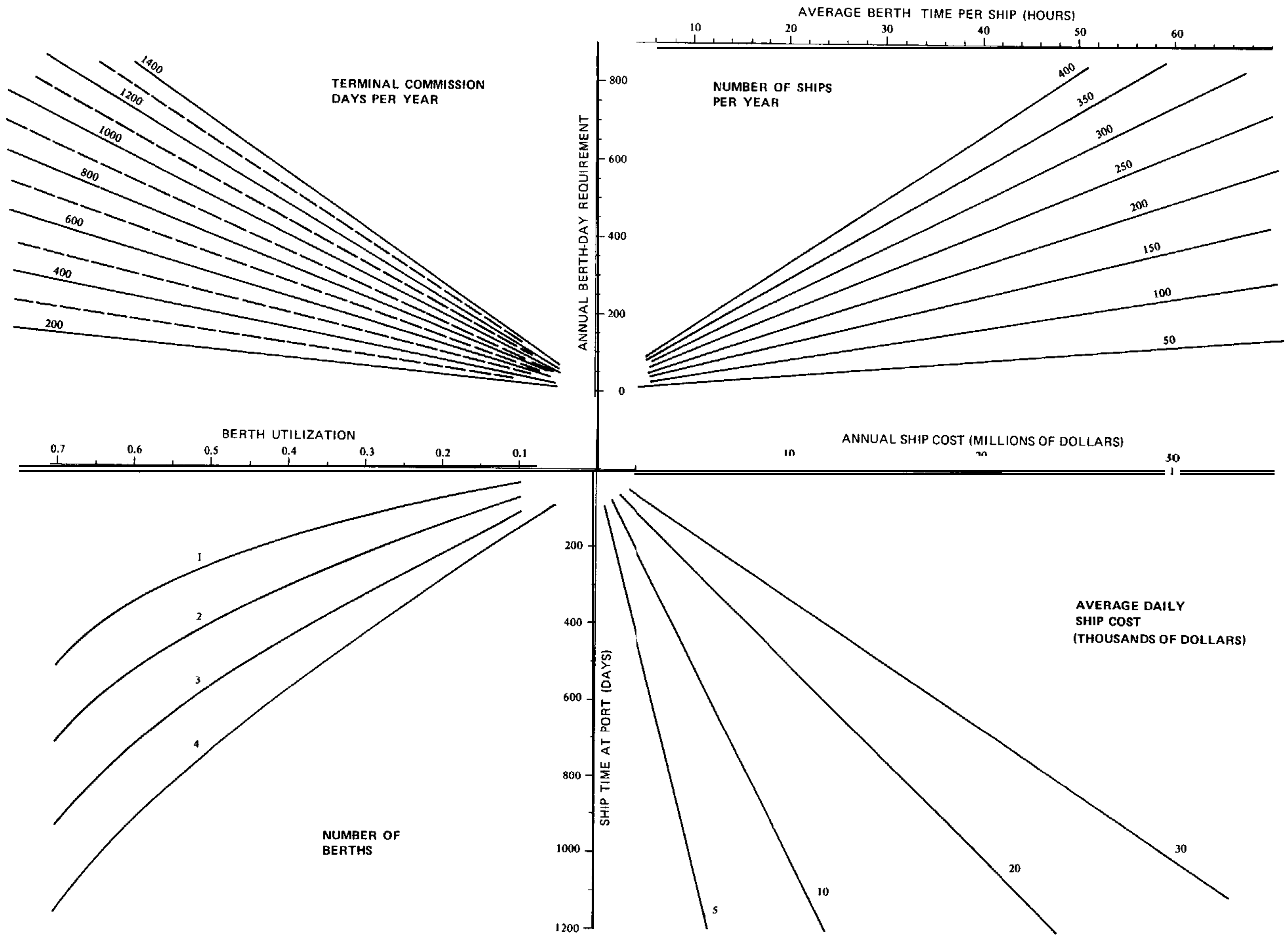


FIGURE 49

Dry bulk cargo terminal, planning chart II: ship cost



343. The turning-points on the axes give the planner the following information: effective capacity of each ship-loader or unloader; through-ship gross loading or unloading rate: through-ship net loading or unloading rate (which is equivalent to the gross rate if the berth is worked 24 hours per day); and average berth time for individual ships. The through-ship net rate is a key figure in describing the productivity of a bulk berth.

344. For planning chart II. the planner starts with the average ship berth time. A similar method is used as for planning chart I, with the following turning-points: number of ships per year; number of terminal commission days per year; number of berths; and the average daily ship cost while at port. The number of terminal commission days per year is the sum of the number of commission days for each berth. For each set of turning-points, the intersections of the trajectory and the axes give the planner the following information: annual berth-day requirement; berth utilization; ship time at port; and annual ship cost while at port.

345. The relationship between berth occupancy and ship time at port is based on queueing theory. The Erlang 2 distribution was used for both the service time distribution and the inter-arrival time distribution. Unlike break-bulk cargo terminals, there is a tendency, in the case of dry bulk cargo terminals, towards some scheduling of arrivals, and for this reason the slightly smoothed Erlang 2 arrival distribution has been assumed rather than the Erlang 1 (i.e. negative exponential) distribution. These distributions are discussed in annex II, section D.

346. The first chart can also be used by the planner to determine the best combination of rated capacity, number of facilities and daily operating period necessary for a specified berth time for a particular shipment size. When a suitable combination has been found, the planner can then use the second chart to select the number of berths necessary for the forecast annual throughput. The approximate number of ships per year is calculated by dividing the annual throughput forecast by the average shipment size. In order to determine the optimum number of berths, estimates must be made of total ship times at port with different numbers of berths. The optimum number of berths will be the number at which the total of berth costs and ship costs is lowest.

347. The export stockpile is needed as a buffer between the delivery system to the terminal and the ship-loading system. The delivery system's arrival distribution is dependent on the production rate and the inland transport system. Generally, the rate of arrival is much slower than the ship-loading rate, and the economics are such that the ship should not be kept waiting. Therefore, when a ship arrives, the quantity for shipment should be in port storage.

348. With regard to the import stockpile, the converse is true. the hinterland transport system operating at a much slower rate than the ship unloading rate. The stockpile should never be so large that a ship is prevented from unloading, nor so small that inland distribution is disrupted and the industries using the bulk commodities are affected.

349. The planner is faced with the problem of selecting an inventory level and storage capacity which will minimize costs by acting as a buffer between the variable demand and supply. If the level falls too low, the situation will occur where either the ship or the industrial zone is kept waiting for cargo. If the storage capacity is insufficient. the system supplying cargo to the stockpile-either the hinterland transport or the ship—will have to wait. As against these waiting costs, there are the capital and operating expenditures involved in creating and maintaining the stockpile.

350. The area required for the stockpiles is dependent on the following factors: shipload size; ship arrival distribution; hinterland transport distribution; and ship-loading and unloading rates. For export cargo, the hinterland transport requirement depends on production rates. The above factors are stochastic and thus there is no deterministic solution to the question of the appropriate inventory level and storage capacity. Figure 50 shows a typical variation in inventory level over a period of time.

351. Simulation or Monte Carlo methods, as described in annex II, can be used to evaluate the economics of various stockpile policies. However, information regarding the above-mentioned variables will often be limited. Certain assumptions have therefore been made (see the annex to this chapter). The curves based on these assumptions, which are given in figure 51, show the average and maximum stockpile levels which reduce the probability of the disruption of operations for ships, production areas or industrial zones to less than 1 per cent. The full line curves are annotated with the proposed annual throughput of the terminal. They give a relationship between the average shipload size on the horizontal scale and the stockpile capacity on the vertical scale. The cost of holding such an inventory level and developing the necessary capacity may be greater than the cost of the disruptions.

352. The charts should be used with some caution owing to the simplicity of the model, but they should give a good first approximation to the stockpile requirements. Thus, for a terminal handling 1 million tons per year with ships carrying an average of 20,000 tons, the maximum capacity of the stockpile should be 140,000 tons and the average amount of cargo held should be 75,000 tons. These figures must be increased by the amount of the dead stock, which is the residual material not loaded on to the ship in order to prevent ship delays arising from the slow process of clearing up the stockpile. The process of clearing up which is done during idle periods must be completed within a given time-limit.

353. Bulk commodities must often be segregated according to their properties. For example, with regard to imports, each stockpile area must be of sufficient size to accommodate at least a full shipload from each source. One iron-ore importing terminal has made each stockpile area 50 per cent larger than the capacity of the largest ship used. This allows the accommodation of a subsequent shipload of similar ore before the earlier shipload has been fully used up. The need for segregation is thus a factor to be taken into consideration in the planning of bulk cargo stockpiles.

FIGURE 50

Typical variation in dry bulk cargo terminal inventory level

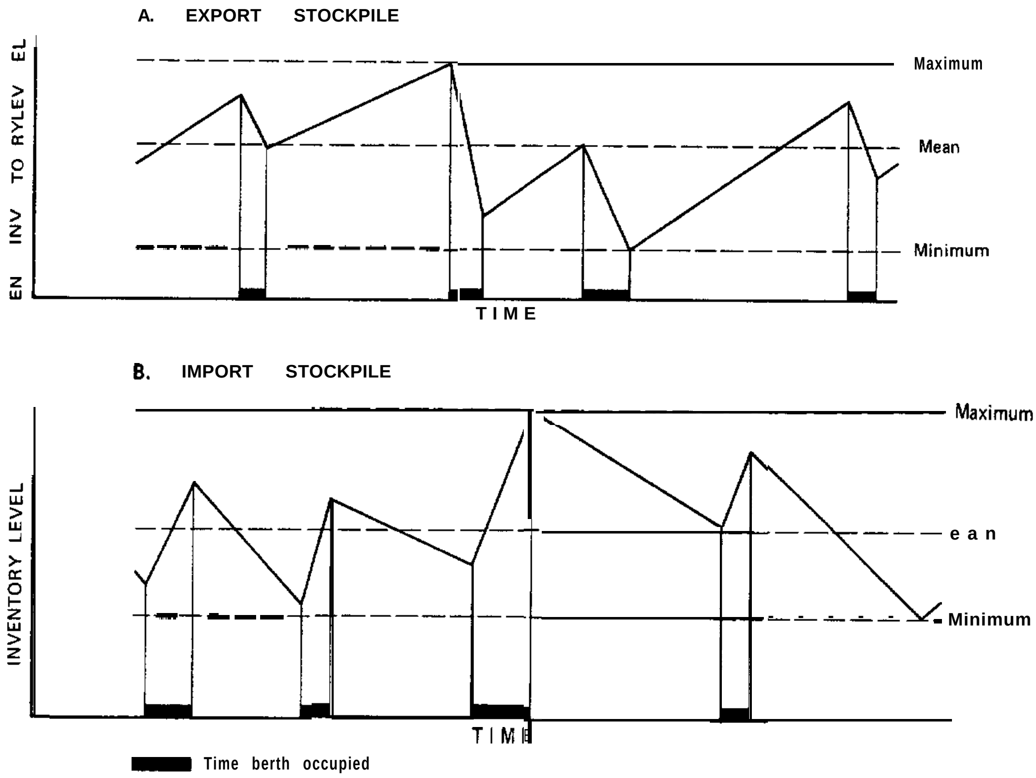


FIGURE 51

Guidelines for export stockpile dimensioning as a function of annual throughput and average shipload

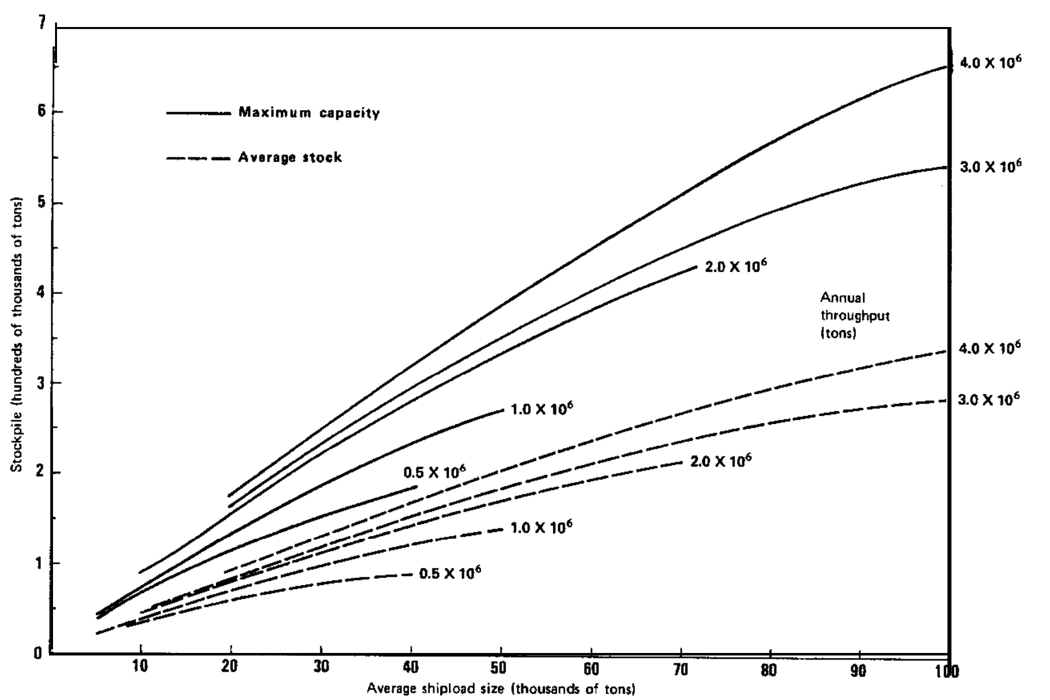
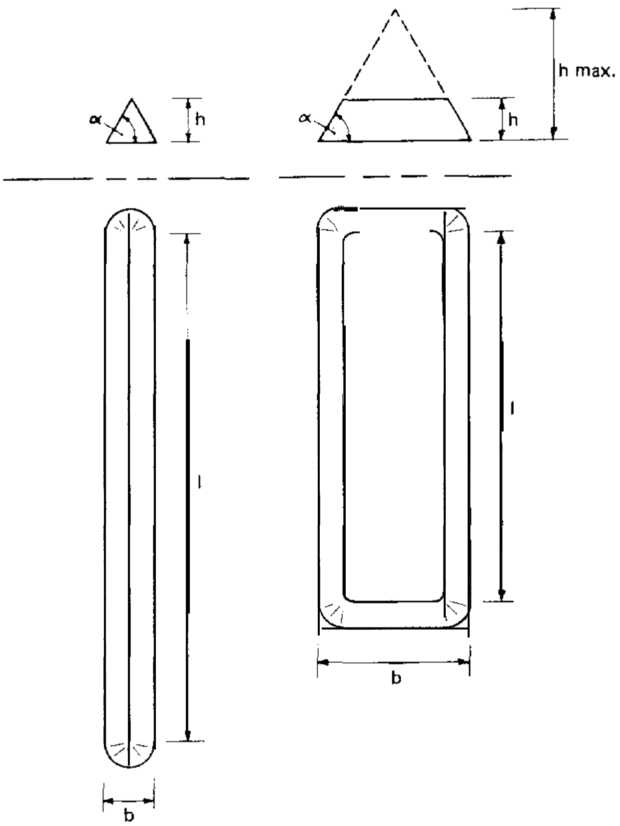


FIGURE 52

Stockpile layouts



354. If a storage facility at the terminal is planned to overcome seasonal or market fluctuations by providing for a continuous supply in spite of a non-continuous consumption. or vice versa, large areas must be set aside. Obviously a high degree of mechanization of the whole storage area in this case is uneconomical, and an appropriate design must be selected.

355. Upon determining the stockpile requirements in tonnes. the planner must then determine the layout and the area required to store this tonnage. Possible layouts are shown in figure 52 where: α=angle of repose, h=height, l=length and b=base. The height and base dimensions of the stockpile are determined by the characteristics of the material, the bearing capacity of the ground and the reach of the stacker/reclaimer. With these dimensions the planner may use the stockpile dimensioning dry bulk cargo terminal planning chart III, shown in figure 53.

356. The figure for the base or width of the stockpile is the starting-point for the use of the chart. The planner descends to the angle of repose of the commodity, which is the angle between a horizontal surface and the cone slope obtained when bulk cargo is emptied on to this surface. Angles of repose for various commodities are given in annex I. He moves to the right to determine the maximum height to which the material can be piled, and to the left to determine the maximum cross-sectional area. The ratio of actual height to maximum height determines the next turning-point. The planner descends from this point to the line indicating the length of the stockpile. The cross-sectional area of the stockpile is given by the intersection of this path with the axes. From the appropriate line he moves to the right to the stowage factor, and then rises to the horizontal indicating the capacity of the stockpile. For a given base and height, the length can be varied to give different stockpile capacities.

357. The task of planning the land transport fleet is simple, but it should never be omitted in forward planning lest the often daunting size of the transport fleet needed is overlooked. Three elements regarding which mistakes in planning are likely to occur are the following:

(n) The number of transport working days per year:

(b) The average number of trips per day;

(c) The number of road vehicles out of action for maintenance and repair.

358. With these cautions in mind, the method of calculation for a single commodity is straightforward and a numerical example is shown in table 7. Here. the implications of carrying the whole output either by road or by rail are given first, followed by a suggestion for a sharing of the load. Reserve capacity is needed, not only for maintenance purposes, but also to make it possible to augment the vehicle fleet temporarily to cope with peak demands.

359. A complication occurs when several different commodities have to be transported by the same facilities. For example, an aluminium smelter may require

TABLE 7

Transport fleet planning for a single commodity

Annual terminal throughput (tonnes)	*Number of transport working days per year*	*Daily transport demand (tonnes)*	*Average vehicle capacity (tonnes)*	*Daily vehicle demand*	*Average number of trips per day*	*Vehicle fleet size*
All by road: 2 000 000	278	7 200	24	300	3	100, plus maintenance reserve = 110 trucks
All by rail: 2 000 000	330	6 060	20	303	1	303, in 5 trains of approximately 60 wagons each
Suggested combination:						
20 per cent by road 400 000	278	1 440	24	60	3	20 plus reserve= 24 trucks
80 per cent by rail 1 600 000	330	4 850	20	242	1	242, in 4 trams of approximately 60 wagons each

FIGURE 53

Dry bulk cargo terminal, planning chart III: stockpile dimensioning

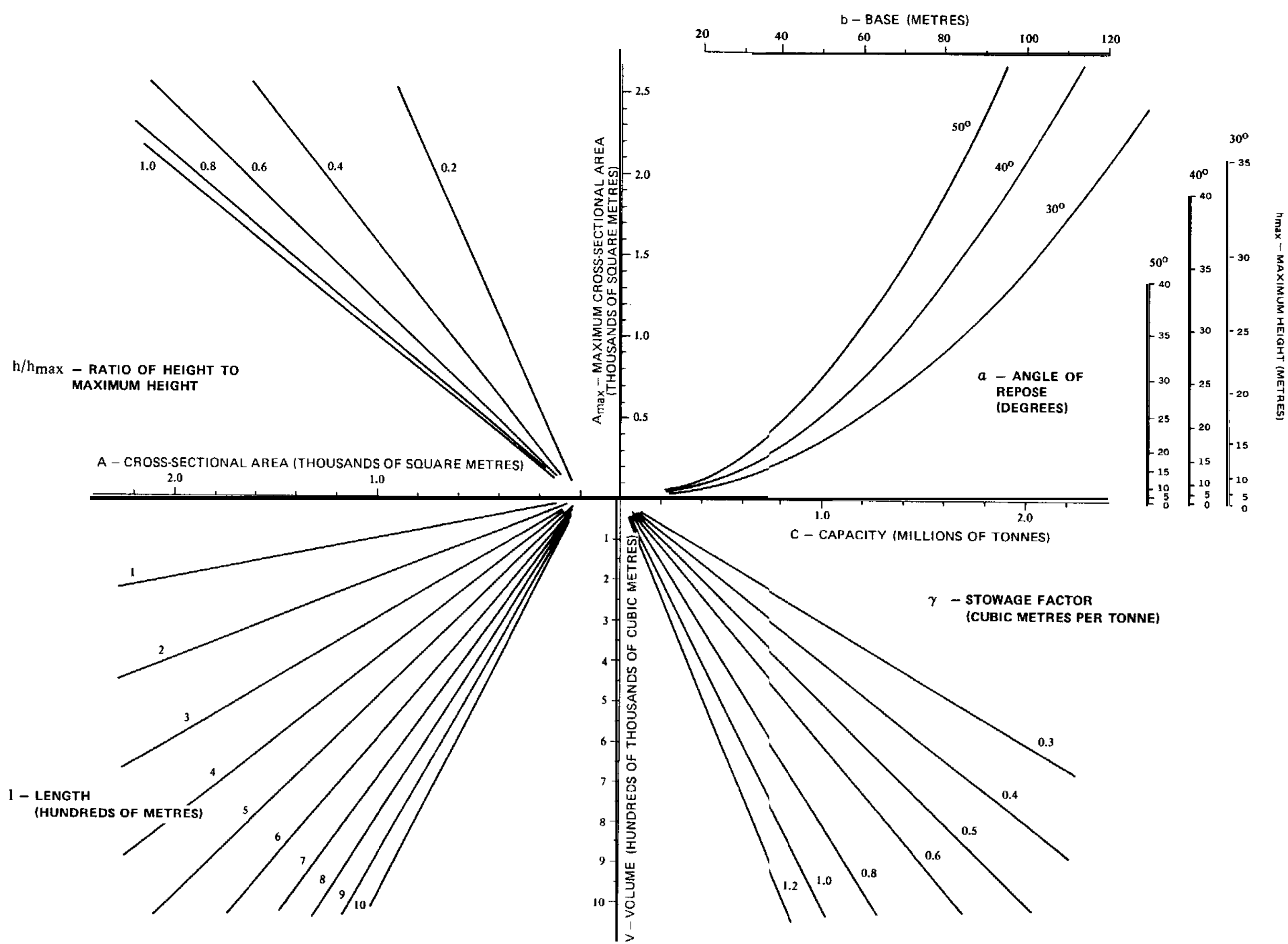


TABLE 8

Transport fleet planning for multiple commodities

Annual smelter throughput

Output : 120 000 tonnes aluminium metal;
Input 240 000 tonnes alumina;
72 000 tonnes petroleum coke.

	Weekly requirement (tonnes)	*Number of days per week scheduled*	*Tonnes per day*	*Average vehicle capacity (tonnes)*	*Daily vehicle demand*	*Average trips per day*	*Fleet size*
Alumina	4 615	4	1 154	20	58	6	10
Coke	1 385	1	1 385	20	69	6	12
		Proposal: 12 vehicles plus 3 reserve = 15 trucks.					
Aluminium metal	2 310	5	462	22	21	4	5+
		Proposal 7 tractor/trailer units, including reserve.					

the import of 1,500 tons of petroleum coke for each 5,000 tons of alumina imported, and it may then export via the same route 2,500 tons of aluminium metal. In such a case it would be normal to plan the transport of these three commodities jointly. In a rail operation it might be possible to introduce a closed-loop train system. In a road operation it might be possible to co-ordinate the haulage of different commodities using a common vehicle fleet. In the aluminium smelter example, since there is no prospect of balancing the import and export flows. and *since,* further, the type of vehicle suitable for alumina and coke is quite unsuitable for aluminium bars and ingots, it would be appropriate to introduce two separate transport systems and tolerate the poor return-load operation.

360. Table 8 gives a numerical example for this solution. An additional feature as compared with table 7 is that the common alumina and coke fleet needs to be scheduled with, say, four days of hauling alumina and then one day of hauling coke. Such a schedule will be dictated by, and will in turn dictate, the buffer stock

TABLE 9

Check-list of questions for planning dry bulk terminals

1. Has there been a search for the best site for the terminal along the coastline, without limiting the search to existing port boundaries? The place of origin or point of processing of the material may be more important than the location of an existing port organization.
2. Has a coherent overall plan for the commodity been prepared? There are often large gains to be made by designing an integrated transport service which incorporates:
   (a) Production and processing of materials;
   (b) Land transport;
   (c) Part stockpiling and handling;
   (d) Maritime transport.
3. Has the industry planner specified the level of service that the terminal is expected to give, and a target port cost per ton related to the commodity selling price?
4. Will the terminal be dedicated to a single user, or will there be several users on a common-user basis?
5 Will the terminal be used for a single commodity (will the commodity require segregation by different grades) or will parts of the installation be used in common with other commodities? In the latter case, have compatibility questions been dealt with?
6. Have facilities for long-term growth been considered? Economically it is preferable to have one high-capacity terminal rather than two low-capacity terminals. Thus expansion must be considered in terms of:
   (a) Installing additional ship-loaders;
   (b) Installing higher-capacity conveyors.
   (c) Increasing the stockpile area.
7. Has the terminal been planned for specific ships in the case of an integrated system. or for a range of ships in the case of a common-user terminal? The ship characteristics to consider are:
   (a) Operating draught;
   (b) Beam and length;
   (c) Type of ship (bulk, combined, general cargo);
   (d) Shape of hold and hatch opening.
8. Has an economic criterion been used for the ship handling rate and the resulting berth occupancy? The high cost of ship's time results in high rates with low berth occupancy (calculations can be checked on the planning charts).
9 Has the cost and suitability of an offshore berthing point been considered versus the cost of dredging?
10. Has pollution of all types--dust, explosive mixtures, health risks-been considered and related to the prevailing wind?
11. Has the pollution prevention scheme been based on a clear specification (quantitatively precise) of what is to be permitted?
12. Has a study of working conditions on the terminal been made? There may be lobs in adverse locations which require special prowsions.
13 Have the local conditions of a prevailing hot climate and salt-laden atmosphere been considered with regard to corrosion of structures and night-time condensation"
14. Have all wind conditions been allowed for, including anchoring of ship-loaders during storms?
15. Has an unambiguous rated capacity for an unloader (loader) been specified, for example. the rate which can be sustained for one hour when unloading (loading) from the centre-hne of the vessel horizontally and from the mean low water level vertically?
16. Have the above considerations been based on actual experience with a similar type of installation rather than manufacturers' figures'!

capacity both at the port and at the smelter, and will be influenced by the economies involved in cleaning vehicles and changing common reception/delivery installations from one commodity to the other.

361. To conclude this section on planning tasks, a check-list of the main questions that the planner of a dry bulk terminal must answer are given in table 9.

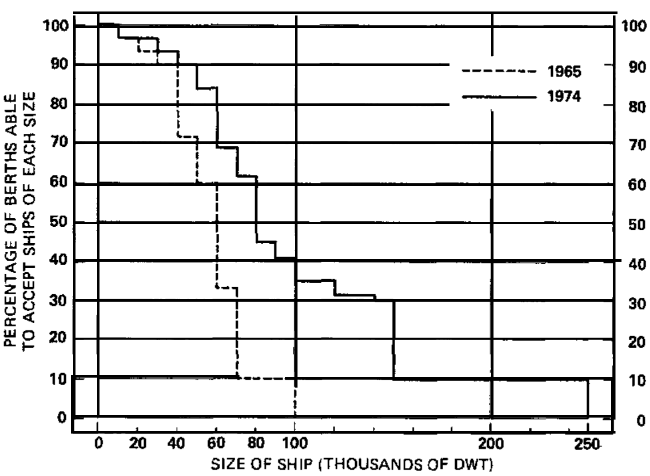
P. Major bulk commodities

1. Iron ore

362. Iron ore is the most important dry bulk commodity in international sea-borne trade, representing in 1980 16 per cent of total dry cargo trade (dry bulk as well as general cargo). Iron ore includes ores such as magnetite, hematite, limonite, siderite and roasted iron pyrites. It is seldom sold in the form in which it is extracted from the ground, normally being processed to improve its characteristics or to increase its iron content. Washing, grinding, screening, agglomerating processes (pelletizing, sintering, briquetting) and various methods of concentration are used for this purpose. Traditionally the separation of waste from the ore took place at the consumer end. However, this is changing, and the trend is towards taking steps at the producing end to increase the iron content of the ore.

FIGURE 54

Iron-ore loading berths: maximum acceptable ship sizes



Source: M. Latham, "Developments in handling dry bulk cargo", in ICHCA, *Progress in cargo handling*, vol. 6, *Changing user requirements* (London, Gower Press, 1976).

363. The ore shipped has a stowage factor which varies between 0.3 and 0.8 cubic metres per tonne. Iron ore is always transported in bulk and in full shiploads. Over the past decade, iron ore trade has been the subject of considerable competition between alternative suppliers, characterized by increasing distance between sources and markets and the employment of the largest possible carriers. With the increased distances, the quick turn-round of specialized ore carriers in ports no longer compensated for the loss of time involved in lengthy ballast voyages. Thus, combined carriers offering greater versatility in the employment of vessels have been replacing the specialized ore carriers. In 1979, 95 per cent of total iron ore shipments were carried by bulk carriers and combined carriers of over 18,000 dwt, and 81 per cent in vessels of over 60,000 dwt.

364. While there are no major discharging terminals for iron ore in the developing countries, there are several loading terminals. For loading terminals, figure 54 illustrates the distribution of berths relative to vessel size, and its evolution with time. Generally, iron ore ports serve as transfer terminals linking two modes of transportation, and hence some stockpiling capacity is almost always necessary to provide a surge capability between the more or less continuous overland movement and the intermittent ocean shipments. Figure 55 shows a typical iron ore export terminal.

365. Ore varies both in the nature of its constituents other than iron and in the percentage of its iron content. Iron ores are generally dusty and, although there is a variation in dust pollution between the various qualities and particle sizes, it is normally necessary to provide dust extraction equipment and to consider terminal siting carefully. Because of the importance of producing steel of a suitable grade for a particular purpose, control is necessary over the blending of ores for blast furnaces. This necessitates the segregation of ores according to their properties. The density of iron ore limits the stacking height because of the limits of the load-bearing capacity of the ground. The angle of repose is normally less than 40 degrees.

2. Grain

366. In 1980 the sea-borne trade in grain was 198 million tonnes, forming 10 per cent of total dry cargo

FIGURE 55

Material flow in ore export port at Nouadhibou, Mauritania

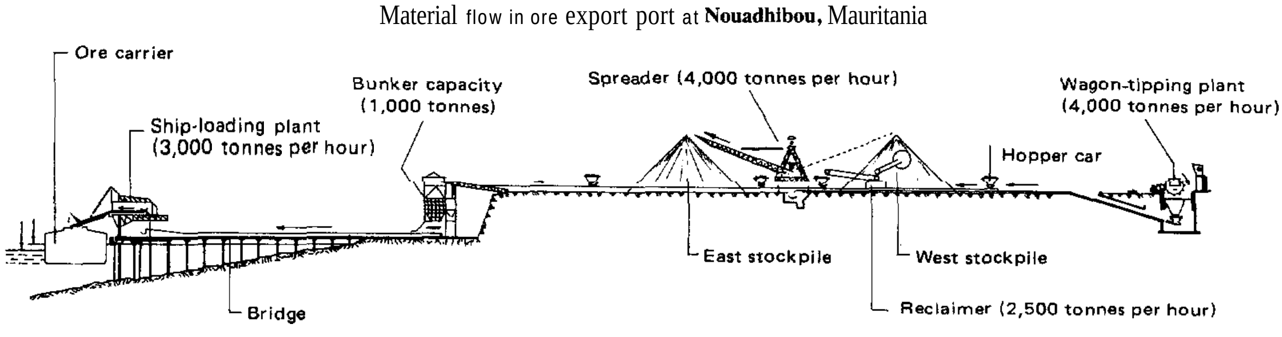


TABLE 10

Sizes of ship employed in the grain trade

(Percentage of world sea-borne trade in grain)

Ship size (dwt)	*1970*	*1971*	*1972*	*1973*	*1974*	*1975*	*1976*	*1977*	*1978*	*1979*
Under 18 000	41	37	2Y	32	33	21	15	10	11	10
18–25 000	21	18	20	18	15	13	11	13	10	10
25–40 000	27	32	36	37	36	35	35	3h	3h	34
40–60 000	10	12	14	12	11	15	18	18	18	17
60 000 +	1	1	1	1	5	16	21	23	25	29

Sources: Fearnley & Egers Chartering Co. Ltd., HPD Shipping Consultants Ltd.

shipments. These shipments were composed of wheat (79.2 million tonnes), maize (70.7), soya beans (26.9), barley/oats/rye (11.4) and sorghum (9.9). In addition, some 10 million tonnes of rice were shipped in the short sea trade. These grains have different densities, which means different stowage and handling requirements. Furthermore, grain is a perishable commodity which requires proper ventilation and protection from the weather and pests during shipment and storage.

367. Sea-borne grain shipments come under two headings: commercial shipments and international aid shipments. Commercial shipments take place, in order of importance, to Western Europe, Japan, the USSR and Eastern Europe from the main exporters, the United States, Canada and Australia.

368. In the grain trade, variations in climatic conditions result in large variations in supply and demand, with consequent fluctuations in transportation requirements. Without the incentive of a sustained level of import demand within each country, and considering the high capital cost of facilities, port development for vessels carrying grain is often not feasible. One solution is the use of mobile pneumatic equipment. Also, the trend to standardization of vessel type and size has been less pronounced than in the other bulk cargo trades. Many types of vessel are employed, ranging from small traditional 'tween-deckers through various bulk carrier types and sizes, into the smaller ranges of combined carriers and even some small tankers. While the size of the average carrier has increased over the years, with the transfer to the trade of combined carriers of approximately 150,000 dwt[13], the ships most commonly used are bulk carriers, the majority being in the 25,000–40,000 dwt range. Ships in this range built during the period 1971-75 were, on the average, 182 metres in length, 25.3 metres in maximum breadth and 10.8 metres in summer draught. The trend towards the use of larger vessels is shown in table 10.

369. An example of a grain terminal is the one owned and operated by the Port Authority of Marseilles for common users, which is primarily used for discharging cereals from vessels. A plan of the terminal is shown in figure 56. Cereals or other materials suitable for pneumatic discharge may be stored in the bulk warehouse.

370. At the terminal. two berths having a total length of 297 metres are used for discharging or loading vessels with a draft of up to 9.8 metres. There are four pneumatic extractors on rails with four intake tubes for discharging vessels, each with a rated capacity of 250 tonnes per hour and an effective capacity of 200 tonnes per hour. Two of the extractors, each with two separate discharge tubes, can also be used for loading but have an actual performance of only 100 tonnes per hour.

371. There are four conveyor belts, two of which are reversible for loading ships, each with a rated capacity of 250 tonnes per hour. The four belts lead to the vertical silo where the cereal is lifted to the top of the weighing and distribution tower. There are four weighing bins, each with a capacity of 3 tonnes, which allows the recording of cereal movement before storage. The vertical silo is made of 57 cells of 420 cubic metres each and 40 cells of 110 cubic metres each, permitting the storage of about 20,000 tonnes of cereals. The silo can discharge to trucks or rail wagons. The manning requirements vary from 14 to 41 depending on the number of pneumatic extractors in use.

3. COAL

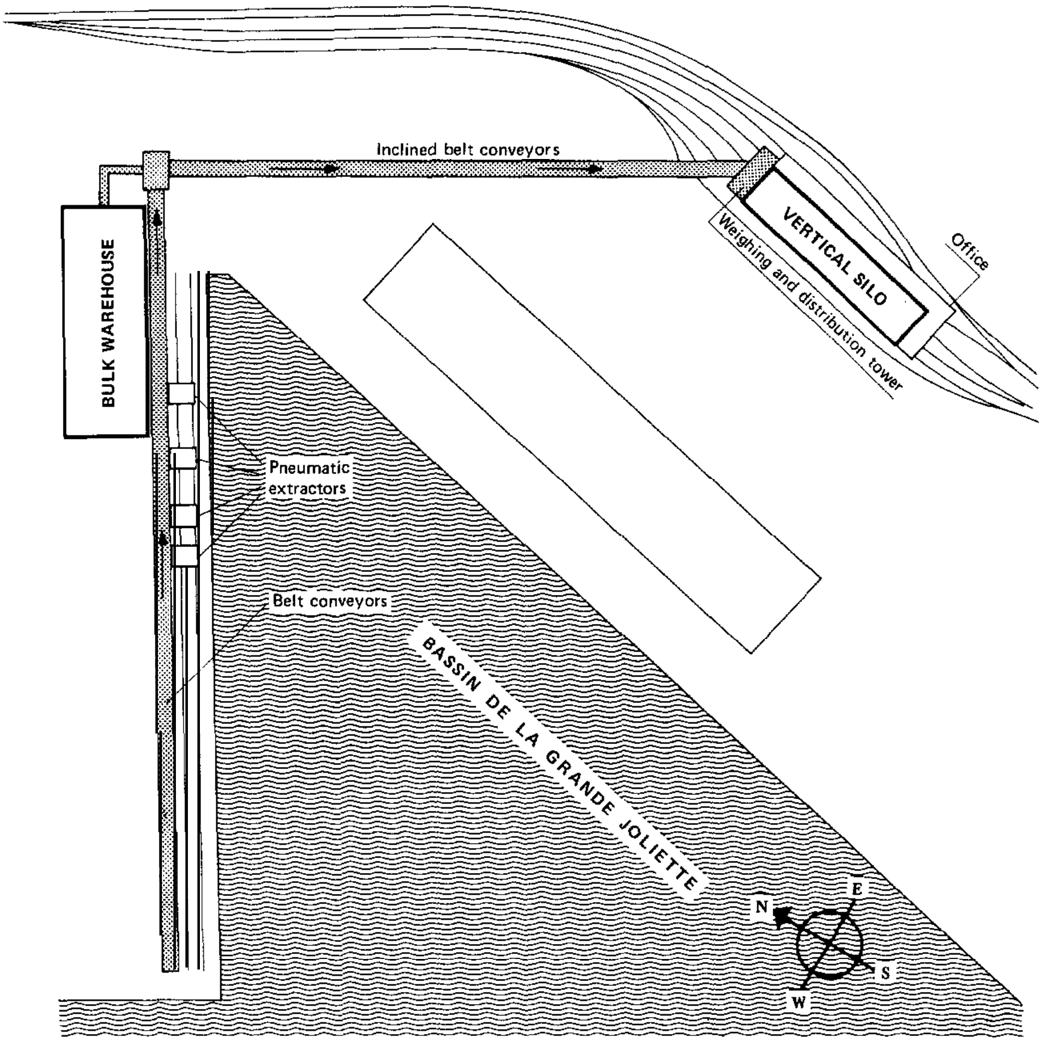
372. The sea-borne coal trade has grown substantially since the 1960s, and in 1980 reached a volume of 188 million tonnes, about 9 per cent of all dry cargo shipments in tonnes. The major importing areas in order of importance are Japan, the United Kingdom and continental Europe, Eastern Europe and the Mediterranean, while the major exporting areas are North America, Australia, South Africa and Eastern Europe. In 1980 Japan accounted for 50 per cent of shipping demand. The majority of the coal transported is coking coal for use in steel-making, and the remaining 45 per cent is thermal coal.

373. With the exception of the near-sea trades, there has been a continual increase in the average size of ship employed to transport coal. In near-sea trade, a wide variety of sizes and types of ship, including barges, are employed; however, bulk carriers are superseding other smaller ship types. In 1979, 74 per cent of the total coal trade in tonnes was transported by bulk carriers or combined carriers of over 40,000 dwt. The bulk of this long-haul trade is handled by full shipments on conventional bulk carriers and combined carriers, with carriers of over 100,000 dwt on some routes. Coal makes up 22 per cent of the total dry bulk shipments by

[13] These large vessels were transferred to the grain trade following the slump in the oil trade which took place from 1974 onwards.

FIGURE 56

Plan of typical grain terminal al Marseilles



bulk vessels of over 40,000 dwt and only 11 per cent of the shipments of combined carriers.

374. Coal has a stowage factor which varies between 1.0 and 1.4 cubic metres per tonne. All types of coal, even anthracite, are subject to spontaneous combustion caused by heating of the coal as it absorbs oxygen from the air. This characteristic must be borne in mind when planning the working of the coal stockpile, so as to prevent portions of the stock from lying dormant for long periods of time. Generally high-ash, low-volatile coals, as used for power stations, can be safely stacked, although some loss from oxidation will be inevitable. On the other hand, high-volatile, strongly caking coals used for coke production in the iron and steel industry will require constant monitoring for the indicative temperature rise in the store, whilst some coals such as steaming coals cannot be stored at all. Generally the dust nuisance is minimal and the use of water sprays at transfer points and discharge positions in extreme cases will reduce this type of pollution. A description of a typical coal import terminal follows.

375. Coal is unloaded by means of two trolley-type grabbing unloaders, the rail-mounted legs of which straddle one or more lines of ground conveyors. Also mounted on the rail tracks is a travelling hopper which receives coal discharged by the unloader grab. By means of a feeder unit fitted to the base of the hopper, coal is discharged on to the jetty ground conveyor. The travelling hopper can be coupled to the unloader so that they travel along the jetty in tandem, or it can be uncoupled and stored out of the way during occasional general cargo operations.

376. The jetty conveyor transfers material via a further system of belt conveyors to the stacking area, where it is received by stacking belt conveyors running the whole length of the storage area. Mounted on rail tracks on each side of the stacking conveyor is a travelling boom stacker. This is a specialized machine consisting of a tripper which discharges on to a boom conveyor capable of being slewed through 270” and derricked from below horizontal to a maximum incline of 15”. The stacker travels under its own power, under the control of an operator, and places the coal in windrows.

377. Reclaiming is carried out by a bucket-wheel reclaimer consisting of a revolving wheel carrying buckets with digging teeth. This wheel is attached to a boom, which also carries a belt conveyor on to which the buckets discharge. This conveyor in turn discharges on to a reclaim belt conveyor which runs parallel to the

stacking conveyor. The reclaimer. which is capable of being derricked and slewed, is designed to reach to the extremities of the coal piles. and is always under the control of an operator. To recover any material normally out of the reclaimer's reach, a bulldozer is used to push the coal within the range of the reclaimer.

378. From the reclaim conveyor. coal is transferred by a further system of conveyors to a tripper located over loading bunkers. These elevated bunkers have surge capacities to act as buffers between the discharge rate to onward transport and the reclaim rate at the coal stack. The tripper is usually under the control of an operator whose duty is to maintain the level of material in the bunkers, although this operation may he performed automatically by the introduction of sophisticated equipment.

379. Below the loading bunkers are situated weigh hoppers which receive a pre-determined quantity of coal from the bunkers. after which all further flow from the bunker is automatically cut off. Empty rail wagons are located beneath the discharge outlets from the weigh hoppers. They are positioned accurately by an automatic wagon positioner under the control of an operator. The same operator controls the opening of the weigh hopper doors. permitting rapid discharge of the material into the wagons.

380. The entire unloading system from the ship to the storage area could be under the control of the ship unloader operator himself in the case of a small terminal. whereas for a larger terminal it would be necessary to install a central control room communicating with all sections and with the operators in the unloading section. Similarly. the loading into onward transport and the associated stack reclaim could be controlled by the operator of the tripper conveyor maintaining the material levels in the loading hoppers. With a larger installation and an extension of automatic controls, the wagon-loading operator could be in control. An important feature of such an installation is an automatic interlock system which prevents any section from being operated before the next section has been run up to the right speed. The total manning requirements of such a terminal per shift would be in the region of 28, made up of four supervisors, 14 operators and 10 shift maintenance staff and conveyor attendants. This figure excludes the main workshop repair staff.

4. PHOSPHATES

381. Phosphate *rock* (minerals containing the fertilizer nutrient phosphorus) is the main raw material for the fertilizer industry and the most important commodity for sea-borne trade within the fertilizer group. This class of minerals accounts for 2.5 per cent of total dry cargo shipments, The 48 million tonnes shipped in 1980 were exported from Morocco. the United States of America, other African countries and the Pacific Islands. An interesting development is the productron of the phosphate intermediate. phosphoric acid. This step significantly increases the P_2O_5 content, a measure of the value of the commodity to the fertilizer industry. The terminal facilities are completely different, as the acid is a liquid which is carried in specialized tankers.

382. The size distribution of vessels employed in the phosphate rock trade shows that 38 per cent of the sea-borne trade was covered by vessels of less than 18.000 dwt, 15 per cent by vessels of 18,000 to 25,000 dwt. 31 per cent by vessels of 25,000 to 40.000 dwt and 16 per cent by vessels of over 40,000 dwt. The majority of phosphate rock loading ports cannot accommodate vessels of more than SO.000 dwt.

383. Phosphate rock is very dusty and absorbs moisture very readily. which can create problems for unloading. It has an average stowage factor of 0.92 to 0.9 cubic metres per tonne. Practically all shipments are in bulk as a powdery concentrate. A large proportion of the crushed rock is very fine and a great deal of dust is given off whenever a transfer of material takes place. It is therefore necessary to ensure that. for example, when material is discharged from a wagon or road vehicle into a ground hopper, provision is made for the dispersal of the heavily dust-laden air. The material itself is non-toxic, but it can be a nuisance to the operator in constant close contact with it at a discharge point.

384. For a typical phosphate rock export terminal. the phosphate can enter the port area by two routes. The first is via a railway direct from the mmes in specially designed, totally enclosed hopper wagons with roof feed openings and bottom discharge. The wagons are positioned over a series of under-rail discharge hoppers. and the phosphate is discharged by the manual operation of the discharge doors from operating platforms running each side of the wagons. The whole operation takes place under cover with appropriate provision for dust extraction. The second route is by road vehicle. Since special tipper trucks are not available, the trucks are discharged with the aid of tipping platforms, again into hoppers.

385. Phosphate is extracted from the hoppers via controllable sliding valve doors on to a belt conveyor, a section of which automatically records the weight of the phosphate passing over it. The phosphate then travels via conveyors to one of two closed stores. depending on quality. where it is distributed by means of an overhead tripper. The storage shed has an "A"-frame design with the slope of the roof equal to the angle of repose of the material.

386. Phosphate for shipping is extracted through the floor of the store by means of underground belt conveyors. the flow through each discharge point being controllable by means of rack-and-pinion-operated clam-shell doors. The angle of repose of the material is such that a sizeable residual quantity is left to form a contingency stock. To recover this material it is necessary to use small bulldozers or remote-controlled drag scrapers.

387. The store's underground extraction conveyors discharge on to a main conveyor and. via an approach arm belt conveyor and a transfer tower. on to two Jetty conveyors situated in a high-level structure running the whole length of the jetty. Each of these conveyors is fitted with a tripper which feeds a ship-loader.

388. The ship-loaders can traverse the full length of the quay and have a fixed boom with a telescopic extension. Attached at the end of each telescopic section is

an extending chute capable of loading ships at all states of the tide. The end of the extending chute is provided with a flexible dust hood for the control of dust emission, together with a deflector plate to help distribute the cargo in the hold of the ship. It is thus possible by means of the long travel motion along the jetty, together with the telescoping of the conveyor boom, which has in addition a luffing operation, to reach any part of the ship being loaded. At the same time, the boom can be retracted to permit clearance of deck superstructure and fittings when the ship-loader is moved from one hatch to another.

389. The whole operation is under the control of the operator of each ship-loader, the preceding conveyor systems being interlocked with its operation. Owing to the relative closeness of the store to the ship-loader, the conveyor system will be allowed to clear itself before the ship-loader is moved between hatches, so no surge storage is required.

390. A typical manning per shift for an installation of this size would be 37, made up of three supervisors, 20 operators and weighmen, six shift maintenance engineers and eight plant labourers and conveyor attendants. Because of the dust generated, several of the jobs can be arduous and dirty, thus requiring a substantial level of relief manning as well as adequate shower facilities.

5. BAUXITE/ALUMINA

391. Bauxite ore when processed into alumina is the basic raw material for the production of primary aluminium. Some 5.2 tonnes of bauxite produce 2 tonnes of alumina, which produce 1 tonne of aluminium. Shipments of bauxite ore and the intermediate product, alumina, represented about 3 per cent of total dry cargo shipments, or 48.3 million tonnes, in 1980. The two raw materials differ greatly in bulk, in density (bauxite typically stows at 0.878 cubic metres per tonne and alumina at 0.585) and in handling characteristics. The trend is towards the conversion of bauxite to alumina at source, which more than halves transportation requirements and therefore limits the growth of bulk shipping and terminal requirements, The share of bulk vessels of over 25,000 dwt in total sea-borne trade was 65 per cent in 1979, the size of vessel employed depending on the route.

392. The major exporters of bauxite/alumina are Australia, West Africa, Jamaica and Central and South America. In the short-sea trade between the Caribbean/South America and United States ports in the Gulf of Mexico, increased use has been made of medium-sized bulk carriers to reduce transport costs, but a proportion of the shipments are still handled by small ore carriers and multiple-deck ships owned or chartered by the aluminium companies. The Australian bauxite shipments to Europe are more suitable for large bulk carriers, with the long haul and growing volume of trade pointing to an optimum size of around 100,000 dwt. This trade is mainly serviced by carriers of 40,000 to 70,000 dwt, which have also been employed for alumina. For the trade between Australia and Japan/North America, medium-sized carriers of up to 40,000 dwt are the preferred size.

393. The integrated structure of the world's aluminium industry results in many terminals being owned and operated by the industry. These commodities, particularly alumina, are dusty and require precautions against plant and area pollution. A conveyor system feeding a closed system ship-loader, with the loading chute in close proximity to the loaded material, will minimize material loss due to dust. Generally, pneumatic or closed screw conveyor systems are used to discharge the vessel.

Q. Multi-purpose bulk cargo terminals

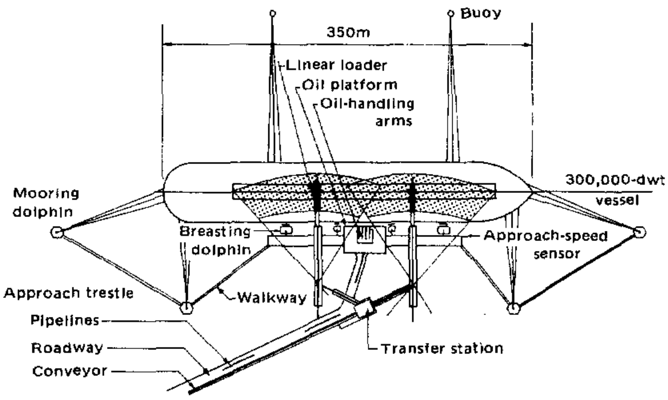
394. If within a reasonable period a separate berth will be justified to cater for a single trade, the installation can be planned on that basis, permitting the most economical use of plant and avoiding problems of contamination between materials.

395. If more than one bulk cargo trade is forecast but throughput for each trade is insufficient to justify separate berths, it may be feasible to establish a bulk cargo handling terminal for more than one material. Commodities such as coal and sugar, petroleum, coke and alumina, as well as ore and coal, can be handled with dual-purpose facilities. In some cases the same equipment may be used for different materials, but separate storage will be necessary for each commodity, and particular care must be taken to ensure that the commodities handled are compatible and that all systems can be thoroughly cleaned after use. Care must be taken in handling and storage to ensure that wind-blown dust does not contaminate other products. In other cases, only, the berthing point can be shared and separate equipment must be used for each material. Figure 57 illustrates a multi-purpose terminal designed for importing oil and exporting iron ore and other dry bulk materials.

396. Equipment will have to be sized to give the best compromise between the requirements of the various materials handled, considering such factors as bulk cargo density, size and type of ships and size of individual cargoes. Imports and exports can be handled at the same berth provided that there is sufficient capacity

FIGURE 57

Example of multi-purpose oil-bulk-ore pier



to permit this and that there is no conflict in scheduled ship arrivals and departures. Sufficient length must be available on the berth to store idle equipment in a position which permits the full length of ships' hatches to be worked by the other equipment. It is simpler to install separate conveyor systems for imports and exports, and the size chosen is usually more economical than is the case when one set of reversible conveyors is used.

397. Combining bulk cargoes and general cargo on a berth is not desirable unless annual bulk tonnages are clearly too low to warrant a separate berth. In that case it is advisable to check on two features:

(a) Loaders and unloaders should be mobile or, if they are rail mounted, the layout of the berth should be such as to provide sufficient quay length for parking them clear of the general cargo operational area;

(h) Conveyor systems should be either elevated on gantries at the rear of the berth or placed in tunnels so that the working area for general cargo is not obstructed. However, the use of tunnels should be considered as a last resort because of the difficulties of maintenance and cleaning.

ANNEX

Bulk stockpile planning

1. The following assumptions on the statistical distributions of the variables affecting the size of the stockpile in conjunction with a simple model have been used to estimate the stockpile requirements as a function of shipload and annual throughput. The interval between ship arrivals follows an Erlang 2 distribution. The shipload size follows a uniform distribution with a range of ±10 per cent. The arrival or delivery distribution of the commodity to or from the terminal also follows a normal distribution with a percentage coefficient of variation of 10 The loading or unloading rate has been set to give a berth utilization of 0.4 and the loading/unloading follows a normal distribution with a percentage coefficient of variation of 5

2. The model records the flow of bulk commodity in and out of the terminal over a period of time and calculates the maximum and the average amounts of the commodity present. Through repeated use of the model, an estimate of the maximum stockpile requirements and the average amount of commodity stored can be determined.

Chapter VIII

LIQUID BULK CARGO TERMINALS

A. Introduction

398. It is difficult to provide guidelines for the design of a liquid bulk cargo terminal, since the equipment required and the number of berths needed are not directly related to the total quantity of bulk liquid to be handled. This results because of the need to segregate the invariably large number of grades of the same liquid commodity. Thus the numbers of storage tanks and other equipment needed depend on the number of different grades of the same commodity expected to arrive at the terminal, rather than on the total quantity. Generally, the rate of discharging liquid cargo is governed by the capacity of the ship's pumps rather than by that of the port handling equipment. The planning of installations for liquid bulk cargoes is therefore a special task which is normally carried out by the industry concerned in close co-operation with the port administration.

399. The main concern for most liquid bulk terminals is safety. Many of the commodities are inflammable or in other ways dangerous, or are a pollution risk both at the time of loading and discharge and in storage. Both the zoning and the detailed technical layout will be governed by these problems. All proposals must be strictly checked from the point of view of safety and pollution, and general comments on this subject are given in part one, chapter VIII.

400. The general design and location of each terminal are of considerably greater interest to port managements than the technical details. The technical design will depend on the actual characteristics of the individual ships which will use the terminal. The following points should be closely checked to ensure compatibility between the vessel and the terminal:

(*a*) Number, length and diameter of loading arms or hoses;

(b) Maximum height of ship's manifold;

(c) Manifold connection specifications;

(d) Number, diameter and maximum pressure of pier pipelines.

B. Crude oil and oil products

401. World sea-borne trade in crude oil in 1980 was 1,362 million tonnes, as compared with the 1979 figure of 1,538 million tonnes. Tankers and combined carriers of over 60,000 dwt accounted for 90 per cent of crude oil movements in tonnes, while tankers of over 200.000 dwt accounted for 45 per cent of movements. Oil product movements, excluding short-sea and coastal trade, amounted to 237 million tonnes in 1980, of which a large proportion was transported in vessels of less than 60,000 dwt.

402. Large crude oil loading and discharging ports are located in quite separate and isolated points, normally far from densely inhabited regions. Easy access from the sea to suitable areas with calm and very deep water is the most important requirement. The draught requirements often lead to off-shore terminals with strong fendering systems to absorb the berthing impact of large tankers. For the import of oil products or small amounts of crude oil for local refineries, the zoning of an oil sector inside the commercial port is necessary. Methods for preventing oil spills from spreading is also an important consideration for the planner. The berthing arrangements for a typical oil terminal are shown in figure 58.

403. Crude oil and oil products have very different properties and may be divided into two main groups:

(a) Black oils. which include crude oil, furnace oils and heavy diesel oils;

(b) White oils, which include motor spirits. aviation spirits, kerosene and gas oil.

The carriage of crude oils has given rise to the greatest pressure for transport economy, leading to the supertanker concept. Figure 59 gives the length, beam and draught requirements of such very large crude carriers (VLCC).

404. Separate sets of handling equipment are required for each group of oils. Under certain circumstances, separate sets of equipment may be necessary for each product, or subgroup of products within a group, to avoid contamination. A strict pumping sequence must be followed in the case of a common set of equipment for a group of products.

405. Crude oils and oil products are hazardous to handle and hence entirely separate berths, jetties or single buoy moorings, completely isolated from other berths and port facilities, are invariably provided for handling such oils exclusively. All items of equipment are specially designed for handling these oils and are suitable for operation in a hazardous atmosphere. To prevent the build-up of static electricity, electrical earthing cables need to be built into the quay or pier.

406. It is recommended that loading and unloading arms should be of fabricated mild steel and operated either manually or hydraulically. Suitable hoses may be used in some cases where quantities to be handled are small. for example with tankers of 18,000-tonne capacity, and where operating pressures and tidal variations are low. Depending on the design discharge or loading rate, the arms may be from 200 mm to 500 mm in

FIGURE 58

Typical jetty arrangement for tanker terminal

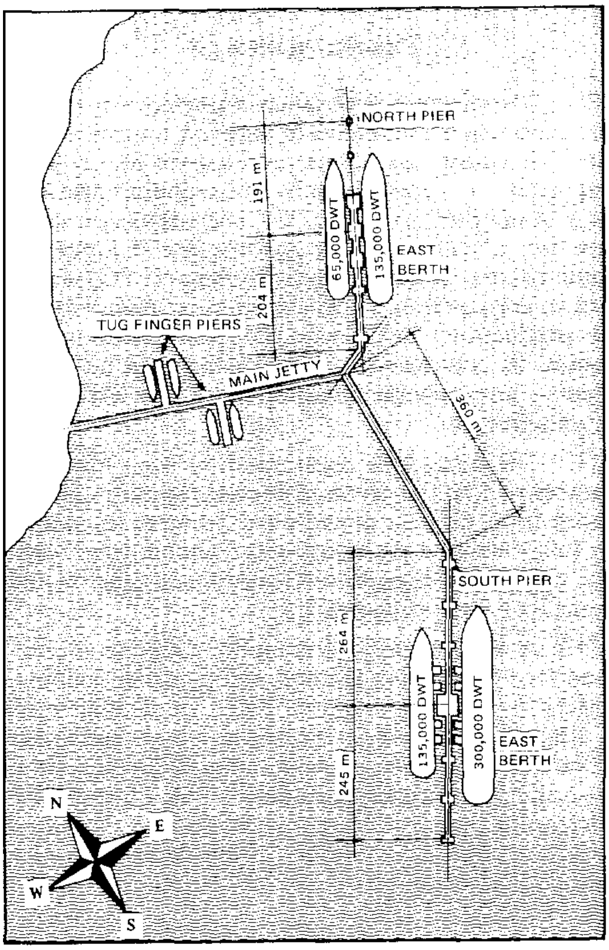
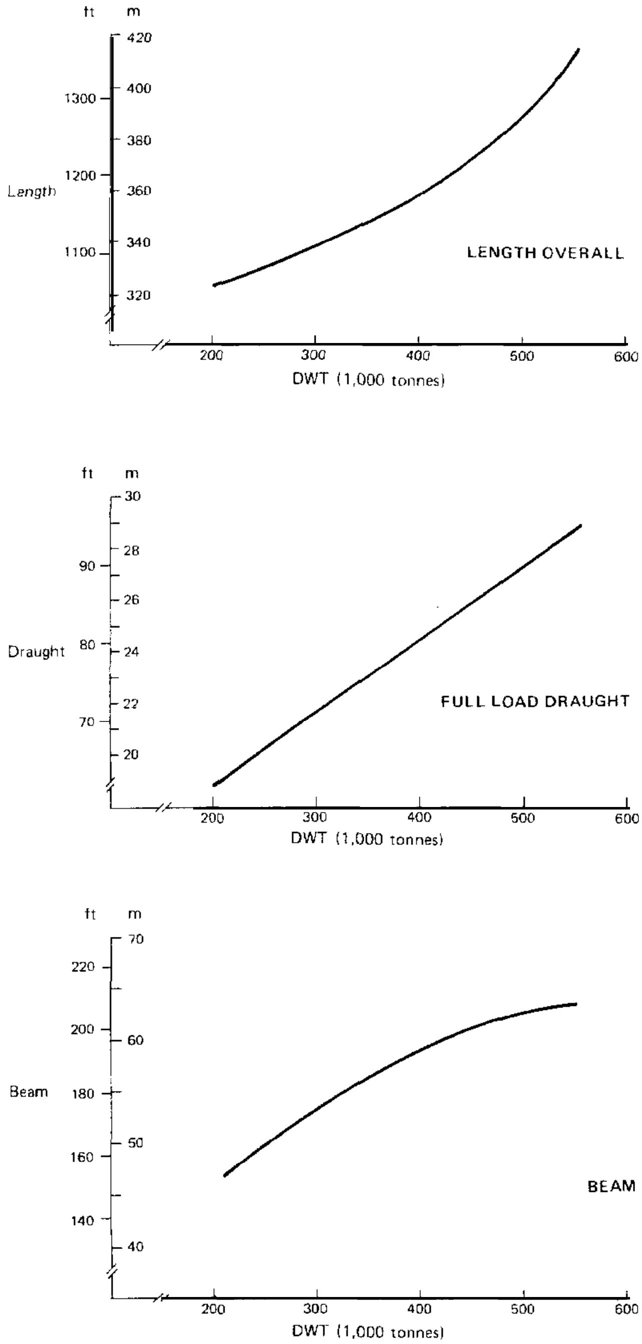


FIGURE 59

Principal dimensions of very large crude carriers



diameter. The rate of pumping from shore to ship will vary widely according to the size of the ship to be loaded. the limitations of its equipment for receipt of oils. and the turn-round time planned. As ships' capacities vary from 500 tonnes to 500.000 tonnes, the range of variation is great. The rate of pumping from ship to shore is governed by the capacity of the ship's pumps. Normally. four cargo pumps are installed. with a typical combined discharging rate of 6.500 cubic metres per hour for a 60,000-dwt tanker and 15.000 cubic metres per hour for a 200.000-dwt tanker.

407. Mild steel pipelines are invariably used. with a diameter normally between 150 mm and 900 mm. Even larger diameters are possible, depending on the quantities to be handled. Pipelines for furnace oils and other heavy black oils may require trace-heating or lagging (covering with insulating material) in temperate climates. Centrifugal pumps are normally used, except for heavy black oils for which positive displacement pumps or rotary pumps may be necessary. Some heavy black oils require heating. even in sub-tropical climates.

408. If products are being pumped through pipelines for a distance of over 3 kilometres. pipeline pigging equipment may be necessary to flush the lines in order to avoid excessive contamination when changing products. or to clean the lines to increase flow. Pig launching and recovery equipment allows the insertion of a hard rubber sphere. or pig. into the pipeline. The pig is forced along the pipe by the oil pressure to the pig trap, where it is recovered. Because of the hazardous nature of these oils, good effective communication between various points along the pipeline is of vital importance. A special telephone system or radio communication system designed for use in such a hazardous atmosphere is required.

409. Spillage collection and disposal equipment is required for pollution control areas where spillage is likely to occur-for example, at points where hoses are connected and disconnected and where pigs are launched or recovered. The equipment consists mainly of

an underground or low-level mild steel tank of adequate size and a small pump for the disposal of the collecting tank's contents back to the appropriate pipeline or tank. In addition, facilities to contain and clean up accidental spillage into the sea, such as oil booms and specialized skimming craft, should be provided.

410. In the case of exporting countries, it is required that ballast water from ships should be discharged ashore before loading. The oil contaminating the water must be separated out before disposal of the water. Suitable equipment, including tanks, oil-water separators and pumping equipment are therefore required.

411. An elaborate system of fire-fighting equipment is required at all hazardous points. The first requirement for this purpose is an adequate supply of extinguishing liquid: water for a non-petroleum fire, and foam for an oil fire. The main items of equipment required are high-pressure pumps, pipelines, hydrants, foam storage tanks and distribution pipelines, monitoring towers and suitable mobile equipment. Provision will need to be made for the storage of an adequate quantity of water if the supply of water is not reliable. Sea water can be used for fire-fighting purposes with suitable equipment designed for the handling of salt water.

412. Welded mild steel tanks are required for the storage of petroleum products. Two distinct groups of storage tanks should be erected, one group for black oils and one group for white oils, each group being surrounded by bonded wails of adequate height. Two types of tanks are available, one type with a floating roof and the other with a fixed cone-roof. The former type reduces evaporation losses while the oils are in storage. All tanks normally have sumps for draining. The capacities of tanks are usually between 500 and 20,000 cubic metres, but can be even larger, depending on requirements. The weight of tanks, and thus also their height, is restricted by the soil conditions in the area. The heating and lagging of tanks may be necessary for heavy black oils in temperate climates. The measurement of quantities in tanks is carried out by dipping or by means of specially installed gauges. Special laboratory equipment, also, is necessary for the quality control of products.

C. Liquefied natural gas

413. Cryogenics is the branch of physics that relates to the production and effects of very low temperatures. Liquefied natural gas, commonly known as LNG, is transported at approximately atmospheric pressure with a temperature of -161°C. The expansion coefficient for LNG to a gaseous form is 630 times the original volume. Liquefied petroleum gas (LPG) is produced in conjunction with petroleum refining and oil-field production. LPG must be transported under pressure, as contrasted to LNG, which can be transported at atmospheric pressure but under extremely low temperatures.

414. The hazardous nature and the very low temperatures of LNG necessitate special facilities entirely isolated from the rest of the port. Surfaces in contact with LNG must be manufactured from alloys to withstand very low temperatures, as ordinary steel would become as brittle as glass.

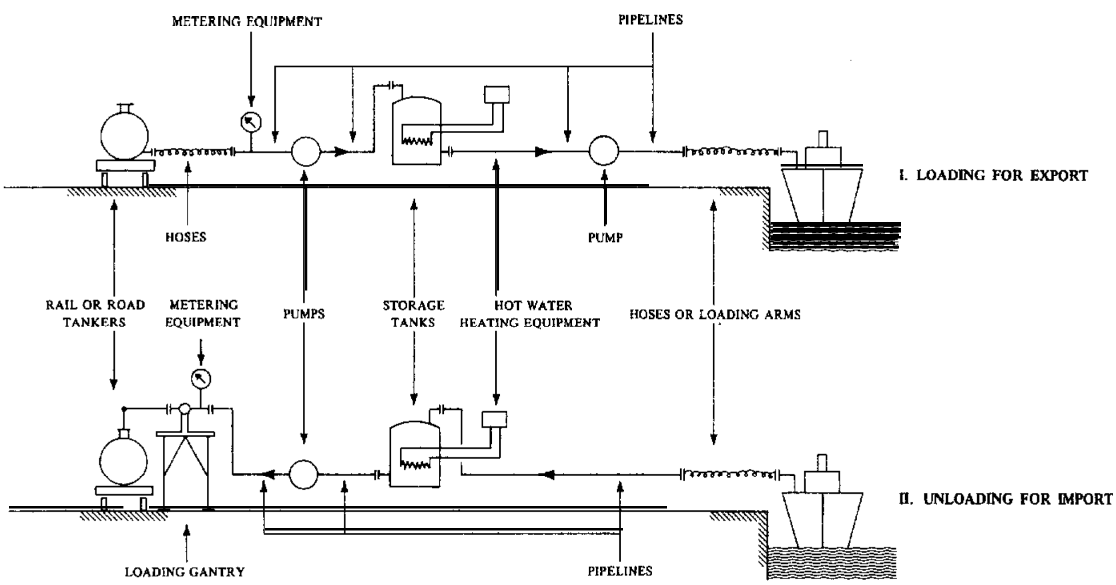
415. A wide variety of complex equipment is required for liquefaction, storage, refrigeration, loading, unloading and regasification of LNG. Depending upon the distance from the gas production area and other factors, not all of these processes may be carried out at the terminal. However, insulated pipelines and insulated storage tanks with refrigeration plant are required for storing LNG in the terminal. Typical export storage tanks have a capacity of 300,000 barrels, or 47,750 cubic metres.

D. Vegetable oils

416. This heading covers a variety of oils-for example, palm kernel oil, cotton-seed oil and coconut

FIGURE 60

Typical vegetable oil installation



oil--each having different properties and specific gravities, Some of them are in a solid state at ambient temperatures and require heating. The handling equipment required will. therefore, vary, hut a typical installation is as shown in figure 60.

417. Handling temperatures range from 15°C to 65°C. When heating is necessary, the maximum temperature change over 24 hours should not exceed 5°C. Oils should not be repeatedly heated and cooled as this results in a deterioration of their quality. The specific gravity varies between 0.8 and 0.95, dependmg on the type of oil and also on its temperature.

418. For loading on to the vessel, special rubber hoses suitable for handling vegetable oils are preferred. However. mild steel loading or unloading arms with special internal linings may be used. Hoses or loading arm sizes normally vary from 150 mm to 200 mm in diameter. Smaller hoses are required for the unloading of rail or road tankers. Suitably designed cast iron pumps should be used. Centrifugal pumps are normally used for this application, but rotary-type or mono-type pumps are also suitable. The normal pumping rate for shore-to-ship pumping is 100–150 tonnes per hour.

419. For pipelines, unhned stainless steel pipes of 150 mm to 200 mm are recommended. The heating and insulation of pipelines may also be necessary in temperate climates. The main valves in tanks and pumps should be of cast steel. All other valves may be cast iron. The washing down of pipelines is carried out with the use of suitable detergents. Pipelines are flushed by means of spherical pigs. Pigging equipment for pig launching and pig recovery is therefore installed at suitable locations.

420. Vegetable oils are stored in welded mild steel tanks with a suitable internal lining. As quantities of bulk vegetable oils handled are relatively small, a tank capacity is normally about 1,000 tonnes or less. All storage tanks should be filled from the top. For certain fatty oils. draw-off points should be provided at various levels along the side of the tank. Storage tanks may be sited outside the port area if necessary, due regard being given to the limitations of the pumping equipment. Quantities in tanks are normally measured by dipping. Tank cleaning and washing equipment is also required. particularly when a different type of vegetable oil is to be stored in the tank.

421. Covered loading gantries with retractable pipes with swivel joints. or suitable rubber hoses, should be provided for loading road or rail tankers. Special meters are also provided on the gantries to measure the quantity received or delivered. Purpose-built road or rail tankers, possibly with heating equipment. are required. Off-loading pumps may need to be provided if the vehicles are not so equipped.

E. Molasses

422. Molasses is a viscous, dark-brown syrup drained from sugar during refining. Temperature control is important both in handling and storage since below 32°C the product solidifies and above 38°C it caramelizes (i.e. becomes sticky like toffee). The specific gravity is 1.34. The handling of molasses differs from that of vegetable oils.

423. Hoses for loading or unloading of ships should be 250 mm diameter or greater and are normally handled by ships' derricks. Mobile cranes may also be required for handling hoses out of reach of ships' derricks. Hoses for the loading or unloading of road or rail tankers should not be of lesser diameter than 150 mm. Only positive displacement-type pumps or rotary pumps, with positive suction head and double bypass to assist start-up, should be used. Normal ship-to-shore pumping rate is 150 tonnes per hour.

424. Pipehnes can be of mild steel or cast iron, but pipe diameters should be 500–600 mm. Cast steel gate valves should be used throughout. Pipelines and hoses should be cleared by compressed air and washed down with fresh water after use.

425. The high specific gravity of the liquid requires specially designed welded mild steel tanks with fixed roofs. No internal tank lining is necessary. A typical capacity of storage tanks is 14,000 tonnes. Hydrostatic gauges should be provided for the measurement of the tank contents.

426. Road or rail tankers should be purpose-built. and should be lagged and provided with heating facilities and off-loading pumps with 150 mm-diameter outlets. The average capacity of such tankers is 30 tonnes. It may also be necessary to provide weigh bridges to measure quantities loaded into road or rail tankers.

F. Rubber latex

427. Liquid latex is a milky viscous sap exuded from rubber trees when tapped. Approximately 36-38 tonnes of rubber are obtained from 100 tonnes of latex. The fluid is miscible with water, and forms rubber by coagulation. The coagulation of latex can be prevented by the addition of ammonia or foremaldehyde. Temperature control is important and the temperature should not be allowed to fall below 5°C or rise above 32.5°C. The normal tank storage temperature is about 29°C. The specific gravity of liquid latex is 0.94.

428. Special rubber hoses. normally of 150 mm or 200 mm diameter, are used. Screw displacement-type pumps or mono-pumps with a neoprene stator are recommended for this purpose. Centrifugal pumps may also be used. The normal pumping rate for loading ships is 150–200 tonnes per hour.

429. Pipeline and storage tank requirements for rubber latex are similar to those for vegetable oils, but in the case of rubber latex it is generally recommended that stainless steel ball valves should be used. Diaphragm valves may also be used. The capacities of storage tanks vary between 200 tonnes and 2,500 tonnes, and an internal coating of microparaffin wax is sometimes applied to the walls of the tank to prevent the formation of deposits of rubber.

G. Liquefied ammonia

430. Ammonia is a colourless anhydrous gas, with a bitter smell. While ammonia is not easily inflammable, when mixed with air or with oxygen it can form an explosive mixture. It is a highly irritant and toxic gas, dangerous to the eyes, skin and respiratory system. Anhydrous ammonia contains nitrogen, which is one of the basic elements in fertilizers. Liquid ammonia is used primarily to produce nitrate fertilizers (ammonia nitrate) or compound fertilizers (granulated compound fertilizers).

431. Ammonia gas becomes liquid when cooled to -33°C at atmospheric pressure. Liquid ammonia is transported by special carriers of 3,000 to 40,000 dwt. Delivery to land-based tanks is by means of the ship's pumps with typical discharge rates of 600 tons per hour, with 6-inch articulated arms and ammonia at -33°C. One or several such arms connect the ship's intake with the thermally insulated land-based pipes.

432. Storage tanks must be protected from solar rays, heat and all products which react when mixed with ammonia. Temperature must be maintained at -33°C by means of compressor sets. The design should minimize the chance of direct discharge in the event of an accident. The storage depot must be provided with gas masks in a central well-identified location with easy access. A water-sprinkling system with a high discharge rate must also be provided.

H. Phosphoric acid

433. Phosphoric acids made from natural phosphates are green- or brown-coloured sticky liquids. At 20°C the specific gravity of a 50-per-cent solution of technical phosphoric acid is 1.65. Technical acids are corrosive for metals such as iron, zinc and aluminium. Stainless steel, copper, bronze, brass, some plastics, rubber and acid-proof paints are resistant to phosphoric acid at normal temperatures. At temperatures above 80°C, only glass, ebonite, carbon and acid-proof refractory materials resist completely. While phosphoric acids are non-inflammable and non-explosive compounds, they react with many metals by releasing hydrogen which can result in explosions and fires. Phosphoric acids cause irritation to the skin and eyes.

434. Phosphoric acids are used in the manufacture of fertilizers, as they contain phosphorus. They are mixed with other fertilizing compounds, either as acids or after neutralization by ammonia. Transportation takes place in special vessels up to 25,000 dwt and the discharge and loading operation is done through stainless steel pipes and a ship-to-shore hose connection. Typical rates are 600 tons per hour.

435. Phosphoric acids are stored in steel cisterns with an inner lining of rubber (self-vulcanizing 4-mm-thick rubber sheets). The cisterns stand in watertight concrete tanks that can hold the contents of a full cistern in case of leakage or accident.

Chapter IX

MISCELLANEOUS FACILITIES

A. Service craft

436. Port planning requires the provision of adequate accommodation for service craft. These craft include tugs, barges, fire-boats. water taxis, trash boats, pilot boats and floating construction and maintenance equipment such as pile drivers, salvage and dredging equipment, cranes and floating oil-spill equipment.

437. The principal service craft are likely to be the fleet of tugboats, barges and pilot boats. Tugboats are used for towing, docking, undocking and shifting vessels. Tugs also provide the needed towing capacity for moving barges and other types of floating equipment. Barges can be used for delivering bunkers and drinking water to vessels at berth or anchorage. Pilot boats are required for placing pilots on vessels as they enter port and taking pilots off as vessels leave. The pilotage area should therefore be placed in a position near the entrance to the port.

438. Service craft, with their limited draught requirements. present little problem to the port planner in terms of providing adequate water depths. However, sufficient calm water berthing space and suitable docking facilities must be made available for these essential activities.

439. Berthing facilities that were built for other purposes can often be economically converted for use by service craft. In ports where berths have become obsolete due to increasing ship size. the old berths can be converted for service craft. In new ports, the maritime facilities provided for the floating units used on the construction may be designed so that later they can act as a harbour for the service craft.

B. Service facilities

440. Ship operators use their stay in port for working cargo also to service their ship. These services can be broadly divided into four groups: fresh water; bunkering and lubricating oils; ship repairs: and provisions.

441. The supply of fresh water is a basic necessity, and the quantity required will depend upon the duration of the voyage, the ship's capacity to produce fresh water while at sea and its capacity in terms of available tanks, taking into account the loading of cargo and fuel. Demand for fresh water will be high if shore supplies are cheaper than the cost of making fresh water by ships' plants during the voyage.

442. Berth design should therefore provide for fresh water pipelines with metered outlets for connection by flexible hoses to the ship's tanks. The pipeline system can be connected to an overhead tank system so that pressure available would be sufficient to supply water to a ship at the rate of 15–20 tons per hour in a 2.5-inch pipeline.

443. Another facility for water supply, both for ships at buoys and at berth when demand is heavy (for example for passenger vessels). is water barges. The barges can load fresh water trom shore sources and move to the ship's side under tow or under their own power if self propelled. They are fitted with pumps capable of delivering water through flexible hoses at a rate of 50–100 tons per hour.

444. Also for limited quantities. water can be supplied by S-S-ton road lorry tankers which bring water to the ship's side.

445. Bunker facilities for ships are a basic service facility which can also provide a profitable source of revenue for ports. Bunkers can be provided by pipelines connected to oil storage installations; the rate of supply usually varies between 50 and 100 tons per hour. Alternatively, tank lorries may be used.

446. Ships at buoys can be supplied by a flexible floating pipeline connected to the shore pipeline outlet. Bunkering at buoys can also be carried out with oil barges. Lubricating oil needs are normally met by supplying oil in drums.

447. Facilities for ship repairs vary according to the extent of the work. Major repairs will require dry dock facilities and major marine workshops. These are fully fledged industrial facilities, which are discussed further in section F below.

448. Minor above-water repairs. repairs to wireless and radar, and to equipment and engines are available in most ports through marine engineering firms. These repairs can be undertaken and finished at berth during the normal stay of a ship.

449. However, if there is adequate demand, it may be possible to allocate one or two berths especially for ship repair, where these berths are ill suited for cargo working. Ship repair berths may require less draught as bulk vessels and tankers will most probably be repaired when empty. At the rear of the quay, repair and careening shops will be served by ship-repairing cranes that usually have a counterbalanced long-span jib, slewing on top of a high tower and running on rails parallel to the quay.

450. In repair centres where oil tankers will be repaired, a degassingideballasting station must be provided. This receives ballasting and de-aerating waters from tanks containing petroleum products, and it facilitates the separation of petroleum products from water in settling basins. Water so purified must comply with

the international standards for its petroleum product content before being discharged into the sea.

451. Provisions for crews will require recognized ship-chandlers at the port who can procure and supply grocery items and other stores to ships calling at the port. These trading firms normally require no port facilities.

452. However, certain provisions such as spirits, cigarettes and some groceries may not be locally produced, but must be supplied from imports. When they are re-exported to ships, they will not be liable for national customs duties. Such stores are therefore stored in customs bonded warehouses which may be in the port area to allow rapid supply. The goods are released with the appropriate documentation and transferred to the ship under customs escort.

C. Passenger terminals

453. The planning of passenger terminals is outside the scope of this handbook and is therefore only briefly mentioned. A fuller discussion of the subject may be found in Nagorski's book on port problems in developing countries.[14] The trend for some years in passenger vessels has been towards cruise-type ships which are actually tending to become smaller rather than larger. The average size of cruise ship is at present about 20,000 gross tonnes but it will probably fall to the 10,000- or 12,000-ton mark. Cruise vessels drawing less than 8 metres, are equipped with special manoeuvring gear so that they manoeuvre safely in a limited space and usually accommodate some 1,000 passengers. Most orders being placed are for combined passenger and car-ferry vessels.

454. Passenger ships can use general cargo berths when certain specialized facilities are provided. For example, a second storey on a transit shed may serve as the passenger terminal building with facilities for customs, immigration and health. However, the allocation of passenger ships to general cargo berths can cause problems in view of the priority which normally has to be given to cruise vessels and other passenger liners, and the disruption of cargo operations which this can cause. The passenger ship traffic must be taken into account when calculating the number of commission days available for the general cargo traffic using the terminal. Where passenger or cruise traffic is substantial, it is advisable either to allocate a separate berth or to provide a well-sheltered mooring and a fleet of launches. This latter alternative is not possible when a combined passenger and ro/ro type service uses a port.

455. If a port authority decides to provide a passenger terminal, the following points should be considered:

(a) The location of the terminal should be such that traffic jams will cause minimum disruption to cargo flows to and from the port;

(b) Open and sheltered areas will be required for the freight to be carried;

(c) Car parks are required for staging of vehicles if a ro/ro service is offered, and for vehicles meeting passengers;

(d) The terminal building will provide facilities for a number of services and be connected to the passenger vessel by telescopic gangways;

(e) A shore-based or floating ramp wall will be required for ro/ro services.

456. The passenger traffic and the cargo and vehicle traffic should be separated. The terminal building is likely to have several floors. The ground floor will have shops, foreign exchange, car-hire agencies, shipping companies, a tourist information office and waiting-rooms. The first floor will be assigned to services and controls such as customs, police, luggage, operating staff, shipping company, forwarding agents, post office and telephones. The upper floors are reserved for caterers with restaurants and self-service cafeterias The terminal building will also be provided with ramps or lifts for disabled people and for the transfer of luggage from different levels.

457. To promote this traffic, local authorities should simplify procedures to facilitate passenger movement. A sufficient number of control stations must also be provided to prevent long delays to passengers and vehicles.

D. Fishing ports

458. A fishing port is no longer a point of transfer of goods from one mode of transport to another. Rather it is an industrial zone for unloading, processing and marketing fish as well as for maintaining and servicing the fishing fleet. In consequence, a fishing port is an integral part of the national fishing industry rather than part of the country's transportation system. A modern fishing port is an important element in promoting the fishing industry of a country.

459. Facilities for handling a fishing fleet can be in the form of a wharf or jetty in shallow water, usually at the extremity of the normal cargo-handling areas, or in a special basin. This separation is desirable to isolate fishing smells from commercial port operations. Where fishing is a more important activity, a quite separate, well-selected location is needed. If the number of boats to be accommodated is considerable, a large area of sheltered water is required, while the numerous facilities will necessitate the provision of substantial space on land.

460. Local fishing boats can be expected to have a maximum draught of 2 metres, while larger motor trawlers and fish carriers may draw up to 3.5 metres. Berthing facilities for high-sea fishing with large trawlers require a cl-metre draught. An unloading quay apron width of 6 metres is sufficient. The apron should have a slope towards the waterfront, normally of 1 in 20, to facilitate washing down.

461. The length of unloading wharf should normally be sufficient to complete the unloading of all

[14] B. Nagorski, ***Port Problems in Developing Countries- Principles of Port Planning and Organization*** [Tokyo, International Association of Ports and Harbors, 1972).

boats active in the local fleet during the peak period. The factors to consider when determining the length of quay are as follows:

(a) Average and peak number of vessels unloading their catch at one time;

(h) Quay length per vessel required during unloading;

(c) Average and peak quantity of catch unloaded per vessel;

(d) Unloading speed, including preparation time before and after the actual unloading;

(e) Time available for unloading during the day.

462. For hygienic reasons and to preserve a high degree of quality of the fish, the unloading operation should be carried out as quickly as possible. Quayside cranes or derricks may be required, and in special cases pneumatic systems, vertical and horizontal conveyor belts, bucket elevators or pumps may be used.

463. After unloading, the boats are normally berthed herring-bone fashion or double banked. The berthing space required will depend on the number of boats, peak periods determined by national holidays or fishing patterns, and the availability of mooring or anchorage areas.

464. A covered hall. extending the length of the wharf, is needed for washing, sorting, boxing, weighing, icing, marketing. distribution and possibly storage. The hall should consist of two sections separated by a wide alley-way. The waterside section, used mainly for washing fish, should slope to the waterside and may be 8 metres in width; the landward side, used for sorting and packing, should be of similar width and have a rear loading platform for trucks. The total width of the hall should thus be approximately 25 metres.

465. The floor of the shed should be provided with an anti-skid surface. In the shed, running water and electric power for lighting must be available. The water supply is often separated into a fresh and a sea water supply, with the latter having high pressure and capacity for cleaning purposes. The electrical system requires special specifications because of the wet and corrosive environment.

466. Open areas for drying and repairing nets, for repairing boats, and for slipways and a workshop are also needed. The remaining facilities needed may be:

(a) A cold storage plant;

(b) An ice-making plant;

(c) Provision stores;

(d) Gear sheds;

(e) Fuel tanks;

(f) Electric lighting;

(g) A fresh water distribution system;

(h) Fire-fighting equipment;

(i) Offices, rest-rooms and a canteen;

(j) Fish-processing plants;

(k) Fish-meal factories.

467. The above brief comments on fishing port facilities give an indication of the main points to be considered. Further details are given in a report on the subject by the FAO.[15]

E. Marinas

468. Where the development of a marina for pleasure craft falls within the port authority's jurisdiction, reference can be made to various PIANC reports on the subject of pleasure navigation." Another source of information is the report on small craft harbours prepared by the American Society of Civil Engmeers in the series of manuals and reports on engineering practice."

469. In general, a marina will need to provide protection (sheltered water), navtgational aids. an anchorage basin, open moorages and a marine service station. On land, administration and supervisory facilities, marine supply store. general stores and public toilets and showers will be required to assure successful operation. Other facilities to consider are launching ramps and derricks or crane lifts for the transfer of boats between land and water.

F. Dry docks and floating docks

470. Ships must be regularly dry-docked so that the hull, propeller. rudder blade and bow thruster can be checked, cleared of seaweed and barnacles and if need be, repainted. In case of damage, dry-docking may also be required to carry out the repairs. The required facilities are costly and to be profitable must be used intensively.

471. Dry docks require a suitable supporting foundation. From the outside they resemble locks; however, one end of the dock is permanently closed. They include a pumping station to drain and keep the dock dry, a supporting system (props and keel-blocks) to hold the ship and long-span. heavy-lift capacity cranes.

472. Dry docks are expensive works, whose economic life may be as long as 100 years. Therefore provision for future ship sizes should be made when determining the dimensions of the dock. When there is room, the length of the dock may be extended without problem. The design length will be 5-10 metres greater than the length of the largest ship. the width 4-6 metres greater than its beam and the depth 0.5-l metre greater than its draught. Cranes will run on rails along the side walls. A repairing berth may be located on the outer side of a lateral wall which will permit use of the cranes for both facilities. Dry docks require limited maintenance.

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[15] FAO. "Fishery harbour planning". Fisheries Technical Paper No. 123.

[16] See in particular the final report of the PIANC International Commission for Sport and Pleasure Navigation (annex to *Bulletin* No. 25 (Vol. III/1976)) and the reports on standards for the construction, equipment and operation of yacht harbours and marinas. on the layout and structure of approach and protective structures, and on the land storage of yachts (Supplement to *Bulletin No 33* (Vol II/ *1979)).*

[17] American Society of Civil Engmeers. *Report on Small Craft Harbors* (New York. 1969).

473. Where the bearing strength of the soil is limited and if deep water is available, a floating dock may be a better alternative. A floating dock is normally a steel structure, comprising a horizontal float (apron) and two side walls that keep the structure rigid and stable during operation. The dock has both ends open.

474. The dock is submerged to a depth that will allow the ship to enter it. The ship is then secured to the dock and watertight caissons are emptied by means of pumps until the apron rises above sea level, so that the ship is raised out of the water. The side walls normally carry travelling cranes.

475. Floating docks are characterized by their lifting capacity, which corresponds to the ship's displacement. Usually a 20,000-ton dock can accommodate an unladen vessel of 50,000–60,000 dwt. The great advantage of floating docks is their mobility, which allows them to be moved within the port or to another port.

476. However, the maintenance for a floating dock is greater than that required for a dry dock. Modern floating docks are welded steel structures and their plates, which are alternately exposed and immersed, are prone to pitting and to the attachment of seaweed. Cathodic protection can be used to prevent corrosion and the immersed section can be cleaned and painted by sinking only one side of the dock, which lifts the other side out of the water.

G. New types of marine transport vessels

477. Research and development in the field of marine transport technology has produced several new types of vessels, vehicles and methods of propulsion. Two of these types are the hovercraft and the hydrofoil. None of these new types of craft are expected to be of a substantial size and it is likely that they will remain limited to ferry services carrying passengers and vehicles.

478. Speed, manoeuvrability and lack of wash and wake are the main advantages of hovercraft. The amphibious flexible skirt hovercraft requires a wide shallow concrete ramp with a maximum slope of 1 in 20, rather than a berth. Old lighterage berths could be readily converted to this use. All cargo-type hovercraft are still in the early stages of development.

479. At present hovercraft are limited to carrying passengers and vehicles. Hovercraft rest on a limited number of supports which therefore require strong pavements to sustain the heavy loads. Facilities for the passengers and vehicles are as for a passenger terminal.

480. The use of hydrofoils has been confined to high-speed passenger ferry services and military vessels. Hydrofoil craft at present do not require more than 3 metres of draught and therefore passenger berths can be used with a special gangway.

481. The port authority should be ready at the appropriate time to provide facilities for these new types of craft. As it is difficult to estimate the future needs in terms of land area and water frontage, the master plan should allow for the necessary flexibility to accommodate these developments.

ANNEXES

Annex I

GENERAL INFORMATION

A. Conversion factors

1. LENGTH

1 centimetre (cm) = 10 millimetres (mm) = 0.3937 inches (in)
1 metre (m) = 100 cm = 3 2808 feet (ft)
1 kilometre (km) = 1000 m = 0 6214 miles (mi)

1 inch = 2.5400 cm
1 foot = 12 in = 0.3048 m
1 yard (yd) = 3 ft = 0.9144 m
1 fathom = 6 ft = 1.8288 m
1 mile = 5,280 ft = 1.6093 km
1 nautical mile = 6,080 ft = 1.8531 km

2. AREA

1 sq metre (m²) = 10.000 sq cm (cm²) = 10 7638 sq ft
1 hectare (ha) = 10.000 m^2 = 2.4711 acres
1 sq km (km^2) = 100 ha = 0.3861 sq mi

1 sq yd = 9 sq ft = 0.8361 m^2
1 acre = 4,840 sq yd = 4046.9 m^2

3. VOLUME

1 cu m (m^3) = 1,000 litres (1) = 1.3080 cu yd
= 35.3147 cu ft
1 cu ft = 0 02832 m^3
1 cu yd = 27 cu ft = 0.7646 m^3

4. CAPACITY

1 litre (1) = 1000 cu cm (cm^3) = 0.035315 cu ft
= 0.2200 Imperial gallon
= 0.2642 US gallon
1 hectolitre = 100 1 = 22.00 Imperial gallons
= 26.42 US gallons

1 pint = 0.5683 litres
1 US gallon = 3.7854 litres
= 0.8327 Imperial gallon
1 Imperial gallon = 4.5461 litres
= 1.2009 US gallons
1 Imperial bushel = 1.2844 cu ft = 0.03637 m^3
= 8 Imperial gallons = 1.0321 American bushels
1 American bushel = 1.2445 cu ft = 0.03524 m^3
= 0.9689 Imperial bushel
1 US barrel = 5.6146 cu ft = 158.99 litres
= .15899 m^3
= 42 US gallons
= 34.9726 Imperial gallons
1 gross register ton = 100 cu ft = 2.83 m^3 of permanently enclosed space
1 net register ton = 100 cu ft = 2.83 m^3 of permanently enclosed space for cargo and passengers
1 shipping ton = 40 cu ft = 1.13 m^3 of permanently enclosed cargo space

Gross tonnage: measure of overall size of a ship determined in accordance with the provisions of the IMO International Convention on Tonnage Measurement of Ships (Regulation 3). which came into effect in July 1982. The gross tonnage is equal to the volume of all enclosed spaces of the ship in cubic metres, adjusted by a factor related to the overall volume

Net tonnage: measure of the useful capacity of a ship determined in accordance with the IMO Convention on Tonnage Measurement (Regulation 4).

5 WEIGHT[a]

1 gram (g) = 0.002205 pound (lb)
1 kilogram (kg) = 1,000 g = 2.2046 lb
1 tonne = 1,000 kg = 2204.6 lb
= 0.98421 long ton
= 1 10231 short tons
1 pound = 0.4536 kg
1 hundredweight (cwt) = 112 lb = 50.802 kg
1 long ton = 2240 lb = 1 0165 tonne
= 35 cu ft of salt water = 1.12 short tons
1 short ton = 2000 lb = 0.90719 tonne
0.89286 long ton

6. UNITIZATION

(a) ISO pallets

Designation	*Dimensions* *Millimetres*	*Inches*	*Ratings (Kilograms)*
A	800 × 1 200	32 × 48	1 000
B	1 000 × 1 200	40 × 48	or
C	1 200 × 1 200	48 × 48	1 500
			or
D	1 200 × 1 800	48 × 72	2 000

(b) *ISO containers*

Type	*External dimensions* *Millimetres*	*Feet*	*Gross weight (metric tons)*
1A	12 190 × 2 438 × 2 438	40 × 8 × 8	30.5
1AA	12 190 × 2 438 × 2 591	40 × 8 × 8½	30.5
1B	9 125 × 2 438 × 2 438	30 × 8 × 8	25.4
1BB	9 125 × 2 438 × 2 591	30 × 8 × 8½	25 4
1C	6 058 × 2 438 × 2 438	20 × 8 × 8	20.3
1CC	6 058 × 2 438 × 2 591	20 × 8 × 8½	20.3
1D	2 991 × 2 438 × 2 438	10 × 8 × 8	10.2
1E	1 968 × 2 438 × 2 438	6⅔ × 8 × 8	7.1
1F	1 460 × 2 438 × 2 438	5 × 8 × 8	5.1

[a] The deadweight tonnage is the weight a vessel can carry when fully laden, which may be expressed in tonnes, long tons or short tons.

7. Grains (standard)

Type	Pounds/Imperial bushels	Imperial bushels/long ton
Wheat	60	37.3
Maize	56	40.0
Soya beans	63	35.6
Barley	48	46.7
Oats	32	70 0
Rye	56	40.0
Sorghum	59	38.0

8. Oils

Gravity		Barrels		Tonnes per 100 m^3
Degrees API	Specific gravity[b]	Per tonne	Per long ton	
10	**1.000**	6.30	6.40	99.8
12	.986	6.39	6.50	98.4
14	.973	6.48	6.58	97.1
16	.959	6.57	6.68	95.1
18	.947	6.66	6.76	94.5
20	.934	6.75	6.86	93.2
22	.922	6.84	6.95	92.0
24	.910	6.93	7.04	90.8
26	.898	7.02	7.13	89.6
28	.887	7.10	7.22	88.5
30	.876	7.19	7.31	87.4
32	.865	7.28	7.41	86.3
34	855	7.37	7.49	85.3
36	.845	1.46	7.58	84.3
38	.835	7.55	7.67	83.3
40	.825	7.64	7.76	82.3
42	.816	7.73	7.85	81.4
44	.806	7.82	1.95	80.4
46	.797	7.91	8.03	79.5
48	.788	8.00	8.13	78.6
50 . .	.780	8.08	8.21	77.8
55	.759	8.30	8 44	75.7
60	.739	8.53	8 67	73.7
70	.702	S.98	9.12	70.1

B. Commodity characteristics

1. Table I is intended to help port planners in several tasks:

(a) The conversion of traffic forecast figures given in tons into shiploads, according to ship size, for the planning of probable ship calls;

(b) The conversion of tonnages of a cargo mix into the volume of future port storage capacity required;

(c) The grouping of commodity forecasts into totals to be allocated to each class of port terminal and of port storage.

2. The list of commodities Included is not exhaustive but should cover the overriding majority of traffic offered to a port. In the case of general cargo, it is not possible to be comprehensive but sufficient data is given to permit the conversion of a preliminary general cargo mix tonnage to a volume requirement.

3. The stowage factors given have been mainly derived from a standard work.[c] The stowage factor of any commodity is the figure which expresses the number of cubic feet or cubic metres which a ton of 2,240 lb will occupy in stowage and includes a proper allowance for broken stowage and dunnage. These stowage factors are not absolute and should serve merely as a useful guide in the absence of local figures. In most cases only a central value in each range is given, since it will not normally be feasible to deal with a range of values during the planning task. This approximation is sometimes very rough, but it will generally be at least as accurate as the traffic forecast itself. The table is intended for use in the estimation of storage requirements and not for the purpose of accurate operational planning for specific ship cargoes.

4. Similarly, the degree of accuracy called for is not so great as to warrant differentiating between the stowage factor of a ship, the stowage factor in a port store, and the weight/measurement ratio given in the consignment documents. The figures given can, within the limit of forecasting accuracy, be used interchangeably for each of these cargo characteristics for port development studies.

C. Discount factors

5. Table II provides factors to allow discounted cash flow analyses to be made. For example, when the rate of interest or time value of money is 12 per cent, the present value of a sum of money that will be received after five years is 0.56743 rimes the sum of money.

6. The discount factor is calculated by the formula:

$$d.f. = \frac{1}{(1+r)^n}$$

where
$d.f.$ = discount factor;
r = annual rate of interest as a fraction;
n = number of years before sum received

D. Amortization factors

7. Table III provides factors to allow the calculation of capital charges based on the life of the asset and the rate of interest. For example, an item of equipment costing $100.000 with a life of 10 years and a rate of interest of 10 per cent would have an annual amortization charge of $100,000 times 0.16275, or 616,275.

8. The amortization factor is calculated by the formula:

$$a.f. = \frac{r}{1-(1+r)^{-n}}$$

where
$a.f.$ = amortization factor;
r = annual *ate of interest as a fraction;
n = life of the asset.

E. Random number table

9. Table IV, a table of random numbers, is provided to allow the use of such techniques as the Monte Carlo simulation. To select a random sample the user must decide upon an arbitrary method of choosing entries from the table. He must then decide upon some arbitrary method of selecting the required number of positional digits from each entry. For example, the first and the last digit of each entry may be used to give a two-digit number. The procedure is repeated until a sufficient number of samples is obtained.

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[b] **Specific gravity** $= \frac{141.5}{\text{Degrees API} + 131.5}$

[c] R. E. Thomas, *Stowage; the Properties and Stowage of Cargoes*, rev. by O. O. Thomas, 6th ed. (Glasgow, Brown, Son and Ferguson, 1968).

TABLE I

Selected commodity characteristics for port planning

Commodity	*Physical characteristics:* Bulk commodities, angle of repose where relevant (degrees)	Stowage factor (cubic metres/ton (cu.ft./ton)): Bulk	Bags	Other	*Handling characteristics:* Method of handling	Class of storage	Special requirements
LIQUID CARGOES							
Crude oil		1.2 (42)			Pipeline	Tank	
Oil products		1.2 (43)			Pipeline	Tank	
Latex		1.0 (37)			Pipeline	Tank	
				Drums 1.5 (52)			
Vegetable oils		1.1 (39)			Pipeline	Tank	
				Barrels, drums 1.8 (64)			
Molasses		0.8 (27)			Pipeline	Tank	
				Baskets, casks 1.4 (50)			
Wines							
				Casks, tanks 1.8 (63)			
DRY CARGOES							
Ores, minerals and chemicals'							
Alumina	35	0.6 (21)			Loader/conveyor	Covered	Cleaning of conveyors and storage area necessary when alumina handled after bauxite at common facilities
Bauxite	28 (dry)-49 (wet)	0.8 (28)					Dust filter
			1.1 (39)				
Cement	40*	0.7 (23) 0 9-1.5			Conveyor screw and pneumatic	Totally enclosed	Exclusion of moisture, dust filter
			1.0 (34)				
				Drums, casks 1.1 (40)			
Chrome ore	35	0.4 (14)					
				Cases 0.4 (15)			
Coal	30–45	1.4 (48)			Unloader/belt conveyor	Open	For certain grades, fire precautions
Coke	37	2.4 (85)			Unloader/belt conveyor	Open	
Gypsum		1.1 (38)			Unloader/belt conveyor	Covered	
			1.2 (44)				
Ilmenite sand	40	0.4 (13)			Unloader/belt conveyor	Open	
Iron ore	30–50	0.4 (14)			Unloader/belt conveyor	Open	Dust filter for certain grades
Iron pyrites	40	0.7 (25)			Unloader/belt conveyor	Open	
Kaolin (china clay)	30–35	1.1 (39)			Unloader/belt conveyor	Covered	
			1.3 (46)				
Lead ore	40	0 4 (13)			Conveyor	Covered	
			0.5 (17)		Package		
Magnesite	35	0.7 (25)			Conveyor	Covered	
Manganese ore		0.5 (17)			Conveyor	Covered	
			0.7 (23)				
Nickel ore			0.6 (20)				
				Barrels 0.7 (25)	Package	Covered	
Petrocoke	30–40	1.5 (52)			Unloader/conveyor	Open	
Phosphate (rock)	30–34	1.0 (34)			Unloader/conveyor	Open or closed	Dust filter

* The angle of repose of cement is difficult to define as it depends upon the amount of air in the cement. With a constant supply of air, the angle of repose can be as low as 7° but when the cement is consolidated and has little or no air in it, the angle of repose approaches 90°.

Commodity	Physical characteristics: Bulk commodities, angle of repose where relevant (degrees)	Stowage factor (cubic metres/ton (cu.ft./ton)): Bulk	Bags	Other	Handling characteristics: Method of handling	Class of storage	Special requirements
Potash	32-35	0.9 (33)			Unloader/conveyor	Closed	Dust filter
			1.0 (36)				
Salt	45	1.0 (37)			Conveyor	Covered	Humidity
			1.1 (37)		Package	Covered	Controlled
				Barrels 1.4 (41)	Package	Covered	
	30–40	0.5 (19)			Conveyor	Open	
				Cases 1.7 (60)	Package	Open	
Sulphur	35–40	0.9 (31)					Precautions against health and fire risks
			1.0 (36)	Barrels 1.3 (47)	Conveyor	Covered	
Superphosphates	35		1.1 (39)		Package	Covered	
Foodstuffs and vegetable products:							
Animal meals			1.5 (53)		Package	Covered	
Bananas				Cartons 3.9 (138)	Pocket conveyor	Closed	Refrigeration
Barley	16-28	1.5 (54)			Conveyor	Covered	
			1.7 (60)		Package	Covered	
Citrus fruits				Cases, cartons, etc. 2.5 (88)	Package	Covered	Cool store
Cocoa			1.9 (6.7)				
				Cases 2.5 (87)	Package	Covered	Protection from weevils
Coffee			1.8 (65)		Package	Covered	
Copra		2 1(73)			Conveyor	Covered	
			2.9 (103)				
Cotton				Bales 2.7 (94)	Package		
Deciduous fruits				Cases, cartons, etc. 2.7 (97)	Package	Covered	Cool store
Esparto grass				Bales 4.2 (150)	Package	Covered	
Flour			1.3 (45)				
				Sacks, barrels 1.6 (55)	Package	Covered	
Grapes				Cases, barrels 3.9 (140)	Package	Covered	
Maize	30–40	1.4 (44)			Conveyor (pneumatic)		Protection from vermin and weevils
			1.5 (54)				
Oats	32	2.1 (75)			Bags	Enclosed	
			2.3 (8.0)		Package		
Oil seeds		1.8 (63)					
			2.1 (74)				
				Cases. kegs 2.0 (70)	Package	Covered	
Other vegetables			2.0 (71)				
				Cases. barrels, 1.61 (57)	Package	Covered	
Potatoes		1.6 (57)					
			1.7 (60)				
				Cartons, baskets, barrels 2.7 (95)	Package	Covered	
Rice			1.5 (54)				Protection from vermin and weevils
				Kegs 1.9 (69)	Package	Covered	
Rye	30	1.4 (50)					Protection from vermin and weevils
			1.6 (55)		Conveyor	Covered	
Semolina			1.7 (61)		Package	Covered	Protection from vermin and weevils

TABLE I (*continued*)

Commodity	Physical characteristics: Bulk commodities, angle of repose where relevant (degrees)	Stowage factor (cubic metres/ton (cu.ft./ton)): Bulk	Bags	Other	Handling characteristics: Method of handling	Class of storage	Special requirements
Soya beans	29	1.2 (44)	1.4 (50)		Conveyor	Covered	Protection from vermin and weevils
Sugar	32	1.3 (46)	1.3 (46)		Conveyor	Covered	Protection from vermin and weevils
Sugar, green				Baskets 1.5 (52)	Package	Covered	
Sugar-beet			3.8 (135)		Package	Open	
Tapioca			1.5 (53)		Package	Covered	
Wheat	25-28	1.3 (47)	1.s (52)		Conveyor	Enclosed	Protection from vermin and weevils
Animal products:							
Bacon				Cases 1.7 (59)	Package	Covered	Refrigeration in hot climates
Butter				Cases, cartons, kegs 1.7 (60)	Package	Covered	Refrigeration in hot climates
Bones		2.4 (84)			Conveyor	Open	
Bones, calcined		2.8 (100)	1.8 (65)		Conveyor	Covered	
Canned meats				Cases 1.7 (60)	Package	Covered	Cool store
Cheese				Cases, cartons 1.4 (50)	Covered		Cool store or refrigeration
Frozen:							
Beef		2.6 (92)			Pocket conveyor	Enclosed	Refrigeration
Lamb		3.2 (115)			Pocket conveyor	Enclosed	Refrigeration
Whale-meat			2.3 (SO)		Pocket conveyor	Enclosed	Refrigeration
				Cartons 2.1 (75)	Pocket conveyor	Enclosed	Refrigeration
Hides, wet				Cartons, bales. bundles 1.8 (65)	Package	Covered or open	Good ventilation
Milk, dry or powdered			1.9 (68)	Cases, cartons 2.0 (72)	Package	Covered	
Milk, condensed				Cases, cartons, kegs 1.7 (60)	Package	Covered	
Skins, dry hides				Loose 5.2 (185)	Package	Covered	
				Bales 4.2 (150)	Package	Covered	
Wool				Pressed bales 2.5 (87)	Package	Covered	
				Pressed bales 1.4-2.5 (50–90)	Package	Covered	
				Pressed bales (greasy) 4.2 (150)	Package	Covered	
				Pressed bales (dumped) 0.5 (18)	Package	Covered	
Fish products:							
Canned fish				Cases 1.7 (60)	Package	Covered	
Fishmeal			1.8 (63)		Package	Covered	

TABLE I (*concluded*)

Commodity	Physical characteristics: Bulk commodities, angle of repose where relevant (degrees)	Stowage factor (cubic metres/ton (cu.ft./ton)): Bulk	Bags	Other	Handling characteristics: Method of handling	Class of storage	Special requirements
Fish oils		1.1 (40)			Pipeline	Tank	
Frozen fish				Barrels, cases 1.6 (56)	Package	Enclosed	
				Boxes 2.1 (75)	Package	Enclosed	Refrigeration
Forest products:							
Cork				4.2 (150)	Crane	Open	
Hardwood				0.9-1.4 (30–50)	Crane	Open	
Paper				Rolls 2.5 (90)	Crane	Covered	
				Bales 1.4-2.8 (50–100)	Crane	Covered	
Pit props and plywood				2.2-3.4 (80–120)	Crane	Open	
Plywood, chipboard				2.3 (80)	Crane	Covered	
Rubber				Sheet 1.7 (60)	Crane	Covered	
				Bales, bags 1.9 (66)	Crane	Covered	
				Crepe, cases 2.0 (70)	Crane	Covered	
Sleepers				1.3 (45)	Crane	Open	
Softwood				1.4–2.0 (50–70)	Crane	Open	
Wood-pulp				Pressed bales 1.7 (60)	Crane	Open	
Metal products:							
Copper				Ingots 0.3 (11)	Crane	Covered	
				Coils 0.9 (30)	Crane	Covered	
copper concentrates	45	0.5 (16)	0.7 (25)				
				Slabs 0.3 (12)	Crane	Covered	
Iron and steel				Pig-iron 0.3 (10)	Crane	Open for short periods	Provision for drainage
				Billets 0.3 (12)			
				Bars 0.4 (15)	Crane	Covered for long-term storage	
				Steel plates 0.3 (12)			
Scrap iron and steel		1.0 (35)			Crane	Open	
Tin				Ingots 0.3 (9)	Crane	Open	
Tin plate				0.3 (12)	Crane	Covered	
Zinc				Ingots 0.4 (15)	Crane	Covered	
Zinc concentrates	40	0.6 (21)			Crane	Covered	
Vehicles:							
Motor vehicles, unpacked				4.0-8.0 (150-300)	Crane	Open	
Motor vehicles, knocked down				1.0 (35)			

TABLE II

Discount factors

Number of years	Annual rate of interest (percentage) 1	2	3	4	5	6	7	8	9	10	11	12
1	0 99010	0.98040	0.97088	0.96154	0.95239	(1.94340	0.93458	0 92593	0.91744	0.90910	0.90091	0.89286
2	0 98030	0.96117	0.94260	0.92456	0.90703	0.89000	0.87344	0 85734	0.84169	0 82645	0.81163	0.79720
3	0.97060	0 94233	0.91515	0.88900	0.86384	0.83962	0.81630	0 793X4	0.77219	0.75132	0.73120	0.71179
4	0 96099	0 92385	0.88849	0.85481	0.82271	0 79210	0.76290	0.73503	0.70843	0.68302	0.65874	0.63552
5	0 95147	0 90574	0.86261	0.82193	0. 7x353	0.74726	0.71299	0 68059	0.64994	0.62093	0.59346	0.56743
6	0 94205	0.88798	0.83749	0 79032	0.74622	0.70497	0.66635	0.63017	0.59627	0 5644X	0.53465	0.50664
7	0.93272	0.87057	0.81310	0.75992	0.71069	0.66506	0.62275	0 58350	0.54704	0 51316	0.48166	0.45235
8	0.92349	0 85350	0.78941	0.73070	0.67685	0 62742	0.58201	0 54027	0.50187	0.46651	0.43393	0.40389
9	0 91435	0.83676	0.76642	0.70259	0.64462	0.59190	0.54394	0.50025	0.46043	0.42410	0.39093	0.36062
10	0 90529	0.X203.5	0.74410	0.67557	Cl.61392	0.55840	0.50835	0 46320	0.42242	0.38555	0.35219	0.32198
11	0 89633	0.80427	0.72243	0.64959	0.58469	0.52679	0.47510	0 42889	0.38754	0 35050	0.31729	0.28748
12	0 88746	0.78850	0.70139	0.62460	0.55684	0 49697	0.44402	0.39712	0.35554	0.31864	0.28585	0 25668
13	0.87867	0.77304	0.68096	0.60058	0.53033	0.46884	0.41497	0.36770	(1.32618	0.28967	0.25752	0.22918
14	0.86997	0.75788	0.66112	0.57748	0.50507	0 44231	0.38782	0.34047	0.29925	0.26334	0.23200	0.20463
15	0 86136	0.74302	0.64187	0.55527	0.48102	0 41727	0.36245	0 31525	0 27454	0.23940	0.20901	0.18270
16	0 85283	0 72845	0.62317	0.53391	0.45812	0.39365	0.33874	0.29190	0.25187	0.21763	0.18830	0.16313
17	0.84438	0.71417	0.60502	0.51338	0.43630	0.37137	0.31658	0.27027	0.23108	0.19785	0.16964	0.14565
18	0.83602	0 70017	0.58740	0.49363	0.41553	0.35035	0.29587	0.25025	0.21200	0.17986	0.15283	0.13004
19	0.82775	0.68644	0 57029	0.47465	0.39574	0.33052	0.27651	0.23172	0.19449	0 16351	0.13768	0.11611
20	0.81955	0 67298	0.55368	0.45639	0.37690	0.31181	0.25842	0.21455	0.17844	0 14865	0.12404	0.10367
21	0.81144	0.65978	0.53755	0.43884	0.35895	0.29416	0.24152	0.19866	0.16370	0.13514	0.11175	0.09256
22	0.80340	0.64685	0.52190	0.42196	0.34186	0.27751	0.22572	0 18395	0 15019	0.12285	0 10067	0.08265
23	0 79545	0.63416	0 50670	0.40573	0.32558	0.26180	0.21095	0.17032	0.13779	0 1116X	0 09070	0.07379
24	0.78757	0.62173	0.49194	0.39013	0.31007	0.24698	0.19715	0 15770	0.12641	0.10153	0.08171	0.06589
25	0.77977	0.60954	0.47761	0.37512	0.29531	0 23300	0.38425	0 14602	0.11597	0 09230	0.07361	0.05883

Source: Calculated by the UNCTAD secretariat

TABLE III

Amortization factors

	Annual rate of interest (percentage) 1	2	3	4	5	6	7	8	9	10	11	12
1	1.01002	1.02001	1.03001	1.04001	1.05001	1.06001	1.07001	1.08001	1.09000	1.10001	1.11001	1.12001
2	0.50752	0.51506	0.52262	0.53020	0.53781	0.54544	0.55310	0.56077	0.56847	0.57620	0.58394	0.59170
3	0.34003	0.34676	0.35354	0.36035	0.36722	0.37412	0.38106	0.38804	0.39506	0.40212	0 40922	0.41635
4	0.25629	0.26263	0.26903	0.27550	0.28202	0.28860	0.29523	0.30193	0.30867	0.31548	0.32233	0.32924
5	0.20605	0.21216	0.21836	0.22463	0.23098	0.23740	0.24390	0.25046	0.25710	0.26380	0.27058	0.27741
6.	0.17255	0.17853	0.18460	0.19077	0.19702	0.20337	0.20980	0.21632	0.22292	0.22961	0.23638	0.24323
7	0.14863	0.15452	0.16051	0.16662	0.17283	0.17914	0.18556	0.19208	0.19870	0.20541	0.21222	0.21912
8	0.13070	0.13652	0.14246	0.14853	0.15473	0 16104	0 16747	0.17402	0.18068	0.18745	0.19433	0.20131
9	0.11675	0.12252	0.12844	0.13450	0 14070	0.14703	0.15349	0.16008	0.16680	0.17365	0.18061	0.18768
10	0.10559	0.11133	0.11724	0.12330	0.12951	0.13587	0.14238	0.14093	0.15583	0.16275	0.16981	0.17699
11	0.09646	0.10218	0.10808	0.11415	0.12039	0.12680	0.13336	0.14008	0.14695	0.15397	0.16113	0.16842
12	0.08885	0.09457	0 10047	0.10656	0.11283	0 11928	0.12591	0.13270	0.13966	0.14677	0.15403	0.16144
13	0.08242	0.08812	0 09403	0.10015	0.10646	0.11297	0.11966	0.12653	0 13357	0.14078	0 14816	0.15568
14	0.07691	0.08261	0.08853	0.09467	0.10103	0.10759	0.11435	0.12130	0.12844	0.13575	0.14323	0.15088
15	0.07213	0.07783	0.08377	0.08995	0.09635	0.10297	0.10980	0.11683	0.12406	0.13148	0.13907	0.14683
16	0.06795	0.07366	0.07962	0.08583	0.09228	0.09896	0.10586	0.11298	0.12030	0.12782	0.13552	0.14340
17	0.06426	0.06998	0.07596	0.08220	0.08870	0.09545	0.10243	0.10963	0.11705	0.12467	0.13248	0.14046
18	0.06099	0.06671	0.07271	0.07900	0.08555	0.09236	0.09942	0.10671	0.11422	0.12194	0.12985	0.13794
19	0.05806	0.06379	0.06982	0.07614	0.08275	0 08963	0.09676	0.10413	0.11174	0.11955	0.12757	0.13577
20	0.05542	0.06116	0.06722	0.07359	0.08025	0.08719	0 09440	0.10186	0.10955	0.11746	0.12558	0.13388
21	0.05304	0.05879	0.06488	0.07129	0.07800	0.08501	0.09229	0.09984	0.10762	0.11563	0.12384	0.13225
22	0.05087	0.05664	0.06275	0.06920	0.07598	0.08305	0.09041	0.09804	0.10591	0.11401	0.12232	0.13082
23	0.04889	0.05467	0.06082	0.06731	0.07414	0.08128	0.08872	0.09643	0.10439	0.11258	0.12098	0.12956
24	0.04708	0.05288	0.05905	0.06559	0.07248	0.07968	0.08719	0.09498	0.10303	0.11130	0.11979	0.12847
25	0.04541	0.05123	0.05743	0.06402	0.07096	0 07823	0.08582	0.09368	0.10181	0.11017	0.11875	0.12750

Source: Calculated by the UNCTAD secretariat.

Table IV

A table of 1,400 random units

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	104x0	15011	01536	02011	Xl647	91646	69179	14194	62590	36207	20969	99570	91291	90700
2	2236X	46573	25595	85393	30995	89198	27982	53402	93965	34095	52666	19174	39615	99505
3	24130	48360	22527	97265	76393	64809	15179	24830	49340	32081	30680	19655	6334X	58629
4	42167	93093	06243	61680	07856	16376	39440	53537	71341	57004	00849	74917	9775x	16379
5	37570	39975	81837	16656	06121	91782	60468	81305	49684	60672	14110	06927	01263	54613
6 ...	77921	06907	11008	42751	27756	53498	18602	70659	90655	15053	21916	81825	44394	42880
7	99562	72905	56420	69994	98872	31016	71194	18738	44013	48840	63213	21069	10634	12952
8	96301	91977	05463	07972	18876	20922	94595	56869	69014	60045	18425	84903	42508	32307
9	x9579	14342	63661	10281	17453	18103	57740	84378	25331	12566	58678	44947	055x5	56941
10	85475	36857	53342	53988	53060	59533	38867	62300	08158	17983	16439	11458	18593	64952
11 ...	28918	69578	88231	33276	70997	79936	56865	05859	90106	31595	01547	85590	91610	78188
12	63553	40961	48235	03427	49626	69445	18663	72695	52180	20847	12234	90511	33703	90322
13	09429	93969	52636	92737	XX974	33488	36320	17617	30015	0X272	84115	27156	30613	74952
14	10365	61129	X7529	X5689	48237	52267	67689	93394	01511	2635X	85104	20285	29975	89868
15	07119	97336	71048	08178	77233	13916	47564	81056	97735	X5977	29372	74461	28551	90707
16 ...	51085	12765	51821	51259	77452	16308	60756	92144	49442	53900	70960	63990	75601	40719
17	02368	21382	52404	60268	89368	19885	55322	44819	01188	65255	64835	44919	05944	55157
18	01011	54092	33362	94904	31273	04146	18594	29852	71585	85030	51132	01915	92747	64951
19	52162	53916	46369	58586	23216	14513	83149	98736	23495	64350	9473X	17752	35156	35749
20	07056	97628	33787	09998	4269X	06691	76988	13602	51851	46104	88916	19509	25625	58104
21	48663	91245	85828	14346	09172	30168	90229	04734	59193	22178	30421	61666	99904	32812
22	54164	58492	22421	74103	47070	25306	7646X	26384	58151	06646	21524	15227	96909	44592
23	32639	32363	05597	24200	13363	38005	94342	28728	35806	06912	17012	64161	18296	22851
24 ...	29334	27001	87637	87308	58731	00256	45834	15398	46557	41135	10367	07684	36188	1x510
25	02488	33062	28834	07351	19731	92420	60952	61280	50001	6765X	32586	86679	50720	94953
26	81525	72295	04839	96423	24878	X2651	66566	14778	76797	14780	13300	87074	79666	95725
27	29676	20591	68086	26432	46901	20849	89768	81536	X6645	12659	92259	57102	80428	25280
2X	00742	57392	39064	66432	84673	40027	32832	61362	98947	96067	64760	64584	96096	98253
29	05366	04213	25669	26422	44407	44048	37937	63904	45766	66134	75470	66520	34693	90449
30	91921	26418	64117	94305	26766	25940	39972	22209	71500	6456X	91402	42416	07x44	69618
31	00582	04711	87917	77341	42206	35126	740x7	99547	81817	42607	43808	76655	62028	76630
32	00725	69884	62797	56170	86324	88072	76222	36086	84637	93161	76038	65855	77919	88006
33	69011	65795	95876	55293	18988	27354	26575	0X625	40801	59920	29841	80150	12777	48501
34	25976	57948	29888	88604	67917	48708	18912	82271	65424	69774	33611	54262	85963	03547
35	09763	83473	73577	12908	30883	18317	2x290	35797	05998	41688	34952	37888	3x917	88050
36	91567	42595	2795x	30134	04024	86385	29880	99730	55536	84855	29080	09250	79656	73211
37	17955	56349	90999	49127	20044	59931	06115	20542	18059	02008	73708	83517	36103	42791
38	46503	18584	18845	49618	02304	51038	20655	58727	28108	15475	56942	53389	20562	87338
39	92157	89634	94824	78171	84610	82834	09922	25417	44137	48418	25555	21246	35509	20468
40 ...	14577	62765	35605	Xl263	39667	4735X	56873	56307	61607	4951X	89565	20103	77490	18062
41	98427	07523	33362	64270	01638	92477	60969	98420	04880	45585	46565	04102	46880	45709
42	34914	63976	88720	82705	34476	17032	87589	40836	32427	70002	70663	XXX63	77775	69348
43	70060	28277	39475	40473	23219	53416	94970	25832	69975	94884	19661	7282X	00102	66794
44	53976	54914	00990	67245	0x350	82948	11398	4287X	80287	88267	47363	46634	06541	97809
45	76072	29515	40980	07391	58745	25774	22987	80059	39911	96189	41151	14222	60697	59583
46	90725	52210	x3974	29992	65831	38857	50490	83765	55657	14361	31720	57375	5622X	41546
47	64364	67412	33339	31926	14883	24413	59744	92351	97473	89286	35931	04110	23726	51900
48	0X962	00358	31662	25388	61642	34072	81249	85648	56891	69352	48373	4557X	7x547	81788
49	95012	08379	93526	70765	10592	04542	76463	5432X	02849	17247	28865	14777	62730	92277
50	15664	10493	20492	38891	91132	21999	59616	Xl652	27195	48223	46751	22923	32261	X5653
51	16408	81899	04153	53381	79401	21438	83035	92350	36693	3123X	59649	91754	72772	02338
52	18629	X1953	05520	91962	04739	13092	97662	24822	94730	06496	35090	04822	86774	98289
53	73115	35101	4749x	X7637	99016	71060	88824	71013	1x735	20280	23153	72924	35165	43040
54	57491	16703	23167	49323	45021	33132	12544	41035	80780	45393	44812	12515	98931	91202
55	30405	X3946	23792	14422	15059	45799	22716	19792	099x3	74353	08668	30429	70735	25499
56	16631	35006	85900	98275	32388	52390	16815	69298	X2732	38480	72817	32523	41961	44437
57	96773	20206	42559	78985	05300	22164	24369	54224	35083	19687	11052	91491	60383	19746
5x	38935	64202	14349	82674	66523	44138	00697	35552	35970	19124	63318	29686	03387	59846
59	31624	76384	17403	53363	44167	64486	6475X	75366	76554	31601	12614	33072	60332	92325
60	78919	19474	23632	27889	47914	02584	37680	20801	72152	39339	34806	08930	85001	87820

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
61	03931	33309	57047	74211	63135	17361	62825	39908	05607	91284	68833	25570	38818	46920
62	74426	33278	43972	10119	89917	15665	52872	73823	73144	88662	88970	74492	51805	99378
63	09066	00903	20795	95452	92648	45454	0'1552	88815	I6553	51125	74375	97596	16296	66092
64	42738	12436	87025	14267	20979	04508	64535	31355	86064	29472	47689	05974	52468	16834
65	16153	08002	26504	41744	81959	65642	74240	56302	00033	67107	77510	70625	28725	34191
66	21457	40742	29820	96783	29400	21840	15035	34537	33310	0h116	95240	15957	36572	06004
67	21581	57802	02050	89728	17937	37621	471175	42080	97403	48626	68995	43805	33386	31597
68	55612	78095	83197	33732	05810	24813	86902	60397	16489	03264	88525	427X6	05269	92532
69	44657	66999	99324	51281	84463	hU543	79312	93454	68876	25471	93911	25650	12682	73572
70	91340	84979	46949	81973	37949	61023	43997	15263	80644	43442	89203	71795	99533	50501
71	91227	21199	31935	27022	84067	05462	35216	14436	29X91	68607	41867	14951	91696	85065
72	50001	38140	6632 1	19924	72163	09538	12151	06878	91903	18749	34405	56087	82790	70925
73	65390	05224	72958	28609	81406	39147	25549	4X542	42627	45233	57202	94617	23772	07896
74	27504	96131	83944	41575	10573	08619	64482	73923	36152	05184	94142	25299	84387	34925
75	37169	94851	39117	89632	00959	16487	65536	49071	39782	17095	02330	74301	00275	4X280
76	11508	70225	51111	38351	lY444	66499	71945	05422	13442	7X675	84081	66938	43653	59894
77	37449	30362	06694	54690	04052	53115	62757	95348	78662	11163	81651	50425	34971	52924
78	46515	70331	85922	38329	57015	15765	97161	17869	45349	61796	66345	61075	49106	79860
79	30986	81223	42416	58353	21532	30502	32305	86482	05174	07901	54339	58861	74818	46942
80	63798	64995	46583	09785	44160	78128	83991	42X65	92520	X3531	80377	35909	81250	54238
81	82480	84846	99254	67632	43218	50076	21361	64816	51202	88124	41870	52689	51275	83556
82	21885	32906	92431	09060	64297	51674	64126	62570	26123	05155	59194	52799	28225	85762
83	60336	98782	07408	53358	13564	59089	26445	29789	85205	41001	12535	12133	14645	23541
84	43937	46891	24010	25560	86355	33941	25786	54990	71899	15475	95434	98227	21824	19585
85	97656	63175	89303	16275	07100	92063	21942	18611	17348	20203	18534	03862	78095	80136
86	03299	01221	05418	38982	55758	92237	26759		21216	98442	08303	56613	91511	75928
87	79626	06486	03574	17668	07785	76020	79924	25651	83325	88428	85076	72811	22717	50585
88	85636	68335	47539	03129	65651	11977	02510	26113	99447	68645	34327	15152	55230	93448
89	18039	14367	61337	06177	12143	46609	52989	74014	64708	00533	35398	58408	13261	47908
90	08362	15656	60627	36478	65648	36764	53412	09013	07832	41574	17639	82163	60859	75567
91	79556	29068	04142	16268	15387	12856	66227	38358	22478	73373	88732	09443	82558	05250
92	92608	82674	27072	32534	17075	27698	98204	63863	11951	34648	88022	56148	3492s	57031
93	23982	25835	40055	67006	12293	02753	14827	23235	35071	99704	37543	11601	35503	85171
94	09915	96306	05908	97901	28395	14186	00821	80703	70426	75647	76310	88717	37890	40129
95	59037	33300	26695	62247	69927	76123	S0842	43834	86654	70959	79725	93872	28117	19233
96	42488	78077	69852	61657	34136	79180	97526	43092	04098	73571	80799	76536	71255	64239
97	46764	86273	63003	93017	31204	36692	40202	35275	57306	55543	53203	18098	47625	88684
98	03237	45430	55417	63282	90816	17349	88298	90183	36600	78406	06216	95787	42579	90730
99	86591	81482	52667	61582	14972	90053	x9534	76036	49199	43716	97548	04379	46370	28672
100	38534	01715	94964	87288	65680	43772	39560	12918	86537	62738	19636	51132	25739	56947

Source: Bureau of Transport Economics and Statistics of the Interstate Commerce Commission, Washington, D.C.

Annex II

MATHEMATICAL TECHNIQUES

A. Monte Carlo risk analysis

1. The Monte Carlo technique is a procedure for obtaining approximate evaluations of mathematical expressions, consisting of one or more probability distribution functions. **In** essence, the technique consists of simulating an experiment to determine the overall statistical properties of a system by the random sampling of each component of the system. The actual taking of a physical sample from the real system is either Impossible or too expensive and thus simulated sampling must be used. Simulated sampling involves replacing the actual component distribution by a theoretical assumed probability distribution, and then sampling from this theoretical distribution by means of a random number table.

2. The technique has wide practical applications and can be used for risk analysis when various investment alternatives are being evaluated. In the matter of port development. future events are probabilistic. For example, the planner does not know for certain that in three years' time the terminal will have to handle 1 million tonnes of break-bulk cargo. He may know that there is a high probability that the volume of cargo will be not less than 800,000 tonnes and not more than 1,400,000 tonnes. Thus, the future terminal throughput can be described in terms of probability distribution function. Other elements, such as productivity and gangs per ship per shift can also be described by probability distributions. With estimates of these distributions, the Monte Carlo technique may be used to evaluate the performance and cost associated with various investment alternatives.

3. The probability for the occurrence of any given combination as the result of the throwing of a pair of six-sided dice is made up of the separate probabilities for the occurrence of each face of each individual dice. Where the Individual probabilities are equal, as would be the case for unbiased dice, it is possible to calculate the joint probabilities. But where the individual probabilities are unequal and unknown-If the dice were biased, for example-the calculation is not possible and it is necessary to carry out an experiment to estimate the joint probability. The drawing of numbers from random number tables like the one given in annex I is a form of experiment.

4. The technique as applied to port planning can best be illustrated by a numerical example. Let us suppose that a planner has arrived at the following statistical estimates for a berth group in the year 1985:

Traffic demand probability

Tonnes	*Percentage*
400 000–600 000	15
600 000–800 000	20
800 000-I million	30
1-1.2 million	20
1.2-1.4 million	15

Productivity probability

Tonnes par *gang hour*	*Percentage*
8-12	40
12–16	40
16-20	20

Gangs per ship per shift probability

Number of gangs	*Percentage*
2	20
3	50
4	30

5. If the planner now requires to find the joint probability distribution of the berth-day requirement he must carry out, either by hand or by computer. the drawing of random numbers to represent a large number of possible outcomes of each of the three parameters.

6. For traffic demand, the five different tonnage ranges are assigned the set of numbers chosen from 0–99 which gives them the appropriate range of probability.

Tonnes	*Probability percentage*	*Number range*
400 000–600 000	(15)	00–14
600 000–800 000	(20)	15-34
800 000–1 million	(30)	35-64
1-1.2 million	(20)	65-84
1.2-1.4 million	(15)	85-99

The productivity probabilities are allocated numbers similarly:

Tonnes per how	*Probability percentage*	*Number range*
8–12	(40)	0–39
12-16	(40)	40–79
16–20	(20)	80–99

Finally, the gangs per ship per shift probabilities are allocated numbers:

Number of gangs	*Probability percentage*	Number *range*
2	(20)	0–19
3	(50)	20–69
4	(30)	70-99

7. The Monte Carlo experiment now proceeds by drawing a set of three random two-digit numbers-say the first two digits of the first three numbers in the column (I) of annex I, table IV, namely, 10, 22 and 24. The number 10 implies a tonnage of 400,000–600,000 tonnes; 22 implies a productivity of 8–12 tonnes per hour; 24 implies 3 gangs. A calculation for the first sample set of data is now carried out (using the mid-range figure to represent tonnage and tonnes per hour, and assuming a fixed fraction of time worked per day of 0.6).

First sample

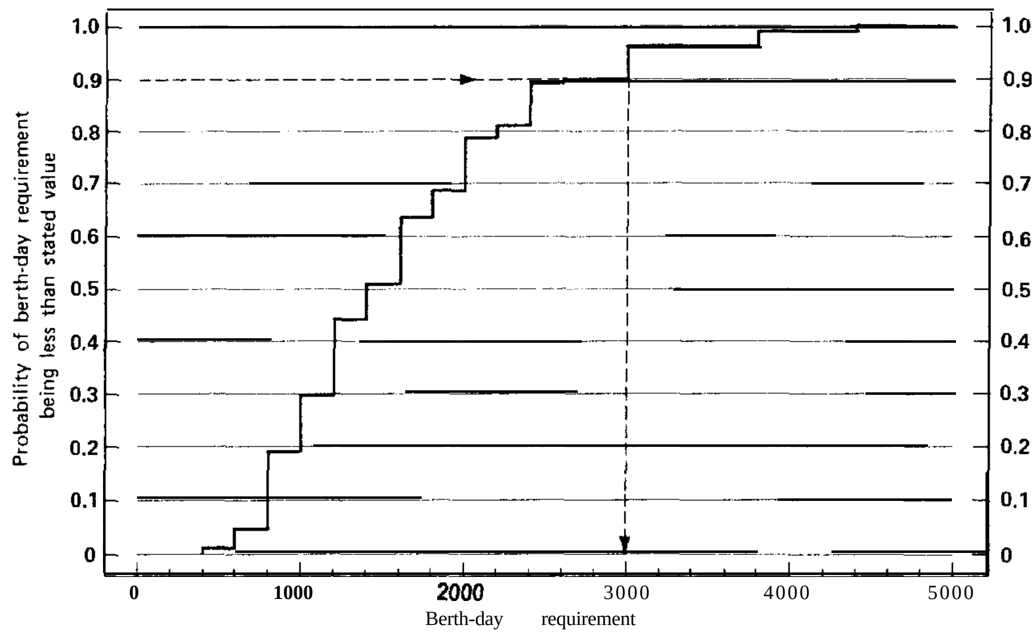
$$\text{Berth-day requirements} = \frac{500{,}000 \text{ tonnes}}{10 \text{ tons/hour} \times 3 \text{ gangs} \times 0.6 \times 24}$$

$$= 1.157 \text{ berth-days}$$

8. This single figure of 1.157 is recorded as the result of the first sample and the process is repeated-perhaps 50 to 100 times-to give a new probability distribution which can be drawn as shown in figure I, and which will be of interest to a decision-maker. The decision may then be taken that it is reasonable to plan for the 90 per cent berth-day requirement probability, i.e. 3,000 berth-days.

FIGURE I

Cumulative probability distribution for Monte Carlo numerical example



Y This procedure would normally be carried right through to the more easily understood decision measurement of the net present value of the investment proposal, and in that case a computer programme to carry out all the calculations would be justified However laborious such a procedure is. It is always possible to do it manually and it may be more attractive to set a student to work on this for a fortnight than tog" to the expense and trouble of computer programming. The queueing curves incorporated in the planning charts can be used to calculate the waiting-times, and in fact the planning charts can also be used to calculate the berth-days for each sample of tonnage, productivity and gangs per shift.

B. Simulation

10. Simulation is a branch of modern management science and is a technique for modelling a complex process which would otherwise defy mathematical description, because of the stochastic[a] behaviour and non-linear characteristics of the process. In simulation. the system is broken down into a number of subsystems that are fairly easy to describe mathematically. These parts are then combined to give a model of the whole system, and then responses to various inputs can be measured. The parameters of the model can be varied, which enables the user to simulate proposed changes to existing or future processes and hence evaluate the economics of various alternatives without costly capital investment.

11. Because of the large number of repetitive calculations and the volume of data involved in a simulation model. many models are run on a computer. For this reason, various simulation languages have been developed to allow more rapid implementation of the conceptual model into a working model The most commonly used languages are:

GPSS
SIMULA
CSL
SIMSCRIPT
SIMON
GASP II

In addition, non-simulation languages can also be employed. and models are often developed using computer languages such as FORTRAN, COBOL, ALGOL. PASCAL and PL/1.

[a] Stochastic behaviour is behaviour which appears random but can be described by a definite statistical pattern.

12. The following general points should be borne in mind when considering the use of computer simulation techniques:

(a) Simulation gives the model's response to a given situation;

(*b*) Simulation is a useful training aid and an excellent method for research into system behaviour:

(c) Simulation allows many alternatives to be tried.

(*d*) The cost of simulation may affect the decision whether or not to use the technique;

(*e*) Simulation development costs are difficult to forecast accurately;

(*f*) General models that can be applied without modification will normally provide only limited information;

(*g*) Very often, the formulation and "debugging" of the model will supply the answer without the need to run the model.

13. Although the use of simulation for port development was recommended in a preliminary report by the secretariat as a method of practical value. it was noted that the method can be used only in cases where adequate statistical data are available.[b] After subsequent research and applications of the method.' the secretariat was able to specify the following prerequisites to obtaining the full benefits from the technique:

(*a*) **Accurate** and precise traffic forecasts and future cargo handling rates;

(*b*) Expertise in simulation methods. both in model development and in model use;

(c) Sufficient time to allow for data collection, model definition, documentation, programming, testing and validation, followed by a period to obtain results from the model for various investment alternatives.

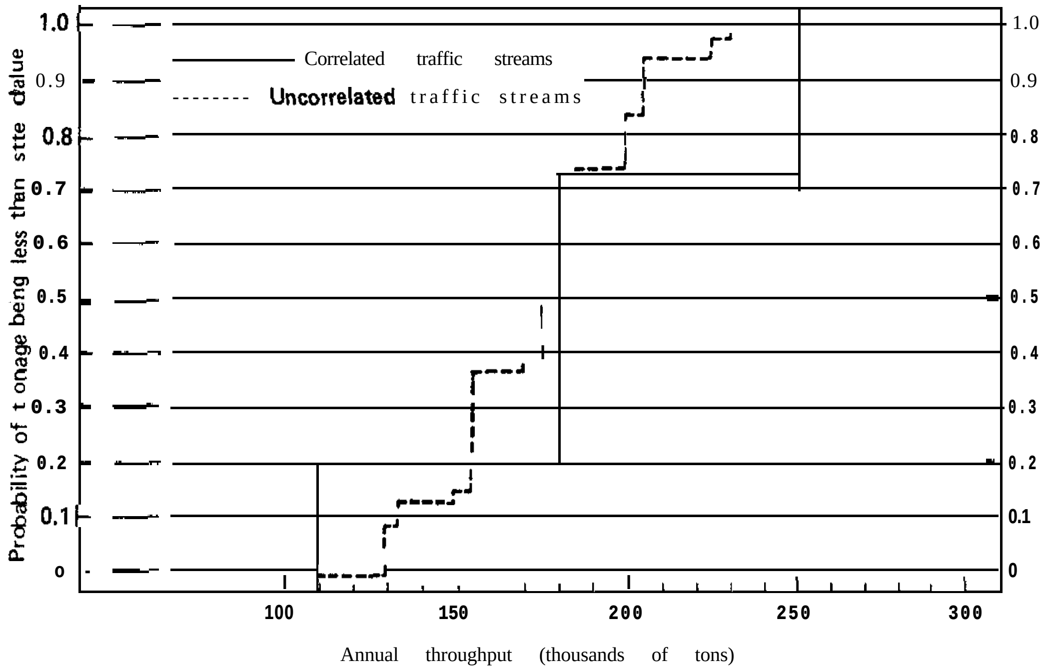
II. In many cases these conditions will not apply to port planning in developing countries. This war the reason for the development of the planning charts described in this publication. In the majority of cases, these charts are more appropriate than simulation.

[b] *Development of Ports: Improvement of Port Operations and Connected Facilities* (United Nations publication, Sales No. E.69.II.D.17). Introduction, para. 3.

[c] See "Technological progress in shipping and ports: the application of systems analysis to port planning" (TD/B/C.4/132), paras. 12–21.

FIGURE II

Comparison of **total** tonnage distribution for correlated and uncorrelated cases



C. Combination of traffic class uncertainties

15. The detailed analysis of traffic, category by category and route by route, is to some extent wasted unless a satisfactory method exists of recombining them into the aggregated traffic of a berth group, for it is only at this level that performance calculations can be made.

16. A numerical example is used to illustrate the technique of combining traffic forecasts into an aggregate berth group traffic forecast. It is assumed that a terminal is to receive three different classes of traffic. The tonnages and probabilities for each traffic are forecast as shown in table V.

17. When the various traffic streams are independent, the joint probability is given by multiplying the individual probabilities together for each combination. Thus the probability of the highest forecast, namely, 250,000 tons. being fulfilled is 0.2 × 0.3 × 0.1 or 0.006. while the probability for the lowest forecast, namely, 110,000 tons, is 0.3 × 0.1 × .012.

18. Table VI tabulates the various combinations and the probability of their occurrence The independent nature of each traffic stream smooths the demand on the berth group. However, when such separate forecasts are interdependent or, in mathematical terms, correlated, the combined probabilities will be different. When one factor is completely dependent on or correlated with another, then it is said to have a correlation coefficient of 1.0.

19. For completely correlated traffic, the probability of the high, medium and low forecast for the numerical example given above would be 0.2. 0.533 and 0.267 [d] The expected volume of traffic is given by:

$$250 \times .2 + 180 \times .533 + 110 \times .267 = 175.3 \text{ thousand tons,}$$

as compared with the expected volume of traffic for the uncorrelated case of 177.78 thousand tons. Thus the factor of correlation affects the distribution in this case rather than the expected value. The cumulative probability for the two cases is shown in figure II. For this example, the throughput which would have only a 10 per cent probability of being exceeded would be 205,000 tons for the correlated case but 250,000 tons for the uncorrelated case.

[d] For each forecast the probability is determined by adding the individual probabilities together and then dividing by the number of traffic streams, in this case 3.

20. Attempts to estimate the optimistic and pessimistic values of each separate category as well as their most likely values are not normally justified, since the combination of these estimates is itself sensitive to estimates of the degree of correlation between the various traffic categories, and these correlation coefficients will seldom be sufficiently accurately known. Instead, the estimates should be limited to the central, most likely, value of each category, with the assumption that the overall trend of the aggregated traffic will apply equally to each.

21. The exception to this will be where particular categories clearly have a range of uncertainty which is substantially different from the overall uncertainty. In that case, the difference from the trend may be separated, combined with the differences in other categories according to whether these are independent or correlated, and then added to the aggregated estimates.

22. However. these mathematical refinements are unlikely to add much accuracy to the final estimates and they bring their own dangers in giving an appearance of precision which is unjustified. It is more satisfactory to deal with uncertainty in a more practical way. For example, where within the context of an average annual growth rate of 10 per cent in a particular traffic, there is a possibility for each of two routes, that the growth will be higher than the average, the planner will be forced to contemplate the future picture or scenario with both such extraordinary trends. To make his scenario consistent and reasonable he will need to consider the extent to which the two above-average trends can coexist. He should be able to arrive at a common-sense way of synthesizing the overall traffic which in reality will be as accurate as the mathematical way, and much more convincing.

TABLE V

Terminal cargo traffic forecast and probability

Traffic	Traffic tonnage (thousands of tons) and probability estimates		
	High	Medium	Low
A	1001.2	75/.5	50/.3
B	801.3	60/.6	401.1
c	701.1	45/.5	201.4

TABLE VI

Combinations of traffic forecasts and probabilities

Combination			*Traffic forecast (thousands of tons)*	*Probabilities*	*Contribution to expected total traffic (thousands of tons)*
A	*B*	*C*			
H*	H	H	250	.006	1.5
H	H	M**	225	.030	6.75
H	H	L***	200	.024	4.80
H	M	H	230	.012	2.76
H	M	M	205	.060	12.30
H	M	L	180	.048	8.64
H	L	H	210	.002	4.2
H	L	M	185	.010	1.85
H	L	L	160	.008	1.28
M	H	H	225	.015	3.375
M	H	M	200	.075	15.00
M	H	L	175	.060	10.50
M	M	H	205	.030	6.15
M	M	M	180	.150	27.00
M	M	L	155	.120	18.60
M	L	H	185	005	.925
M	L	M	160	.025	4.0
M	L	L	135	.020	2.7
L	H	H	200	.009	1.8
L	H	M	175	.045	7.875
L	H	L	150	.036	5.40
L	M	H	180	.018	3.24
L	M	M	155	090	13.95
L	M	L	130	072	9.36
L	L	H	160	003	II JR
L	L	M	135	015	2.025
L	L	L	110	012	1 32
				1 000	177 78

*High forecast. **Medium forecast. ***Low forecast

TABLE VII

Summary of analysis of port data collected for congestion surcharge study

Port and year	*Number of observations in sample*	*Mean tonnage per ship*	*Mean berth time (hours)*	*Tons per ship-hour at berth*	*Erlang no.**
Mombasa					
1970	190	2 122	180	19.60	2
1971	197	2 438	148	16.43	2
1972	196	2 179	120	18.20	2
Khorramshahr					
1971	143	2 617	121	21 56	3
1972	135	2 747	126	21.88	3
1973	123	3 718	133	27.86	3
Dar es Salaam					
1969	144	1 377	82	16.89	2
1970	144	2 027	119	17.01	2
1971	144	2 186	157	13.89	2
1972	143	1 833	135	13.59	

Source: Data collected by the UNCTAD secretariat.

* Erlang number of theoretical distribution best fitting the observed berth time distribution.

D. Statistics of ship arrival. service distributions and waiting time

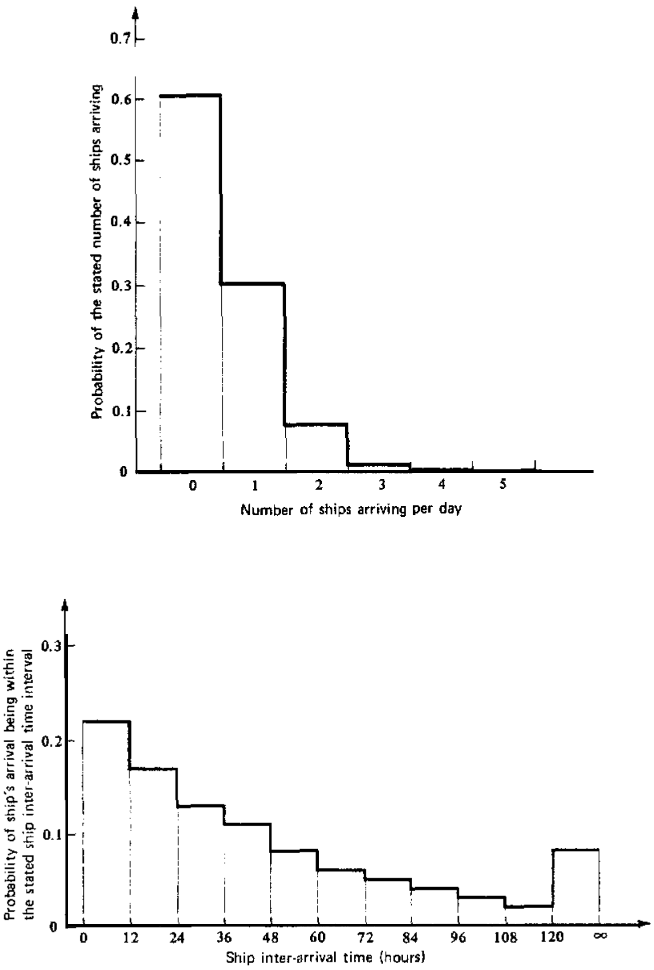
23. UNCTAD research has confirmed the widely accepted view that the arrival pattern of break-bulk ships is best approximated by a Poisson distribution. This is equivalent to the distribution of the interval between arrivals being approximated by a negative exponential or Erlang 1 distribution. As an example, the probability distributions for the case where one ship arrives every two days is shown in figure III.

24 Based on data available to the UNCTAD secretariat (see table VII), the decision war taken to use an Erlang 2 distribution for the service or berth time distribution. The servicing operation can be regarded in the following way There are two "stages". not necessarily with a physical significance, each with an Erlang 1 distribution. When the first stage is completed the second stage is immediately begun. The total service time then has the distribution of the sum of the two Independent random variables and may be represented by an Erlang 2 distribution.

25. When the number of "stages" approaches a very large number, i.e. giving a high Erlang number. the service time tends to be constant. but it is necessary for the Erlang number to be very high before this occurs. since the ratio of mean to standard deviation is given by the square root of the Erlang number.

FIGURE III

Arrival pattern of break-bulk vessels with an average of one ship every two days



26. At the other extreme, the Erlang 1 distribution for the service time distribution would result in a large number of service tunes clustered together at zero. While this is a plausible presumption for ship inter-arrival time, it is unrealistic to apply this presumption to ship time at berth. A comparison of the Erlang I and 2 cumulative frequency distributions for a mean service time of five days is shown in figure IV.

27. The application of queueing theory can be used to give a good approximation of the waiting time for various system capacities. The queueing system modelled for a break-bulk berth group is based on the assumptions of random arrivals and an Erlang 2 service distribution. In queueing theory notation this is the $M/E_2/n$ system (M for Markovian or random arrivals, E_2 for Erlang 2 service time and n for number of servers). The $M/E_2/n$ system is very cumbersome mathematically and has not been completely described for cases when $n >$ 2. Fortunately. it is possible to use an approximation suggested in Page's book on queueing theory,' which in most practical cases gives sufficiently accurate results. Table VIII gives, for the $M/E_2/n$ system. the average waiting time of vessels in the queue, in units of average service time. These results have been used in the break-bulk planning chart II to define the relationship between berth utilization and total ship time in port.

28. For specialized terminals the assumption has been made that distribution of the intervals between arrivals is best described by an Erlang 2 distribution rather than by the negative exponential distribution. This is due primarily to the fact that a limited number of operators uses each specialized terminal, with the result that there is some rationalization of arrivals. The assumption of Erlang 2 distributed service times here will give higher estimates of queueing time than would be expected far a terminal where ship turn-round was nearly constant. but from data available to UNCTAD the *latter* is rarely the case. In those cases. particularly in vertically integrated bulk operations, where shiploads are fairly constant, high Erlang numbers of 8 or more have been used.

29. Table VIII quantifies the relationship between waiting time and berth utilization in units of average service time. As an example, a comparison of waiting times for a four-berth terminal for the three queueing systems ($M/M/4$, $M/E_2/4$ and $E_2/E_2/4$) is shown in figure V The sensitivity of waiting time results to the assumed distribution should be noted and borne in mind when evaluating alternatives. The $M/E_2/n$ system is considered the best estimate of queueing tune for break-bulk terminals while the $E_2/E_2/n$ system is best for specialized terminals.

E. Mathematical basis for planning charts

30. The mathematical relationships used to produce the curves in each quadrant of the planning charts are presented below. With this information the planner can reconstruct the curves to a different scale.

(a) *Break-bulk general cargo terminal, planning chart I: berth requirements*

Tons per day per gang = average number of tons per gang-hour × overall fraction of tune berthed ships worked × 24

Tons per ship per day = tons per day per gang × average number of gangs employed per ship per shift

Berth-day requirement = annual tonnage forecast/tons per ship day

Approximate number of berths required = berth-day requirement/(commission days per year × typical berth utilization).

(b) *Break-bulk general cargo terminal, planning chart II. ship cost*

Berth-day requirement per berth = berth-day requirement/number of berths

Berth utilization = berth-day requirement per berth/commission days per year

Total time at port (days) = 365 × number of berths × berth utilization × waiting tune factor[g]

Annual ship cost = total time at port × average daily ship cost (in portj.

(c) *Break-bulk general cargo remind, planning chart 111: storage area requirements*

Holding capacity required (in tons) = annual tonnage through store × average transit time (days)/365[h]

Net holding volume required = holding capacity required/density of cargo

Gross holding volume required = 1.2 × net holding volume required

Average stacking area required = gross holding volume required/ average stacking height

Average storage area required = 1.4 × average stacking area required

Design storage area = average storage area required × (1 + reserve capacity safety factor/100).

[c] E. Page, *Queueing Theory in OR* (London, Butterworths, 1972)

The berth utilization figures used for 2, 3, 4, 5, 6, 7, 8, 9 and 10 berths were .50, .53, .60, 62, .65, .68, 69. and 70 respectively.

[g] The factor is 1 0 plus the average waiting time of ships in the queue $M/E_2/n$ (in units of average service time), as given in table VIII. This total time includes both berth time and queueing time.

[h] The number of times contents of store are turned over during one year is equal to 365 divided by the average transit time.

Table VIII

Waiting-time factor. Average waiting time of ships in the queue $M/E_2/n$ expressed in units of average service time

(Random arrivals, Erlang 2-distributed service lime,

Utilization	Number of berthing points														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.30	.32	.08	03	.02	01		—				—	—			
u.31	.34	.09	03	.02	01		—			—		—	—		
0.32	.35	.09	.03	.02	.01		—				—	—			
0.33	.36	.09	.04	.02	01		—		—			—			
0.34	.37	.10	.04	.02	.01	.01	—			—		—			
0.35	.39	.11	.04	.02	.01	.01	—				—	—			
0.36	41	.11	.04	.03	.02	.01	—				—	—			
0.37	.43	12	.05	.03	.02	.01	—					—		—	
0.38	.44	.13	.05	03	.02	.01	.01					—		—	
0.39	.46	.13	05	03	.02	.01	01					—			
0.40	.48	14	.06	.03	.02	.01	.01				—	—			—
0.41	.50	.15	.06	.03	.02	.01	.01				—	—			
042	.52	.16	.06	04	02	.02	.01	.01			—	—			
0.43	.54	.16	.07	.04	.02	.02	.01	01				—			
0.44	.56	.17	.07	.04	.03	.02	.01	.01				—	—		—
0.45	.59	.18	08	.04	.03	.02	.01	.01			—	—			
0.46	.61	.19	.08	.05	.03	.02	.02	01	.01			—		—	
0.47	.64	.20	.09	.05	.03	.02	.02	.01	.01			—	—		
0.48	.66	.21	.09	.05	.04	03	.02	01	.01			—			
0.49	.69	.23	.10	.06	.04	03	.02	.01	.01	.01		—			
0.50	.72	24	.11	.06	.04	03	.02	.01	.01	.01		—			
0.51	.74	25	.12	107	.04	.03	02	.02	.01	.01	01	—		—	
0.52	.78	26	.13	.07	05	.03	02	.02	.01	.01	.01	—		—	
0.53	.81	.28	.13	08	05	.04	.03	.02	.01	.01	.01			—	
054	.84	.29	.14	.08	.05	.04	.03	.02	.01	.01	.01	.01			
a.55	.88	.31	.15	.09	.06	.04	.03	.02	.02	.01	.01	.01			
0.56	.91	33	.16	.10	.06	.05	.03	.02	.02	.01	.01	.01	.01		—
0.57	.95	.35	.17	.11	.07	.05	.04	03	.02	.02	.01	.01	.01		
058	1.00	.37	.18	11	.07	05	.04	03	.02	.02	.01	.01	.01	.01	
0.59	1.04	.39	.19	.12	.08	.06	.04	.03	.02	.02	.02	.01	.01	.01	
0.60	1.08	.42	.20	13	.08	.06	05	04	.03	.02	.02	.01	.01	.01	.01
0.61	1 13	.44	.22	.14	.09	.07	.05	.04	.03	.02	.02	.02	.01	.01	.01
0.62	1.18	.47	.23	.15	10	07	.06	.04	.03	.03	.02	.02	.01	.01	.01
0.63	1.23	.49	.25	.16	.11	.08	.06	.05	.03	.03	.02	.02	.02	.01	.01
064	1.29	.51	.27	.17	12	.09	.07	.05	.04	.03	.03	.02	.02	.01	.01
0.65	1.34	.53	.29	.19	12	.09	.07	.05	04	.04	.03	.02	.02	.02	.01
0.66	1.40	.60	.31	.20	13	.10	.08	.06	.05	.04	.03	.03	.02	.02	.02
0.67	1.48	.63	33	.22	.14	.11	.09	.06	.05	.04	.04	03	.02	.02	.02
0.68	1.55	.66	.36	.23	.16	.12	.09	.07	.06	.05	.04	.03	.03	.02	.02
0.69	1.62	70	.38	.25	.17	.13	.10	.08	.06	.05	.04	.03	.03	.03	02
0.70	1.70	.72	.42	.27	.19	.14	.11	09	.07	.06	.05	.04	.03	.03	.03
0.71	1.80	.78	.44	.29	.20	.15	.12	.10	.08	.07	.06	.04	.04	.03	.03
0.72	1.90	.83	.48	.31	.22	.17	.13	.11	.08	.07	.06	.04	.04	.04	.03
0.73	1.99	.87	.51	.34	.24	.18	.14	.12	.09	.08	.07	.05	.05	.04	04
0.74	2.08	.93	.54	.36	.26	.20	.16	.13	.10	.09	.08	.05	.05	.05	.04
0.75	2.X	1.00	.59	.39	.28	.22	.17	14	.11	.10	.09	.06	.06	.05	.05
0.76	2.31	1.08	.63	.42	.30	.24	.19	.15	.13	.11	.09	.07	.07	.06	.06
0.77	2.46	1.16	.68	45	.33	.26	.21	.17	.14	.12	.11	.09	.08	.07	07
0.78	2.59	1.23	.73	.49	.36	.28	.23	.19	.16	.13	.12	.10	.09	.08	.07
0.79	2.75	1.30	.79	.53	.40	.31	25	.21	.17	.15	.13	.11	.10	.09	08
0.80	2.95	.140	.84	.57	.43	.34	27	.22	.19	.17	.15	.13	.11	.10	.09
0.81	3.17	.150	.92	.63	.47	.38	.30	.24	.21	.19	.16	.14	.12	.11	.10
0.82	3.45	1.70	.98	.68	.52	.42	.34	.27	.23	.21	.18	.16	.14	.12	.11
0.83	3.75	1.85	1.08	.74	.57	.47	.38	.31	.26	.23	.20	.18	.15	.14	.13
0.84	4.10	1.90	1.16	.81	.64	SO	.42	.34	.29	.26	.22	.20	.17	.16	.15
0.85	4.40	2.05	1.28	.90	.70	.56	.46	.38	.32	.29	.25	.22	.19	.18	.16
0.86	4.75	2.20	1.40	.98	.76	.61	.51	.42	36	32	.28	.25	.22	.20	.18
0.87	5.20	2.40	1 52	1.07	.84	.67	56	.47	40	35	.31	.28	.25	.23	.20
0.88	5 60	2.60	1.68	1.16	.92	75	.63	.52	.45	.39	.35	.31	28	.26	.24
0.89	6.10	2 85	1 83	1.29	1.01	.83	.70	58	.50	.44	.40	.36	.32	.29	.27
0.90	6.60	3.20	2.00	1.43	1.12	.92	.76	.64	.56	.49	.44	.40	.36	.33	.30

Source: Calculated by the UNCTAD secretariat.

FIGURE IV

Comparison of Erlang 1 and Erlang 2 distributions for an average vessel service time of five days

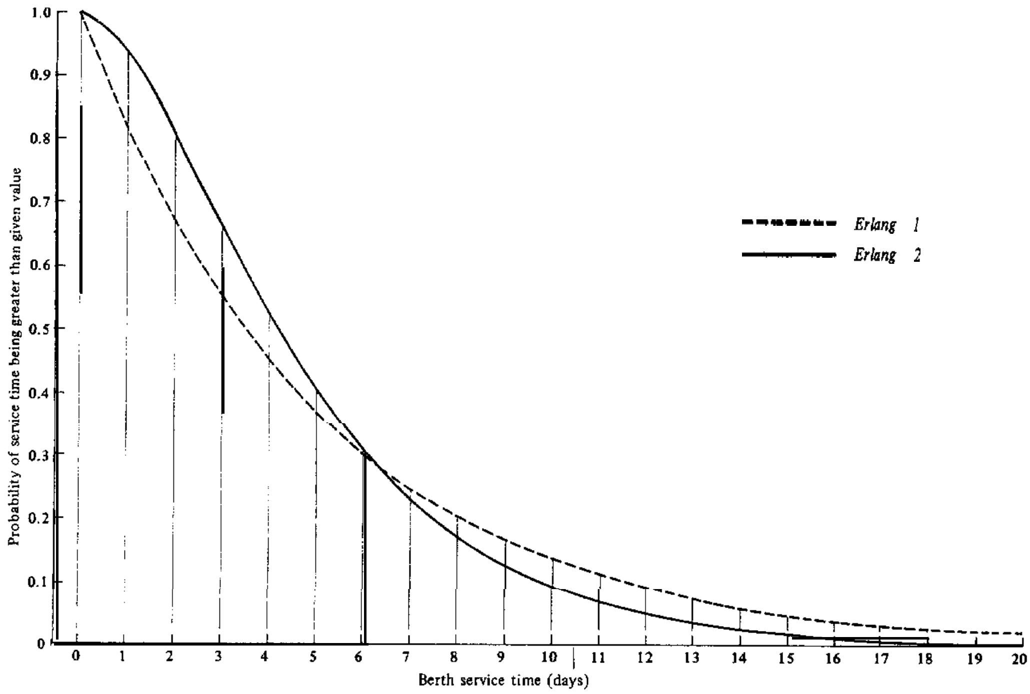


TABLE IX

Average waiting time of ships in the queue $E_2/E_2/n$

(In units of average service rime)

Utilization	*Number of berthing points* 1	2	3	4	5	6	7	8
0.10	.02	0	0	0	0	0	0	0
0.15	.03	.01	0	0	0	0	0	0
0.20	.06	.01	0	0	0	0	0	0
0.25	.09	.02	.01	0	0	0	0	0
0.30 ...	13	.02	.01	0	0		0	0
0.35	.17	.03	.02	.01	0		0	0
0.40	.24	.06	.02	.01	0		0	0
0.45	.30	09	.04	.02	.01	.01	0	0
0.50	.39	.12	.05	.03	.01	.01	.01	0
055	.49	.16	.07	.04	.02	.02	.02	.01
0.60	.63	.22	.11	.06	.04	.03	.02	.01
0.65	.80	.30	.16	.09	.06	.05	.03	.02
0.70	1.04	.41	.23	.14	.10	07	.05	.04
0.75	1.38	.58	.32	.21	.14	11	.08	.07
0.80	1.87	.83	.46	.33	.23	.19	.14	.12
0.85	2.80	1.30	.75	.55	.39	.34	.26	.22
0.90	4.36	2.00	1.20	.92	.65	.57	.44	.40

Source: E. Page, *Queueing Theory in OR* (London, Butterworths, 1972) p. 155.

(d) Container *terminal, planning chart I: container park area*

Holding capacity required (in TEUs) = container movements per year X average transit time/365[i]

Net transit storage requirements = holding capacity required X area requirement per TEU (square metres per TEU)[j]

Gross transit storage area requirements = net transit storage area requirements/ratio of average to maximum stacking height

Container park area = gross transit storage area requirements X (1 + reserve capacity safety factor/100).

(e) *Container terminal, planning chart II. container freight station (CFS) area*

Holding capacity required = CFS container movements per year X average transit time/365[i]

CFS stacking area = holding capacity required X 29[k] average stacking height of general cargo

CFS average storage area = CFS stacking area X (1.0 + access factor)

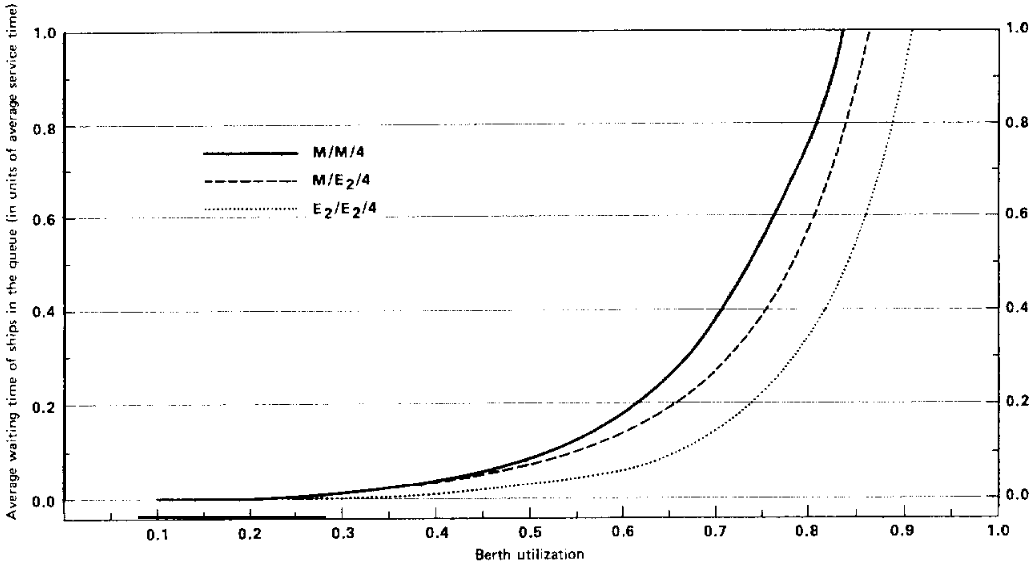
[i] The number of times contents of store are turned over during one year is equal to 365 divided by the average transit time.

[j] Area requirement is dependent on operational method and maximum stacking height

*The cubic capacity of an LSO container of the IC type is 29 m'. The chart assumes that all containers are full.

FIGURE V

Graph showing relationship between average ship waiting time and berth utilization



CFS design storage area = CFS average storage area × (1.0 + reserve capacity safety factor/100[l])

(f) *Container terminal, planning chart III: berth-day requirement*

Units per day per crane = standard ship operating hours per day × average units per hour[m]

Units per day per berth = units per day per crane × gantry-crane factor[n]

Average berth time per ship (in hours) = 24 × average number of moves per ship/units per day per berth + berthing-deberthing delay[o]

Berth-day requirement = average berth time per ship × number of ships per year/24.

(g) *Container terminal, planning chart IV: ship cost*

Berth-day requirement per berth = berth-day requirement/number of berths

Berth utilization = berth-day requirement per berth/commission days per year

Ship time at port = 365 × number of berths × berth utilization × waiting time factor[p]

Annual ship cost × ship time at port × average daily ship cost (in port).

(h) *Dry bulk cargo terminal, planning chart I: berth time*

Ship-loader (unloader) effective capacity (tons per hour) = ship-loader (unloader) rated capacity × through ship productivity ratio

Through ship gross loading (unloading) rate = ship-loader (unloader) effective capacity × ship-loader (unloader) berth configuration factor[q]

Through ship net loading (unloading) rate = through ship gross loading (unloading) rate × standard ship operating hours per day/24

Average berth time per ship (in hours) = average shipment size/through ship net loading (unloading) rate + berthing-deberthing delay.[r]

(i) *Dry bulk cargo terminal, planning chart II: ship cost*

Berth-day requirement = average berth time per ship × number of ships per year/24

Berth utilization = berth-day requirement/terminal commission days per year[s]

Ship time at port = 365 × number of berths × berth utilization × waiting-time factor[p]

Annual ship cost = ship time at port × average daily ship cost (in port).

(j) *Dry bulk cargo terminal, planning chart III: stockpile dimensioning*

Maximum height = 0.5 × base × tan α

Maximum cross-sectional area = 0.5 × base × maximum height = 0.25 × base × base × tan α

Cross-sectional area = ratio of stockpile height to maximum height × (2.0 − ratio of stockpile height to maximum height) × maximum cross-sectional area[t]

---

[l] The safety margin factor has been applied both to access area requirements and to stacking area requirements.

[m] Idle time during standard ship operating hours per day is included in the units per hour productivity factor.

[n] For one crane a, one berth, factor is 1.0; for two cranes 1.8; and for three cranes 2.4.

[o] A typical berthing-deberthing delay would be 2.0 hours, and this figure has been incorporated in the chart.

[p] The factor is 1.0 plus the average waiting time of ships in the queue $E_2/E_2/n$ (in units of average service time), as given in table VIII.

[q] The factors for 1, 2, 3, 4 and 5 ship-loaders (unloaders) per berth are 1.0, 1.75, 2.25, 2.60 and 2.85 respectively.

[r] A typical berthing-deberthing delay would be 2.0 hours and this figure has been incorporated in the chart.

[s] A terminal with two berthing locations each able to berth ships 300 days of the year would have 600 terminal commission days per year.

[t] This formula is derived as follows:

α = angle of repose
h = height of stockpile
b = base of stockpile
h_{max} = maximum height stockpile can attain
r = ratio of h to h_{max}
A = cross-sectional area of stockpile
A_{max} = maximum cross-sectional area of stockpile

The cross-sectional area of the stockpile is given by

$$A = (b - h \cot \alpha)h \text{ or } A = (b - rh_{max} \cot \alpha) rh_{max}$$

Substituting $0.5\, b \tan \alpha$ for the first h_{max} term gives:

$$A = (b - r(0.5\, b \tan \alpha) \cot \alpha) rh_{max} = r(2-r)\, 0.5\, bh_{max}$$

But

$$A_{max} = 0.5\, bh_{max}$$

Therefore

$$A = r(2-r) A_{max}$$

Volume = cross-sectional area × length

Capacity (in tons) = volume/stowage factor.

(k) *Ro/ro terminal planning chart: vehicle storage area*

Vehicle holding capacity required = vehicle movements per year × average transit time/365

Vehicle parking area = vehicle holding capacity required × area requirement per vehicle

Vehicle parking and access area = vehicle parking area × (1.0 + access factor)

Vehicle storage area = vehicle parking and access area × (1.0 + reserve capacity safety factor/100.0).

F. Economic life calculation

31. To determine the economic life of a piece of equipment requires the calculation of the discounted value of all future costs associated with each replacement policy. In general, the costs to be included are all costs that depend upon the age of the machine. Costs that do not change with the age of the machine such as labour costs and power need not be considered. The costs are incurred over a period of time. and must be discounted to the present in the normal way

32. The assumption is made that costs increase each year for items of equipment that deteriorate because of increased maintenance. For this assumption it can be shown that the following rules for minimizing costs apply:

Rule 1: If the cost of replacing every $n + 1$ years is less than the cost of replacing every n years, the item should not be replaced.

Rule 2: If the cost of replacing every $n + 1$ years is greater than the cost of replacing every n years, the item should be replaced.

The mathematical justification of these rules is as follows.

33. We may take a one-year period and call it i and the costs incurred during that period C_i. We may assume that each cost is paid at the beginning of the period in which it is incurred, that the initial cost of new equipment is A, and that the cost of money is r per period.

34. The discounted value K_n of relevant future costs associated with a policy of replacing equipment after every n years is given by summing the discounted costs for the first piece of equipment with the discounted cost for the second piece of equipment, etc., or, expressed mathematically:

$$K_n = A + C_1 + \frac{C_2}{1+r} + \frac{C_3}{(1+r)^2} + \ldots + \frac{C_n}{(1+r)^{n-1}}$$

$$+ \frac{A + C_1}{(1+r)^n} + \frac{C_2}{(1+r)^{n+1}} + \quad + \frac{C_n}{(1+r)^{2n-1}}$$

$$+$$

which is equivalent to

$$K_n = \left(A + \sum_{i=1}^{n} \frac{C_i}{(1+r)^{i-1}}\right) + \frac{1}{(1+r)^n}\left(A + \sum_{i=1}^{n} \frac{C_i}{(1+r)^{i-1}}\right) + \frac{1}{(1+r)^{2n}}\left(A + \sum_{i=1}^{n} \frac{C_i}{(1+r)^{i-1}}\right) + \ldots$$

The right-hand side of the equation may be written as a product of the common factor and the convergent geometric series."

Therefore

$$K_n = \frac{A + \sum_{i=1}^{n} [C_i/(1+r)^{i-1}]}{1 - [1/(1+r)]^n}$$

If K_n *is less* than K_{n+1}, then replacing the equipment every n years is preferable to replacing every $n + 1$ years. The two inequalities

$$K_{n+1} > K_n \text{ and } K_{n-1} > K_n$$

must hold if the best policy is replacement every n years.

35. A worked example is given in table X for a fork-lift truck. The annual cost shown in the second column would be based on maintenance and operating costs from historic records. The third column shows the discount factors for a rate of interest of 10 per cent, For this example the optimum replacement period or economic life is seven years. This can be determined by examining the last column. The estimated maintenance cost for the yearn + I is used to calculate K_{n+1}. If K_{n+1} is greater than K_n then replacement should take place after n years, which for this example is seven years.

36. The existence of inflation will modify the weights" but the method will remain the same. In addition, if the piece of equipment has a scrap value, the initial cost of new equipment can be reduced accordingly.

"The sum of the series $1+x+x^2+\ldots+x^\infty$ is equal to $1/(1-x)$, when x is less than 1 and positive. In this case x is equal to $1/(1+r)^n$.

[v] X becomes $(1+i)/(1+r)$ where i is the rate of inflation and $X<1$. This assumes that the rate of inflation applies to the maintenance costs as well as to replacement costs.

TABLE X

Example of economic life or replacement period calculation for a fork-lift truck

(A = 25,000, r = 0.10)

Year (i)	*Annual cost* (C_i)	*Discount factor* (X^{i-1})*	C_iX^{i-1}	$A + \Sigma C_iX^{i-1}$	$1 - X^i$	$\frac{A + \Sigma C_iX^{i-1}}{1 - X^i}$
1	2000	1.0000	2000	27000	.0909	297030
2	3000	0.9091	2727	29727	.1736	171238
3	4000	0.8264	3306	33033	.2487	132832
4	5000	0.7513	3757	36790	.3170	116057
5	6000	0.6830	4098	40888	.3791	107855
6	7500	0.6209	4657	45545	.4355	104581
7	9000	0.5645	5081	50626	.4868	103998**
8	11000	0.5132	5645	56271	.5335	105475
9	13000	0.4665	6065	62336	.5759	108241
10	16000	0.4241	6786	69122	.6144	112503

* Discount factors are given by the formula $X^{i-1} = \left(\frac{1}{1+r}\right)^{i-1}$

** Since this figure is the lowest, it indicates that the equipment should be replaced after seven years' use.

Annex III

THE PORT DEVELOPMENT REFERENCE LIBRARY

1. Port authorities with port planning responsibility will require more information than can be provided in a single handbook There is a large body of material available and it will often be difficult for the port authority either to know what publications to select or to procure them in time for the specific planning need that may arise.

2. It is therefore advisable for each such authority to assemble a satisfactory reference library in advance of any specific planning task so that when the time comes the project planners can have quick access to the information. For this purpose. the UNCTAD secretariat has prepared a recommended list of port development reference works, which is reproduced below

3. Thr investment of the very large sums of money involved in port development should be based on the best information available and therefore Justifies the allocation of modest funds to purchase the list given in its entirety It might be advisable for authorities to order the entire list through a large commercial hook agent rather than trying to order books individually.

Recommended list of works on port development

Author	*Title*	*Publisher*
	A. WORKS IN ENGLISH ONLY	
Agnew, J. and Huntley, J.	Container stowage: a practical approach	Container Publications Ltd.. Dover (United Kingdom). 1972
American Association of Port Authorities	Port planning, design and construction: a manual prepared by Standing Committee IV, Construction and Maintenance	American Association of Port Authorities, Washington. (D.C.). 1973
American Society of Civil Engineers	Report on small craft harbors	American Society of Civil Engineers. New York, 1969
American Society of Civil Engineers, Task Committee on Port structure Costs	Port structure costs	American Society of Civil Engineers. New York, 1974
Apple, J. M.	Plant layout and materials handling. 2nd ed	Ronald Press. New York, 1963
Baker, C., ed.	Progress in cargo handling, vol. 6, Changing user requirements	Bowker Publishing Co. Ltd.. Epping (Essex, United Kingdom). 1976
Baud&ire, J. G.	Port administration and planning: general introduction	Delft (Netherlands)
Bird, J.	Seaport gateways of Australia	Oxford University Press, London, 1963
Bird, J.	Seaports and seaport terminals	Hutchinson, London. 1971
Bird. J.	The major seaports of the United Kingdom	Hutchinson, London, 1963
Bown, A. H. J.,	Port economics, 2nd ed., rev by W. A Flere	Dock and Harbour Authority. London. 1967
Boyes, J. R. C.	Containerization International Yearbook	National Magazine Co. Ltd., London
Bruun, P. M.	Port engineering, 2nd ed.	Gulf Publishing Co., Houston (Texas), 1976
Dally, H. K.	"Straddle carrier and container crane evaluation". National Ports Council Bulletin No. 3	National Ports Council, London. 1972
Economist Intelligence Unit	Investment: the growing role of export processing zones	EIU Ltd., Special Report No 64, London. 1979
FAO	Fishery harbour planning	FAO, Rome; Fisheries Technical Paper No. 123
FAO, ed.	Conference on fishing ports and port markets, Bremen, 1968	Fishing News, London, 1970
Fugl-Meyer, H.	The modern port, its facilities and cargo handling problems	Danish Technical Press, Copenhagen. 1957
Glassner, M. I.	Access to the sea for developing landlocked states	Martinus Nijhoff, The Hague, 1970
Hedden. W P.	Mission: port development with case studies	American Association of Port Authorities, Washington. (D.C.), 1967

Author	*Title*	*Publisher*
Hoyle, B. S	The seaports of East Africa: a geographical study	East African Publishing House, Nairobi, 1967
International Cargo Handling Co-ordination Association (ICHCA)	Ro-ro shore and ship ramp characteristics: a survey	ICHCA, London, 1978
Lederer, E. H.	Port terminal operation: port terminal management	Cornell Maritime Press, New York, 1945
Nagorski, B.	Port problems in developing countries: principles of port planning and organization	The International Association of Ports and Harbors, Tokyo, 1972
National Ports Council, United Kingdom	Bulletin No. 9: port perspectives 1976	National Ports Council, London, 1976
National Ports Council, United Kingdom	Equipment evaluation: an examination of the use of fork-lift trucks in the ports	National Ports Council, London, 1973
National Ports Council, United Kingdom	Port structures: an analysis of costs and design of quay walls, locks and transit sheds, vols. I and II	Bertlin and Partners, London, 1970
Oram, R B. and Baker, C. C. R.	The efficient port	Pergamon Press, Oxford, 1971
Rath, E.	Container systems	John Wiley and Sons, New York, 1973
Tabak, H. D.	Cargo containers: their stowage, handling and movement	Cornell Maritime Press, Cambridge (Maryland), 1970
Takel, R. E	Industrial port development. with case studies from South Wales and elsewhere	Scientechnica, Bristol (United Kingdom), 1974
Thoman. R. S	Free ports and foreign trade zones	Cornell Maritime Press, Cambridge (Maryland), 1956
Thomas. R. E	Stowage; the properties and stowage of cargoes, rev. by 0. 0. Thomas, 6th ed.	Brown, Son and Ferguson, Glasgow. 1968
UNIDO	Handbook on export free zones	UNIDO, Vienna; Sales No. UNID01100.31
United Nations	Financial management of ports	United Nations document UNCTAD/SHIP/138
United States Department of Transportation	Guidelines for the physical security of cargo	United States Department of Transportation, 'Washington, (D C.), 1972

B. Works available in several languages

Author	*Title*	*Publisher*
Evans, A. A	Technical and social changes in the world's ports	ILO, Geneva, 1969 (Studies and Reports, New Series, 74)
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