Management of Marine Design

Butterworths

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Preface

The work has been supported by The Royal Norwegian Council of Scientific and Industrial Research, under the supervision of its National Maritime Research Committee/Design Sub Committee. The book has been prepared at the Division of Marine Systems Design in the Department of Marine Technology, The Norwegian Institute of Technology, Trondheim.

The author would like to express his gratitude to The Royal Norwegian Council for Scientific and Industrial Research for its economic support, and the Design Sub-Committee and its Chairman Jacob Irgens for their interest in the work and their valuable comments and discussions at the different stages of preparation.

A preliminary edition was distributed to about 70 persons for comments in June 1986. About 25 returned their copy with comments and corrections. On the basis of these comments a few more topics were included, and some chapters and sections rewritten.

The author is grateful to Harry Benford, Ian L. Buxton, Sverre Johan Dahl, Jac. S. Halvorsen and Horst Nowacki who have gone througgh the preliminary edition page by page and checked language and misprints as well as the professional quality. The same thorough review of parts of the book was made by Bjørn Bogenes, Bernt A. Bremdal, Klaus Dwinger, Olav Eftedal, Per O. Ellefsen, Audun Eriksen, Terje Gløersen, Edvin Hareide, Sv.Aa. Harvald, Jacob Irgens, Per Anton Kleppa, Kristen Knudsen, Willy Reinertsen and Nils Christian Øvrum. Valuable comments have also been received from Odd Aanderud-Larsen, J. Banning, Per Olav Brett, Einar Corwin, Kristian Haslum, Erik Heirung, L. K. Kupras, Atle Minsaas, Sverre Møller, Jan-Erik Wahl and Harald Aa. Walderhaug. Their pertinent and valuable corrections, critisism and suggestions have been an important support and guidance for the author.

It is hoped that those who have spent time on the preliminary edition will find that their contributions have been correctly understood and properly used. Responsibility for the end result is the author's, but that for the form of the work is shared with the many who responded so positively to the preliminary edition.

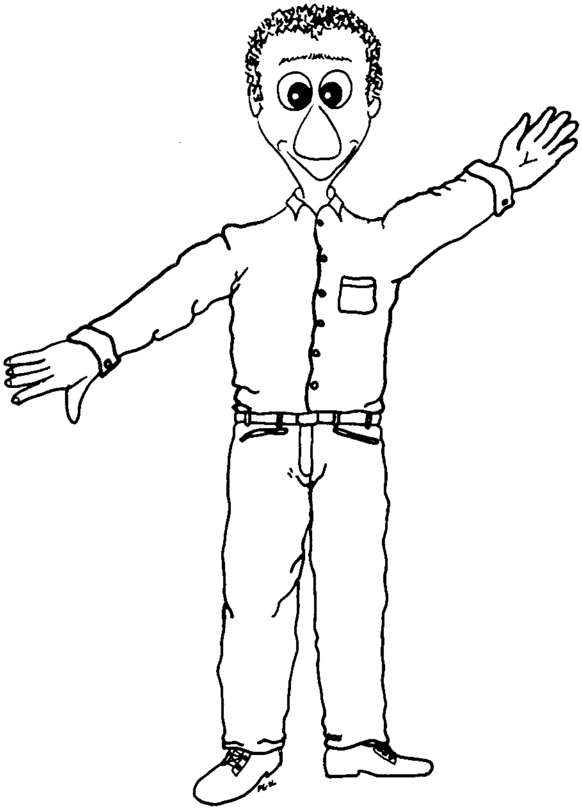
Much assistance and encouragement have been received from my students Arild Jaeger, Torstein Evensen and Per Lillejordet. Jaeger co-ordinated assistance received from others and also made valuable suggestions as to the structure of the book and provided some examples. Evensen and Lillejordet prepared many of the drawings. The typing has been done by Eva Hansen. A great thank you is owed to all these people for their valuable assistance.

Stian Erichsen

Contents

1

INTRODUCTION



'Design is the essence of engineering' said Ian Buxton in a comment on the preliminary draft of this book. Although much good engineering work is done to keep things going, Buxton is undoubtedly right. It is when we create something new, such as a ship, a mechanical device, or an organization, or find a solution to a difficult problem, both of which are part of the design process, that we feel more like engineers than at any other time.

Nothing is like the feeling of pride when a design has been successful, and nothing is like the feeling of despair when the design has turned out to be a failure.

This book is based on the view that the success of a design is, to a large extent, dependent on good communication with the clients, good cooperation between designers and other personnel and on access to relevant and correct information.

The purpose of this book is to provide design engineers with guidance to help them undertake marine designs. Readers are assumed to have already completed their basic education and to be familiar with the technology of ships and mobile offshore platforms.

The book addresses itself to three phases of a design task:

- Organization.
- Execution.
- Presentation of the results.

Each item will be considered with the view in mind that design is based on decision making and that decision making must be based on relevant information.

We begin at the point where the decision to go ahead with the design work, whether comprehensive or simple, has been made. Therefore, evaluation of the market and available resources are not discussed in depth. However, a brief review and a few examples of market research and designing for a market are included in Chapters 17, 18 and 19. It is also assumed that the general aim of the design work, be it to provide plans for a marine transport system, marine drilling platform or other type of marine structure, has been defined.

This book is intended as a guide for designers carrying out comprehensive designs. However, many design tasks will be relatively simple and will not require a great deal of analysis. In those cases some of the recommended procedures and checks may seem too detailed. They can be omitted if they seem unnecessary in the circumstances. However, you should check all the items listed in this book for a given design task and note down the reasons for omitting any item in your design. This procedure can form part of your quality assurance system.

Design should follow a task-oriented strategy and sequence. This book is not intended to provide a strict framework for design. You may find it makes more sense in your case to use a different sequence for your design from that recommended here. However, when departing from the sequence of the book, note down your reasons for doing so. This can form another part of your quality assurance system.

Finally, a few words of caution: the success of a design is, in some respects, dependent on its superiority over competing solutions. Superiority is frequently achieved by finding new and better solutions. Good designers take this into account. They have an open mind for improvements and always question the plausibility of any solution. The importance of this attitude is stressed in this book. But remember that this book only provides a framework for design. If you rely on this framework, you may develop a false feeling of security and your critical sense and awareness of new ideas may be reduced.

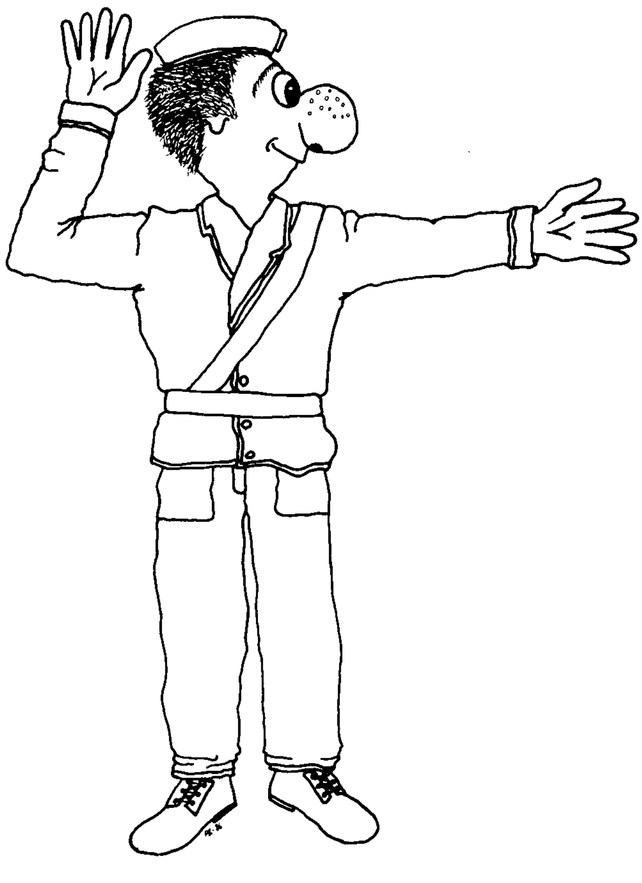
This book should be used as a *design aid*. Readers should act as good designers and should question all rules, methods and procedures before they accept them. They should aim to clarify:

- Whether any rule or method is applicable to the situation at hand.
- Whether new methods have been developed since this book was written.
- What has been the result of using the rule or method in question.

When you have made a decision as to which procedure or rule to apply, spend a minute or two writing down the background and reasons for your decision. This should form part of your documentation system. If you always write down the reasons for the different decisions that you make, you will be able to look back to any earlier stage in the design process. This is very helpful in cases where you feel that your work has diverged from your original intention or when the initial assumptions have to be changed for some reason. These situations frequently occur in the course of a design.

2

ORGANIZING DESIGN WORK



2.1 ORGANIZE FOR FLEXIBILITY

Organizing for flexibility is of great importance when planning a design job because conditions may change as the work progresses: new information may come to light or the original assumptions may be changed.

This book contains many recommendations. Use them to support flexibility, for example to check that your design problems have been dealt with as thoroughly as possible under the circumstances and to stimulate your thinking. Do *not* use the recommendations as a set of directives to take you safely through the design process and relieve you of the obligation to make your own decisions. Adapt the rules to your situation. Do *not* assume that a strict adherence to the rules in this book, or any other rules, will guarantee a good solution. Use your imagination and creativity when applying the rules.

An actual design job may vary from calculating the main particulars of a ship during a short telephone conversation to developing a large integrated transport system which may require continuous effort on the part of many people over several years. Correspondingly, the amount and subsequent organization of the design may vary within wide limits.

In this context, organization is interpreted as the setting up of information flow, the authorization of responsibility, the chain of command for making decisions and the allocation of personnel and other resources for the design work. It is assumed that the responsibility for establishing an organization rests with those who are responsible for developing the design. In some companies this does not occur. In these companies the designers should require the management to take the necessary steps to organize the design work properly.

When organizing a design job it is first necessary to clarify:

- The key problems to be solved.
- The scope of the design.
- The extent to which the design may restrict the company or the clients.
- The resources available.
- Other information needed to judge the type of organization required.

Designers have the responsibility of setting up the organization on the basis of information derived from their management. This means that designers and management must discuss and clarify the objectives at the outset of the design work. Their dialogue should concentrate on the five points mentioned above and they should create an agreed basis for organizing the design work.

Anyone who takes the initiative to begin a design will have an understanding of what is the *key problem*. For example, the existing ships may be too small, or perhaps too old, or the time needed to load and unload them may be much too long. In addition, information that makes it necessary to reformulate the key problem may arise during the course of the design. In all cases, it is necessary to begin with a statement of the key problem. This statement should serve as a basis for dialogue.

The *scope* of a design is an expression of what it may involve. *Liability* should also be of concern to designers because some designs may become a basis for binding contracts. Liability and the scope of the design are discussed in Section 2.3.

The work laid down in a design job must be adjusted with regard to what is *available* in terms of time, manpower and test facilities and to what can be *afforded* in relation to obtainable gains.

Design work should begin with a review and discussion of these points. An organization should be established on the basis of this discussion. For small design tasks a trained designer can make this review in a few minutes. It may take much longer to cover the points in sufficient depth when the task is large and involves many people and departments. In summary, creating a design starts with a review of the problem, the conditions of the design, the available resources and a decision as to how the work should be organized.

For *large projects* it may be best to divide authority and responsibility between:

- A steering committee
- A project group and
- A reference group.

The steering committee authorizes changes in design conditions, checks the progress at certain intervals and makes intermediate and final approval of the designs. The project group carries out the design work. The reference group is an expert advisory body. In the discussion which follows, the management is assumed to act as a steering committee and in-house experts or external consultants are assumed to act as reference groups.

2.1.1 Designer – user relations

In order to clarify the tasks and who is responsible for carrying them out it may be advantageous to consider organizing the project based on the assumption that there will be a team of one or more users who will specify the *user's requirements* and a team of designers who will carry out the design work. Referring to the preceding section the steering committee would represent the users and the designers would be the project group.

It is very important to understand that a set of user's requirements should not be, and seldom are, handed down to a team of designers who then carry out the design work without first reflecting on the task. The user's requirements should be worked out in conjunction with the designers; the original requirements can be taken as a starting point. *Upgrades* and adjustments should be made at planned meetings as the work progresses, the designers gain insight into the problem and the scope for the solutions widens up.

The project group and the steering committee thus have to be in close contact during the design phase. The project group should carry out all work necessary in connection with the design process and the steering committee should act as the approving body which makes decisions that are too important to be made by the project group alone.

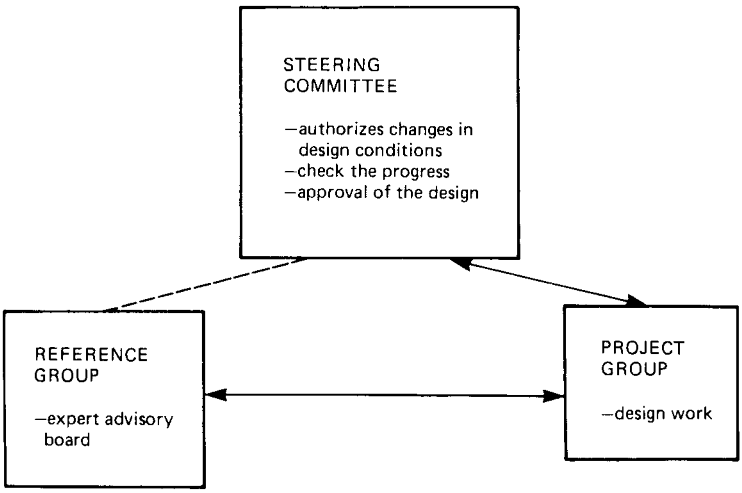


Figure 2.1 A schematic illustration of the allocation of responsibility and the organization of work for design

In many cases independent consultants may be engaged to undertake the design work. The consultants must ensure that a joint project group is established in collaboration with their clients and that the different tasks related to the design work are shared between the members of the group based on their knowledge, experience, and daily work. There should be no distinction between group members employed by the client and group members who are consultants hired for the job.

2.2 DESIGN LOG BOOK

The design work should be documented by drawings, specifications, written recommendations and cost-benefit analyses. Many decisions are made between the start and completion of a project. A lot of information is collected and many alternatives are, perhaps, scrapped. Therefore, with the aid of a computer, it is advantageous to keep an account of:

- The reasons for all major decisions.
- Files of all important information.
- The status of scrapped alternatives.

These records will make it possible to retrace steps and reconsider decisions. A handwritten journal may also be used. An example of such a journal is shown below:

Decision	*Reason*
Base the anti-icing system of the floating production platform, PPP, on steam produced by burning excess gas.	1. The field has gas that otherwise will be burnt off. Report F-27 of 03.07.83. 2. The excess gas will last for at least 5 years. Keywords: Excess gas, Change field. Report F-27/83.
Restrict the beam to 31.45 m	The vessel will have to call at the Kopra Bridge Pass at least once a year. Trans-shipment to the quay outside the bridge pass is not accepted by the customer, Faxifex Ltd. The cargo from the customer generates a revenue of $150 000 per year. Report Oper 33 of 06.08.85. Keywords: Faxifex, Kopra bridge pass, Revenue, Report Oper 33/85.

2.3 THE IMPORTANCE OF THE DESIGN TASK AND THE EXPERTISE REQUIRED

It is important to have a fairly accurate notion of the requirements of a design in order to decide what expertise will be needed to do the job. Some design problems may be solved by personnel in the existing organization. Some design tasks will require a special team or, possibly, a large independent organization to do the job.

The requirement for expertise will be discussed in terms of the purpose of the design task. Some typical situations are assumed. These range from producing a reaction to an incidental inquiry to developing a completely new solution for a market. The demand for expertise is discussed without any reference to manning. Manning is dependent on different factors which will be discussed in Section 2.4.

It is important that one person be given the responsibility of specifying the expertise needed and ensuring that the requirement is met. This responsibility is probably best left to the person in charge of the design project, for example, the head of the project group.

The requirement for expertise will be discussed in a general way below under the assumption that it may be either the buyer or the seller who creates the design. The cases are based on situations in marine industries, but they are of a general nature. Typical situations are described below.

2.3.1 Answering or producing an incidental inquiry

The situation. No obligation is taken on. There is no need to be very precise. The answer must reflect the standard of the company in terms of both design and finished product when the design may lead to delivery of one or more products.

Solution. Produce a routine solution based on internal knowledge and insight. Do not spend too much time on the inquiry.

2.3.2 Giving examples of possible deliveries

Requirements. It is important to indicate clearly what the company can do (if you are a seller) or *wants* (if you are a buyer) . The specifications used in the example may set the standard for later *deliveries* or *purchases*.

Conclusion. Produce a routine solution. Make sure that steps are taken to ensure that the solution represents a realistic example of the quality and cost of the company's deliveries or purchases. Your name represents a certain level of quality which should be reflected in your design.

2.3.3 The basis for early negotiations

Requirements. It is important to define clearly all functional requirements and performance standards, standards of quality, what should be included in the delivery as well as deadlines and terms of delivery. It is important to base these definitions on both your own experience and on the customer's demands.

Conclusion. It is necessary to ensure that:

- Required or offered performance is based on a realistic evaluation of the demands.
- The customer's present and future needs are taken care of.
- Previous experience is taken into account.
- The costs and benefits of the alternative solutions are clearly documented.
- Performances, capacity and quality are described by *numbers* or by direct references to known vessels, rather than phrases.
- Test procedures to verify performances, capacities and the like are clearly specified.
- Reference is made to the proper regulatory bodies, such as national authorities and classification societies and that international rules and regulations are noted. The need for certificates should be foreseen.

2.3.4 The basis for a binding contract

Requirement. It is important to have all items and specifications which are included in the solution clearly defined. Numbers should be used in the definitions whenever possible. The seller (the party which makes the delivery) must know the cost of all items and functions included in the solution. He must also know the capacity demanded of the design. Reference should be made to the proper regulatory bodies and certificates as mentioned in Section 2.3.3. Contract specification is discussed further in Chapter 16.

Conclusion. The design team must have information about the following items before beginning the project:

- The items mentioned in Section 2.3.3.
- Performance and cost of similar designs.
- The interrelation between performance and cost and quality and cost.
- Subcontractors and their range of deliveries.
- Price fluctuations.
- Fluctuations in the rate of exchange.
- Detailed technical solutions.
- Present and future rules and regulations of classification societies, national and international authorities and other regulatory bodies.
- Customer's preferences.
- Production systems and costs.

2.3.5 Developing a replacement of an existing object

Requirement. It is important to avoid producing a copy of an existing object without considering the options. The customer's feelings about the existing solution should be investigated in order to identify potential improvements. It is important to investigate how well existing solutions are adapted to physical constraints, rules and regulations in order to see whether there may be solutions that can earn more and cost less but which are still within the applicable restrictions.

Competitors' solutions should be studied in order to obtain a realistic view of the level and type of competition. Technical developments should be investigated to see if improvements have been or could be developed to improve your solution.

The existing and *forthcoming* rules and regulations of different countries and certifying bodies should be studied to make sure they are adhered to in your design.

An estimate of the likely future trend of service demand and market share should be established based on a study of developments in the past.

Conclusion. It is necessary to have a design capability which includes:

- A very good insight into past performance and experience.
- Close contact with users.
- Insight into the development of demand.
- Expert knowledge of new products, concepts and technology with regard to technique, cooperation with other parties and business arrangements.
- Expert knowledge of how the design solution must fit into existing systems and how an optimal adaptation may be obtained.
- A thorough knowledge of existing and future rules and regulations.
- Expert insight into the development of market demands.
- Design expertise, including expert knowledge of design tactics, idea generating methods and solution synthesizing.

2.3.6 Exploring or developing new ways of doing things

Requirement. This type of design task is in the exploration category. It is frequently the forerunner of a more formal design. It concentrates on concept development and evaluation, without producing any kind of detailed design. It can serve to reveal areas where further investigations and development are necessary.

The purpose of this task is to find new concepts. This may include new ways of *using* an existing object or organization, a new *design* for an object or organization, or some combination of both. This exercise may also be carried out in order to see what solutions would be appropriate in a new market. The expertise required is mainly in the areas of idea generation, exploration of new possibilities and concept development and evaluation.

Insight into market developments, customer's needs and existing and future rules and regulations is necessary. Knowledge of *existing solutions* may be both an advantage and a disadvantage. It is an advantage because if you know which problems have already been dealt with you will not spend more time working on them. On the other hand, a thorough knowledge of the existing solutions may influence your thinking and prevent you from coming up with new ideas. Sometimes it is a good rule to try to forget the existing solutions, at least in some stages of the design.

On the other hand, knowledge of the surrounding world in general can be very useful. This knowledge stimulates the generation of ideas, draws attention to what other people are doing and opens the mind to combinations that otherwise would not have been thought of.

Conclusion. It is necessary to have competence in and capacity for:

- Idea generation and innovation.
- Concept development.
- Collecting background information.
- The items outlined in Section 2.3.5.

2.3.7 Exploring the possibilities for new markets

Requirement. It is necessary to be able to carry out a systematic review of possible markets and market requirements, present a systematic overview and store background information for early retrieval. This is discussed in Chapter 17.

A review of the resources you can provide for a new project is also necessary in order to give the project group an idea of any limiting factors, such as limitations in investments, manpower or competence, which may affect the project. It is very important for the project manager to be clearly informed of any limitations. In addition, competence in idea generation, concept development and market forecasts are required as discussed in Sections 2.3.5 and 2.3.6.

Conclusion. You must have the capacity and competence to provide:

- A thorough and systematic review of interesting markets or market segments.
- A systematic review and record of resources available for a project.

2.4 ESTABLISHING AN ORGANIZATION FOR A PARTICULAR DESIGN TASK

The factors which influence the establishment of a design organization and factors which must be clarified when the organization is established are discussed in this section.

The size of the design team may vary from a single individual who works part-time on a design to many hundreds of people who work full-time on a very large project such as

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the design of an offshore oil installation. However, the majority of design organizations are small. When you read the material below keep this in mind and remember that not all design projects require a large bureaucratic organization.

Factors which influence the organization of a design project include:

- The nature of the design task.
- The available resources.
- The existing company organization.
- The need for expertise.

It is crucial to satisfy the demand for expertise. If this is not met, the design may be a failure. It is a sound practice to develop expertise within your own company. The project group should carefully and critically evaluate the need for expertise at all stages of the project and plan how this demand will be met.

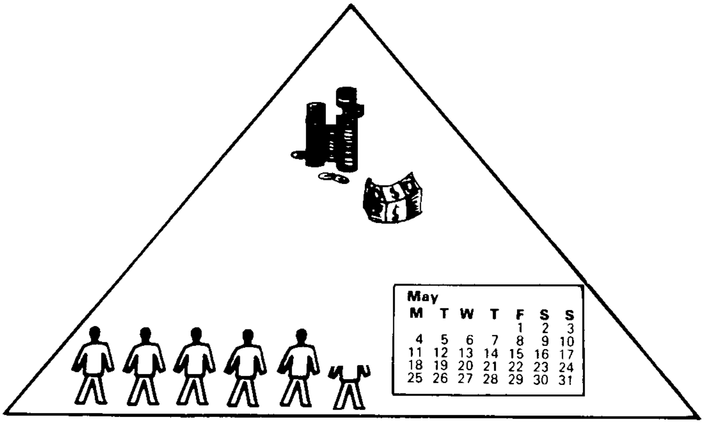

Figure 2.2 A reminder of the fact that also the design itself requires resources; manpower, money and time, and in addition supporting functions

2.4.1 Preparing a design budget

Personnel with specialist knowlege or management experience are the critical resource in a design project. They are a limited resource because they may have other important duties within the company or because they are expensive to hire and difficult to find outside of the company. This must be taken into account when allocating personnel to a design project.

Money and time are also important requirements. Money is needed for travelling and buying information. A certain amount of time is needed to get the job done.

The importance of the design task should be reviewed as discussed in Section 2.3. A budget should be prepared which takes account of both the expertise needed and the resources available. The budget should contain the following:

- The deadline for the completion of the project.
- The type of personnel needed, the number of man hours required and the corresponding internal costs.
- The percentage of working time that individuals not employed by the design department should spend on the design project.
- Time lost due to travel, vacations and holidays.
- A deadline for the start of the design work.
- Money available for:

(a) external experts
(b) travel
(c) information purchase
(d) the use of computers and other design aids
(e) telex, telephone and other communications costs
(f) producing documentation
(g) secretarial and other office services.

A budget containing these elements should be presented to management for approval before the design task is started. Even when a design solution is expected within an hour or so, it is a good idea to check the points listed above before starting the job. The check will clarify who is going to do the job, whom you should make contact with, which design aids to use and where to find relevant information. This extra time spent at the beginning of the job will be easily regained through greater efficiency in the design work itself.

The next section gives an example of how a demand for expertise may be satisfied and what this would require in terms of manpower, time and money.

2.4.2 Satisfying the demand for expertise

The same person may deal with many different tasks and provide a great variety of expertise either on his own or through contacts obtained in his daily work. In any company, design expertise may also be provided by employees who join the design team for a limited period, either by working directly on the design problems, or by participating in reference groups or review boards.

Depending on the task, the design should be carried out by a core of permanent staff who have the opportunity to ask for information and expert advice from specialists both inside and outside the company. Specialists within the company must be given enough time off from their normal duties to allow them to pay sufficient attention to their consultation work on the design project. It is sound practice to develop expertise within the company, but at all stages the project group should carefully and critically evaluate the need for expertise and be free to hire experts from outside as necessary. This should be taken into account when the design budget is prepared.

The example below demonstrates how to budget for design expertise to produce an outline specification for an open type bulk carrier replacement. It should take a design engineer or project leader 30 to 60 minutes to fill in the form shown below, including the time needed for short telephone conversations with the people involved in the project. The completed form should then be presented to the management for approval.

2.4.2.1 Example: mobilizing expertise for a design task

This example is based on a design for a replacement. However, the questions dealt with are also relevant for other design projects. The example form shown here can be used when organizing the design work, as well as when the organization is already set up.

Information required	*Provided by*	*Time and money budget*
1. Performance of existing vessels:		
a) Fuel economy, manning, port operations, speed, etc.	Hans Kristensen, Ship and semi-sub management department	Total 2 hours

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Information required	*Provided by*	*Time and money budget*
b) Customers' preferences, size of shipments, frequency of call, treatment of cargo, duration of contracts, others.	Kristian Nilsen Traffic dept.	Total 4 hours
2. Sources of information:		
a) Customers' estimate	Kristian Nilsen	5 hours during 1 week
b) Own traffic department,		
c) Brokers' forecasts		
3. Other developments:		
a) Technique	Nils Kristiansen Others	Total 10 hours Total 30 hours
Fuel Skin friction Maintenance Communication Cargo handling & packing Mooring	Design department External specialists	Nkr 15 000 in fees
b) Integrated transport Railways Port Authorities Lighter Co. Cargo owners Shippers Stevedores	Kristian Nilsen	40 hours(one week) Travel expenses Nkr 25 000
c) Business arrangements	A. Hafa Financial department	4 hours
Joint ownership Foreign crew Bareboat arrangements Long time contracts Pooling		
4. Adaptation to existing systems: Covered under Integrated transport, 3(b)		
5. Existing and future rules and regulations:		
Classification societies National authorities Port authorities	Nils Kristiansen Others	14 hours(Coordinator) 30 hours
International authorities US Coast Guard Australian Seaboard	External Consultants Telex etc.	Nkr 15 000 in fees Nkr 2 000
6. Design coordination and leadership:	Nils K. Stinesen Design department	90% of time for two weeks

Summary of Costs:
Personnel engaged:

In house:	
Hans Kristensen	2 hours less than 5% of time
Kristian Nilsen	49 hours, 100% of time first week 23% of time second week
Nils Kristiansen	24 hours, 30% of time, two weeks
A. Hafa	4 hours, 5% of time, two weeks
N.K. Stinesen	72 hours, 90% of time, two weeks
Total in house:	151 hours over two weeks <u>Cost Nkr 75 500</u>
External:	
60 hours	Nkr 30 000
Travel	Nkr 25 000
Telex etc.	Nkr 2 000
Sub total	Nkr 132 000
Secretarial assistance etc. 40%	Nkr 53 000
Total cost (budget)	<u>Nkr 185 500</u>

Notes:
Kristian Nilsen, Nils Kristiansen, N.K. Stinesen, must be relieved of 64, 30 and 90% of their daily duties, respectively, during weeks nine and ten. All three to be warned that winter vacation has to be postponed to week 11 or, preferably, week 12.

Reference Group:
Department heads:
Running and Maintenance
Traffic
Finance
Design and Newbuilding

Reviews:
At the outset, to clarify scope
After 1 day, to check intention
After 2 days, to check progress and resources utilization
After 5 days, to check progress and information basis
After 9 days, to make final adjustments
After 10 days, for approval
Allocated time: 15–60 minutes for each review

Approval of set up:

Kakaska, February 10th, 1984 Esp Espesen.

2.4.3 Rules for establishing design teams

A design team has to produce a concrete solution in a limited period of time. A variety of knowledge and experiences must be used in or by the team in order to arrive at a good result. This can make it difficult to establish good cooperation within the team. Therefore, a few points related to team work should be taken into consideration when setting up a design team. These points are discussed below.

2.4.3.1 The project leader

A specific member of the group must be assigned the job of project leader. His responsibility will be to ensure that:

- The design project is properly carried out and the key problems are solved.
- The resources are used correctly and within given limits.
- The project is completed within the given deadline.

The project leader should have the authority to make use of the time of people belonging to any department within the company so long as he stays within the limits of his budget.

2.4.3.2 The relationship between the steering committee and the reference group

The following should be made clear:

- How and at which stages the reference group will be consulted.
- How the progress and results of the project will be reported to the steering committee (the management).
- How approval will be obtained from the steering committee.
- How the steering committee will communicate with the project group.

2.4.3.3 The design objective

The design objective or key problem and design boundaries and restrictions as seen at the beginning of the project should be clearly defined, if possible by exact quantities, and made known to all members of the project group.

2.4.3.4 Handling restrictions and conditions on the design

The design objective, boundaries and restrictions may be too narrowly defined to make development of a good solution possible. How the design team will work in relation to these limitations should be clearly defined.

The success of a design depends partly on how well the design conditions are understood and used. Success is a question of finding the best possible solution under the given conditions and restrictions. In some cases it is necessary to negotiate the interpretation of these restrictions with classification societies, national and international authorities and, perhaps, with the clients. It is important that this negotiation is done in a professional manner. The people who carry out this task must be chosen with care. A procedure for reporting the results of the work to the steering committee should also be established. The contents of the reports and their conclusions should be entered in the design log book.

In most cases it is worthwhile using the form in Figure 2.3 to allocate the responsibility for investigating the design conditions proposing solutions and, if necessary, negotiating interpretations.

Investigating the design parameters means to collect the text of the relevant laws, regulations, port restrictions and similar documents along with their latest revisions and to find out the common practice for adhering to them.

Proposing solutions means to evaluate the laws and judge whether their effect in common practice seems reasonable. The aim is to develop and propose better solutions.

Negotiating terms means to take your own interpretations and suggestions to the relevant authority to try to get them accepted or to seek advice from the authority about finding better solutions. This topic is dealt with in Chapter 4.

2.4.3.5 Composition of the project group

It is important to create good team spirit. If they are read by everyone in the group, the following points may help to create team spirit:

- There must be an authorized leader.
- The leader should be firm, but not dominating.
- Group members who may suppress the opinion of other group members because of their position in the company, experience or general reputation, should be assigned to the reference group or review board, not to the project group.
- Group members who do not stand up for their own opinions, but base their arguments and references on the opinions of people higher up in the company should not be in the project group. Submissive people should also be avoided.
- An even number of team members makes dominance by any individual member easier to avoid.
- Group members should share some common knowledge and experience to make it easier to maintain good internal communication within the group.

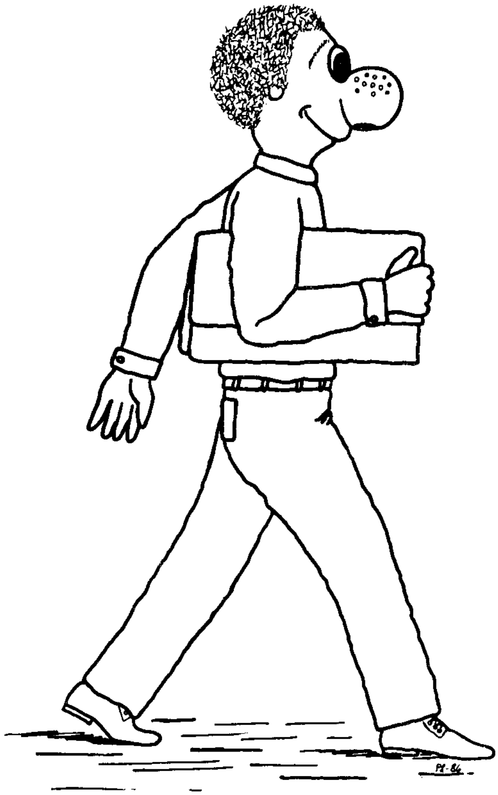
TASKS

	1. Investigate conditions	2. Propose solutions	3. Negotiate interpretations
In relation to:			
1. Subcontractors			
2. Authorities			
3. Classification societies			
4. Cooperating parties			
5. Users			
6. Trade unions			
7. Financing institutions			
8. Consultants			
9. Others			

Figure 2.3 A form to be used when selecting personnel for predesign investigations and negotiations

3

CLARIFYING THE DESIGN OBJECTIVE



3.1 INTRODUCTION

The objective of a design job must be expressed in such a way that no possible solution is excluded. The design aims and the design conditions should be clarified in consultation between the clients and the project group. The clients are the people for whom the design work is being carried out. Clients could include the management of your company or department, one or more users or customers, or someone who employs you as a consultant.

The clients frequently have a firm idea of what they want. Therefore, when they express the aims of the design they may encourage particular solutions or introduce conditions which restrict the possible solutions to some familiar type.

However, good solutions are frequently different from those already known. Therefore design objectives should be expressed in a way that leaves the designer's mind open to new ideas and new ways of doing things. For this reason it is worthwhile spending some time finding a stimulating way of expressing the design aims. This job should be shared between the design project group client or the project leader, and the clients. Together they should try to express the design objectives in a way that clearly states the purpose of the design but at the same time leaves the options open for the wide variety of solutions which may exist. The examples below show good and bad ways of describing design objectives. Good descriptions are those which discuss only the required performance or function.

3.2 WAYS OF EXPRESSING DESIGN OBJECTIVES

There are many ways of expressing design objectives. Some examples of good and bad descriptions are given below.

Bad. Design a bulker where: $D = x$; $B = y$; $L = z$; $d = t$; $V = h$.
Good. Design the transport of x tons of iron ore per year from point A to point B. Or Design a bulker that can be traded in the market for a period of twelve years and is able to call at all important ports and which does not exceed Panmax limits.

Bad. Design a jacket for x metres water depth with weather conditions as outlined in report PGR 85/6 and a top weight of z tonnes
Good. Design a platform to operate at x metres water depth and weather conditions as outlined in report PGR 85/6, to support the drilling and processing of petroleum with a gas/oil ratio (GOR) of 0.1 and an oil equivalent quantity of Q tonnes.

Bad. Design a replacement vessel for M/S XXX.
Good. Design a vessel that can provide the same transport at M/S XXX and is adaptable to the expected developments in techniques and business.

Bad. Design a bulker with less than 10 metres draught.
Good. Design a transport system that can unload bulk cargo in port R where the maximum permissible draught is 10 metres.

Bad. Design a pipeline from offshore field FFF to point PPP.
Good. Satisfy an annual energy demand of k kWh at point PPP through deliveries from offshore field FFF.

Bad. Design boxes for packing cars.
Good. Design a transport for cars that prevents damage to them.

Bad. Design a Suez-max tanker.
Good. Design replacement vessels for the VLCCs and ULCCs.

Bad. Design a fourth generation supply vessel.
Good. Determine the demand for services and supplies in offshore oil field KAAT and design a service that satisfies the demand.

At the beginning of a design job the first task is to reformulate the aims in more abstract (i.e. fuctional) terms. This is because abstract formulations only give poor indications of the possible solutions. Thus they increase the freedom of choice and encourage creativity and inventiveness. Abstract formulations may be used at any stage in the design process whether dealing with overall systems or searching for detailed solutions.

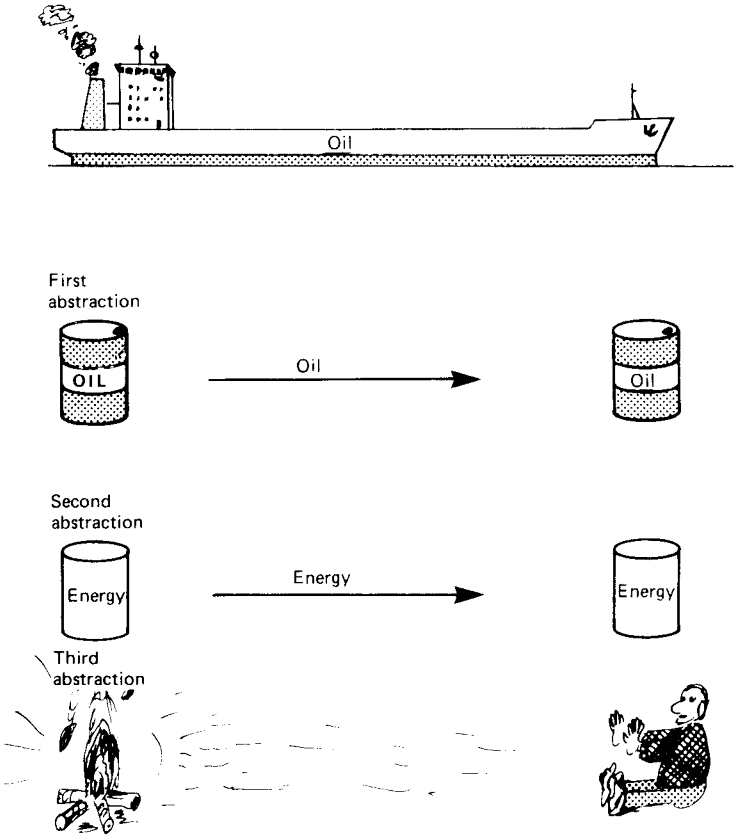


Figure 3.1 Example of abstract reformulations. 'Demand for a tanker' is an aim formulation narrowed down by minds tied to existing solutions. 'Provide energy in a certain place' is a more general formulation opening up for a lot of different solutions

Abstract formulations should be used at the *outset* of the design. In the process of searching for the solution the abstract formulations will be transformed into firm specifications. During the design process the description of the aims in abstract terms evolves into a statement of the required *functional* and *performance* capability and finally becomes the *technical specification* (Benford, 1986). The technical specifications will have the same form as the examples of bad descriptions of design objectives which were given at the beginning of this section. However, technical specifications are developed in the course of a search for a solution within wider limits than those given in the original formulation. The search for solutions is discussed further in Chapter 12, Section 12.4.

3.3 MARKET EVALUATION

What you design is meant to earn income and make a profit. Therefore the market where you sell your designs must be considered. The market consists of users or consumers. In order for you to make a profit they must find it worthwhile to pay for the services or goods which result from your designs. Thus it is necessary to produce designs that are accepted by the users. Therefore, a thorough study and evaluation of the market and potential users is necessary for the formulation of design aims.

Acceptance of a product or service by a market is dependent upon the demand being satisfied and the means of satisfying the demand being at least as good and as inexpensive as those of competitors.

This makes it necessary to investigate a market from two different points of view. Therefore you must aim:

- To forecast economic activity and the corresponding level of demand.
- To reveal recent developments in techniques, business arrangements, organization of service and other factors.
- To forecast the standard of service that will be expected.

The forecasting of demand is discussed further in Chapter 17. Items that the design team should take up with the customers are discussed below. Figure 3.2 illustrates the large number of factors which may influence the activity in a market.

Technical developments are directed by demands for improvements. Improved solutions are, as a rule, more profitable and they should replace existing solutions. Designs that are aimed at existing levels of service, existing technology or existing rules and regulations may lead to a loss of investment. As a starting point, you should assume that better services, more efficient technical solutions and better adaptations to rules and regulations will be developed, if not by you, then by your competitors.

Users will prefer solutions which are:

- Simpler to deal with.
- More economical in relation to income and cost.
- Easier to maintain.
- Easier to replace.
- Easier to adapt to existing systems.
- Easier to operate.
- More versatile.
- More reliable.

The most important users are the customers who pay for the service, but those who operate a new product also greatly influence its success. Therefore, they should also be considered as users. This type of user may include the officers and crew who take a new

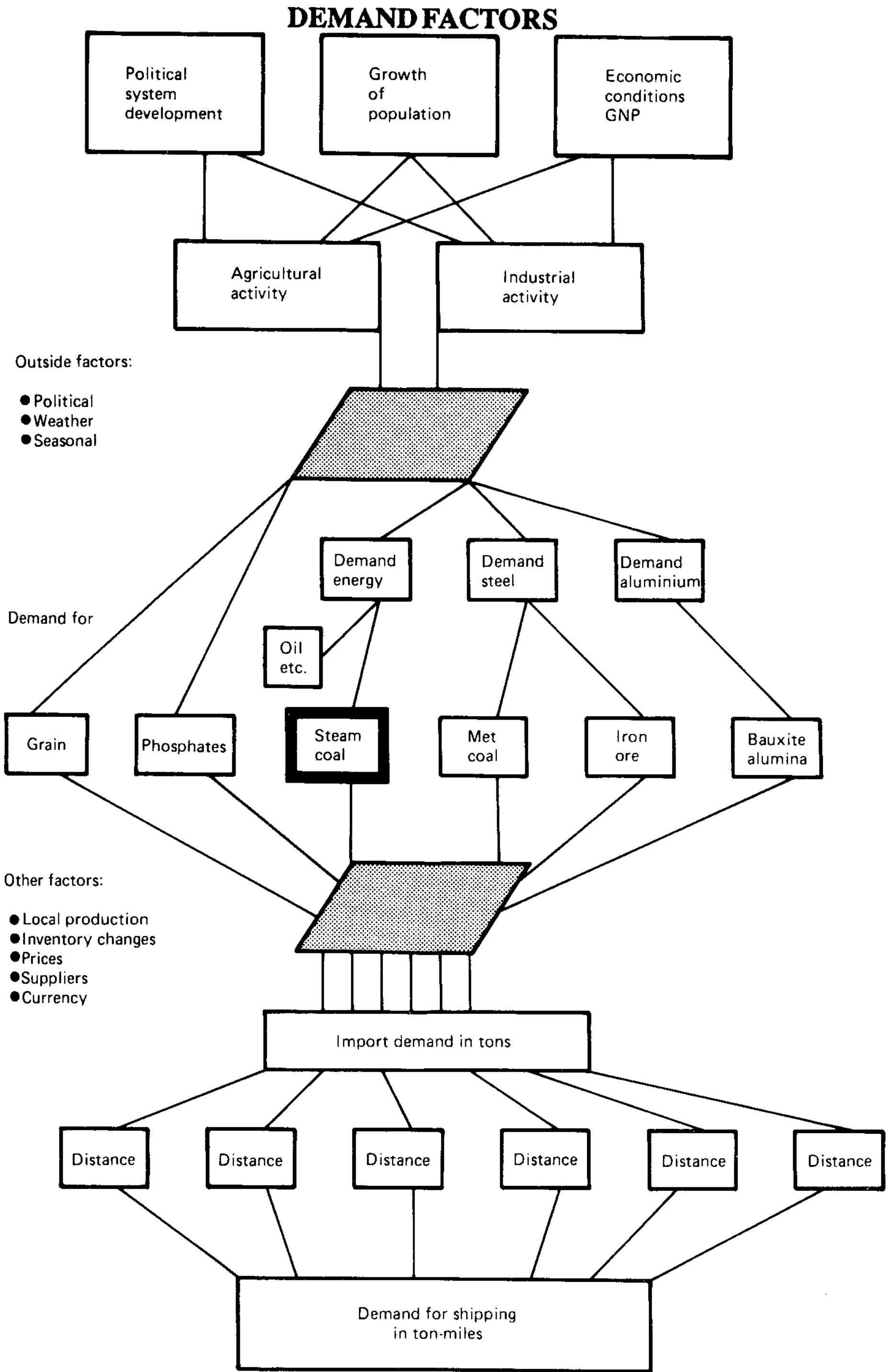


Figure 3.2 A schematic presentation of demand factors that influence demand and supply in the bulk market (Øvrum, 1986)

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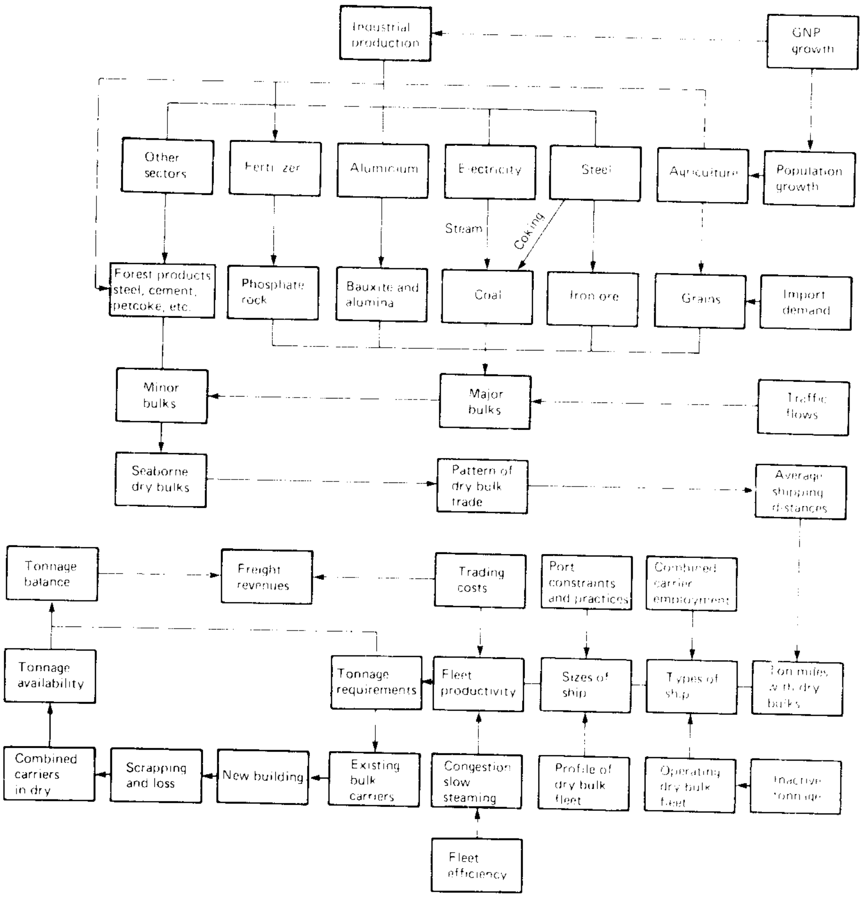


Figure 3.3 A schematic presentation of the inter-relations that influence supply and demand in the bulk market

ship into use, longshoremen who use shipborne equipment for loading and unloading and roughnecks on the drill floor.

The project group should be familiar with how a market reacts to developments in technique, business arrangements, organization schemes and other conditions that may affect technical and organizational solutions.

It is a major challenge to decide how long a particular situation may last and to what extent a particular trend may continue. One basis for deciding is to determine what the consequences would be if a trend continues or a situation remains unchanged and judge whether it seems reasonable that the consequences you have determined will materialize. This is discussed in Chapter 17.

3.4 REVIEWING POSSIBILITIES WITH CUSTOMERS

Needs of customers and users may be latent or apparent. Direct contact with the customers may disclose latent needs. Frequently customers are ignorant of the possibilities that may be created through the use of new techniques and methods. However, when these new possibilities are discovered they may be quick to change their attitude and thus create new demands.

To provide a lasting income designs should anticipate the development of the customers' preferences. This may be achieved by inviting customers to discuss developments in techniques and business arrangements and how these developments may be exploited.

Contact with customers should be used to:

- Reveal major cost items.
- Register and study existing needs.
- Present scenarios of technical and commercial developments.
- Discuss how a service could be improved.
- Investigate whether there are latent demands and what types of technical and commercial services could be used to realize and satisfy these demands.
- Develop customer participation in the design.

It is not sufficient to check facts in many cases. You should also try to find out how customers would react if specific changes were made. The following section lists the sorts of questions you should ask to facilitate a discussion of latent and apparent needs.

3.4.1 Service items to be checked

3.4.1.1 The quality of service

Has there been any change in the quality of service recently?
How may this development continue?
Will changes in the service have any influence on the demand?

To initiate a discussion you could ask what would be the effects of concrete changes. For example, what would be the gain if there was:

- No delay in delivery?
- A shorter delivery time?
- No operation downtime?
- A 30% reduction in fuel costs?

3.4.1.2 Transportation

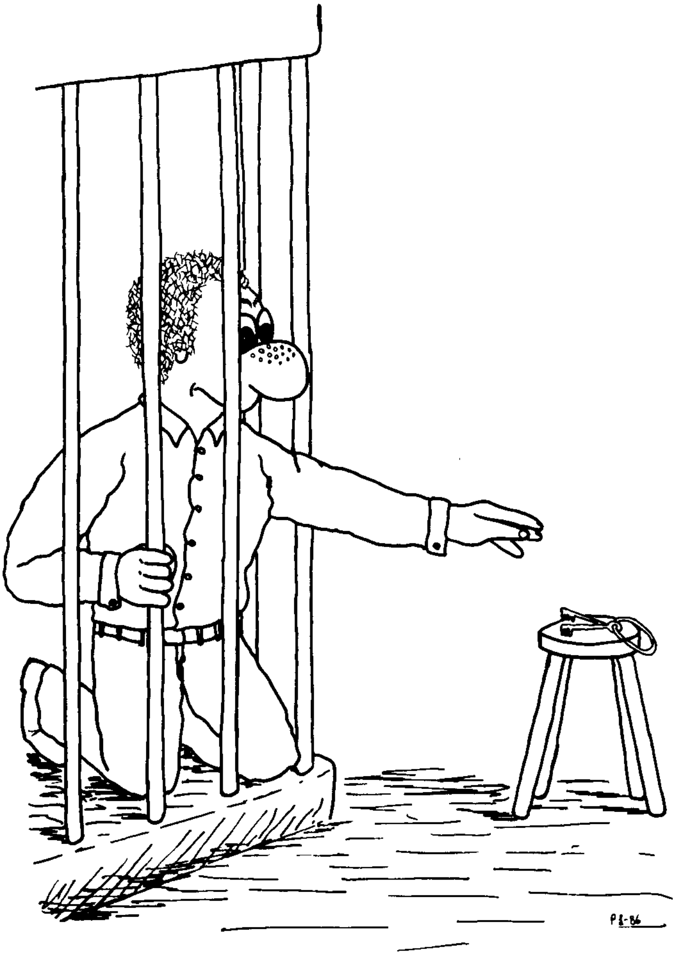
What is the value of the cargo delivered at the final destination?
How large are the transportation costs as a percentage of the total value?
What are the main items included in the transport costs, carriage, packing or handling?
For how many years will the transport service be required?

3.4.1.3 Support services

How many different kinds of support services are needed for the oil field?
Will all different types of support functions be required at the same time?
Could some of the functions be provided by a single vessel?
Does the present set-up provide support functions when required?
Has there been any production downtime due to lack of support service?

4

DESIGN ATTITUDES AND DESIGN RESTRICTIONS



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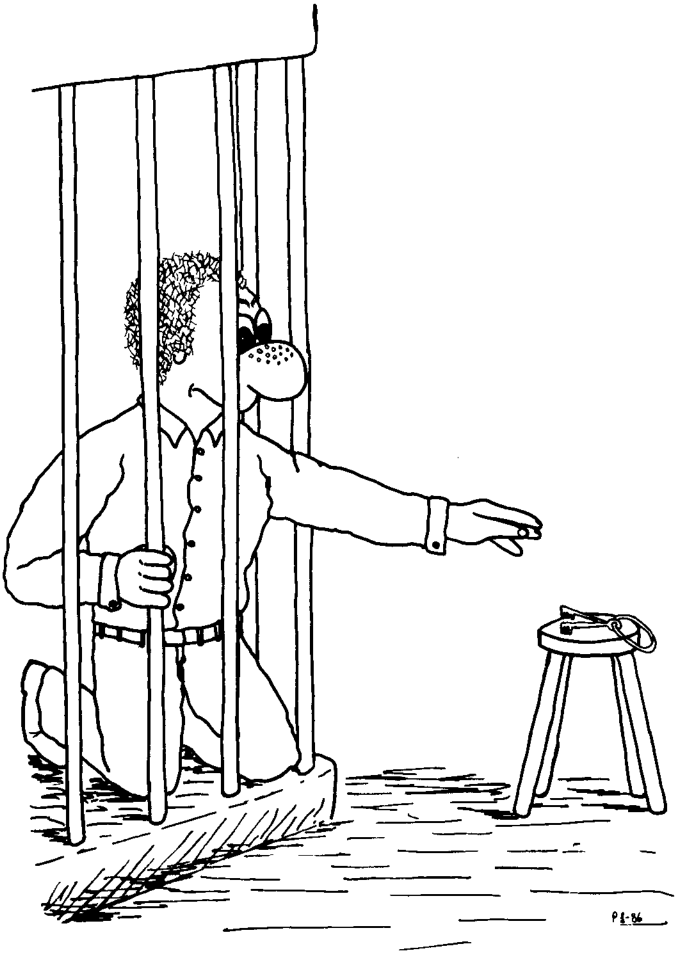
DESIGN ATTITUDES AND DESIGN RESTRICTIONS



4.1 DESIGN ATTITUDES AND THEIR CONSEQUENCES

When undertaking a design job you will always be faced with rules, regulations, demands and preferences which may severely limit your possible solutions. Some of the restrictions are based on national and international law or regulations of the classification society or similar organization. These may have to be accepted as they are. Other restrictions stem from sources such as customers, port authorities, railway or trucking companies. It may be possible to overcome these. The extent to which you should try to change or modify the rules and regulations depends on your attitude or the attitude of your clients. The questions listed below illustrate how your attitude may influence the restrictions placed on your design work.

- Should you accept the customer's conditions or should you try to find better solutions through cooperation and negotiation?
- Should you design only one unit, such as a ship to be traded in the market, or should you design a complete system in which the unit may fit; for example, a transport system?
- Should you seek cooperation with all the parties involved or should you try to come up with a solution that is independent of the others?
- Should you use a flag of convenience or stay national?
- Should you limit your involvement in a project in order to keep capital investments low or should you seek to become involved in all aspects of the project and provide the required capital, if necessary, by loans?
- Should you use new and untested equipment or stick to previously tested equipment in order to reduce risk?

The answers to these questions have their roots in the policy of a company. The design team should make recommendations for change of policy when it is evident that this will help to produce a better design. Recommendations for change should be supported by calculations that indicate what will be gained by the changed policy. Questions related to attitude or policy will almost always arise if the design is of any importance. Procedures for discussing such questions with the management should be established before the design work begins. The check list given in Figure 2.1 may provide a basis for establishing this procedure.

Whatever your attitude, there are two important aspects to keep in mind about conditions and restrictions:

- They must be specified precisely so that there are no doubts about what they are.
- They must be investigated and studied with a view to modifying them or finding an adaptation that provides an edge against the competition.

Designs which can bypass limitations by some means will, as a rule, have a higher earning potential than those that are merely adjusted to them. Frequently a minimum cost adaptation is sought, but in some cases the best design is the one that offers more than the minimum requirement, for example the provision of very comfortable accommodation for crew and passengers, particularly good upkeep of the hull and machinery and duplication of machinery and equipment which are essential to keep the vessel on hire. In addition, a higher speed than the minimum cost speed is frequently chosen.

4.2 RESTRICTIONS

Restrictions may limit dimensions and physical layout, set constraints on operation and require special types of equipment and outfit to be on board. Physical limitations on the design include: beam limit in a lock, draught limits in a port and height limits for a mast. In the majority of cases restrictions have to be accepted as they stand. It is, therefore, important that you find out exactly what the restrictions are and that you obtain your information from a reliable source. Table 4.1 is based mainly upon Ports of the World (Lloyd's of London, 1984). However, even in that book the accuracy of the figures cannot be guaranteed. Therefore you must always double check.

A double check should be based on at least two independent sources. This means that you have to trace the origin of the information. For example, you must determine whether the information comes from pilot associations, national authorities, experienced users or dredging companies. This is because some organizations may underestimate the problems. Therefore they may supply overly optimistic specifications about, for instance, weather conditions, port capacities and cargo handling facilities. Other clients, such as port authorities, cargo owners, offshore contractors and others who are not well established institutions, may want you to produce a design which would satisfy the most extreme conditions, even though these conditions occur so seldom that it is not economic to take them into account.

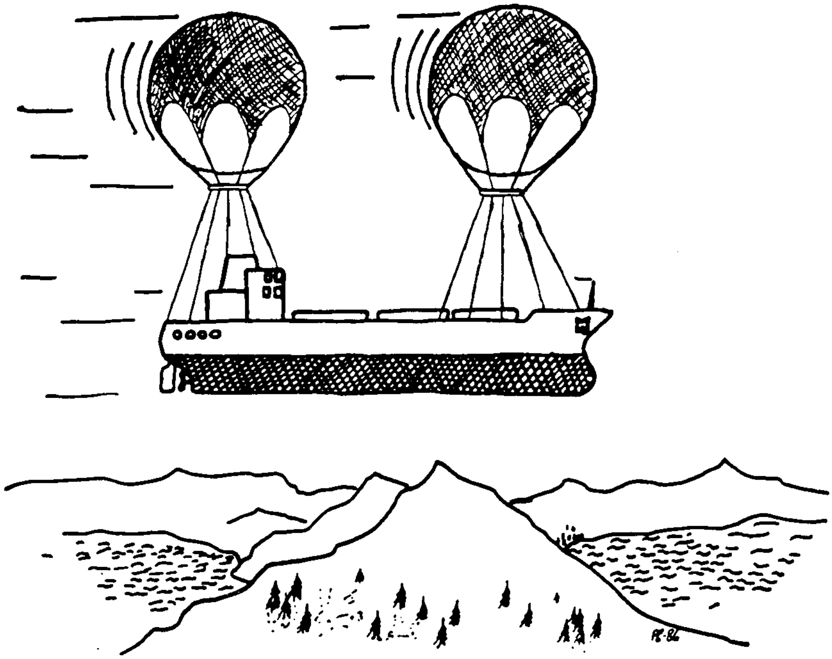


Figure 4.1 Imaginary solutions may often have little basis in reality, but will in spite of this frequently stimulate creativity and inventiveness

Information from established institutions like canal authorities, classification societies, national and international authorities is generally correct at the time it is given. The problem with this information is that it is frequently amended by rules and regulations introduced at later stages. Therefore, it is necessary to obtain a survey of proposed and draft amendments, rules and regulations. This may be very difficult, but you may get some asssistance from your national authorities and classification societies. Be sure to get the relevant information directly from its primary source. Two different books which are based on the same source of information are not the same as two different independent sources.

If a design will have any economic impact it is justifiable to take a great deal of care to verify information and to find the most cost-effective adaptations to the restrictions.

Table 4.1 Examples of limitations on main dimensions. The figures are given without responsibility and should be checked before main dimensions are selected. The limits are applicable for ships' dimensions, except for St Lawrence Seaway, where the dimensions of the locks are given

Place	*Draught (m)*	*Beam (m)*	*Length (m)*	*Ref.*
Antwerp	7.72–18.48			(Lloyd's, 1984)
Dover Strait	23			(NH 077)
Hampton Roads, Virginia	9.14–10.67			(Lloyd's, 1984)
Le Havre	28.6	71		(Lloyd's, 1984)
London	11.6–14.6			(Lloyd's, 1984)
Malakka Strait	23			(Breda, 1984)
Panama Canal (varies with rainfall)	11.28 (12.04)	32.2 (32.61)	289.5	(Lloyd's, 1984)
Rotterdam	19.81 (22.9)			(Lloyd's, 1984)
Rotterdam — General Cargo	7.9–10.65			(Lloyd's, 1984)
St Lawrence Seaway (locks)	7.92	23.16	222.5	(Lloyd's, 1984)
Suez Canal, maximum draught and maximum beam combined may not exceed	16.2	64		(Lloyd's, 1984)

4.2.1 Rules for checking restrictions

Some guidelines for checking information about restrictions are outlined below.

Source. Established authorities such as canal authorities, classification societies, international organizations, national authorities and trend-setting customers.
Action. Check that the information has come *directly* from the authorities. Information from intermediaries may cause a lot of confusion. Be sure to check the date of the information. Changes and modifications may have taken place after the information was published. In any case, check whether amendments or drafts are in preparation.

Source. Local authorities such as port authorities.
Action. Follow the same procedure as you would for information obtained from established authorities. In addition, cross-check all information asking at least two independent sources. Confirm by your own observations if the information is crucial to the design. Local authorities tend to be very optimistic about such things as the performance of local installations, the effect of high tide, the level of service available at a given port or base, labour relations, shift work, barge (or lighter) capacity and tug services. Consult someone who has used the facilities in question if you cannot check for yourself.

Source. Agents, port captains, pilot associations, stevedores.
Action. Carry out the same checks as you would for information obtained from both established and local authorities. Try to interview the people who provide the information. Find out whether they understand the meaning and the importance of the questions you ask.

Many local representatives have a very different background from designers. If you are in any doubt, go and check for yourself.

4.2.2 Ways of adapting to restrictions

Some ways of adapting to restrictions are suggested below.

Restriction. Rules and regulations issued by authorities including governments, international bodies, foreign national bodies and classification societies.
Ways of adapting. *Consult* the authority and try to find the reasoning behind the rules. *Test* your own interpretation. *Suggest* solutions that are to your advantage. Seek expert advice.

Restriction. Conditions imposed by the *customer.* In most cases these are related to packing, stowing, handling and sorting, size of shipments, frequency of calls, reliability of service, weather independency and documentation.
Ways of adapting. Make direct contact with the customer. Try to find the real reason behind the conditions. If you have suggestions try to demonstrate them by practical examples. For instance, invite the customer to visit actual installations or to inspect an operation where your suggestions have been carried out. Try to find out what advantages have been gained by previous customers as a result of your suggestions. Factors which may influence customers' attitudes include:

- *Back-up capacity.* Owners with a large number of ships will be preferred because the large number of ships provide security against delays due to weather, equipment, and breakdowns.
- *Unitizing of cargo,* for example by use of containers, preslinging or palletizing. This may reduce the need for packing or make it necessary to despatch the merchandise in larger or smaller quantities than before in order to match the size of the shipments to the actual type of unit load.
- *Bulking of cargo* which makes packing unnecessary and may make it necessary to produce larger shipments.
- *Improved cargo protection,* for example by containers, better opportunities for segregation such as separate pumps and piping for each tank, dedicated tanks and compartments, improved tank cleaning and improved hatch covers.
- *Mechanized cargo handling* and unitizing of cargo. This will reduce damage to cargo, especially if the units are going through from origin to destination. This makes any detailed sorting on the carrier's premises impossible.
- *Larger ships offer lower freight rates.* However, they must carry more cargo and cannot call as frequently as smaller ships if the inflow of cargo is not increased.
- *Electronic data processing* and modern telecommunications make the issuing of shipping documents simpler and the transfer of data faster.

Restriction. Union rules affecting working time, manning, job sharing, demarcation and pay.
Ways of adapting. Make direct contact with the people involved. Do not trust third parties. Explain your needs and intentions. Try to point out the advantages for the unions.

Restriction. Conference rules, including restrictions on quantities of cargo to be lifted from ports, on number of calls per port and on classification of cargo.
Ways of adapting. These may be hard to change, and the task may be beyond the responsibility of the design team. Try to quantify the effects of the restrictions and to calculate the gain that may be obtained in changing them. Inform your management

accordingly.

Restriction. Limits to the ***draught*** in ports, channels, locks, estuaries, entrances and straits.
Ways of adapting. Check:

- Whether the information is correct.
- Whether you must call at the particular port or quay where the restrictions apply.
- How much it would cost to trans-ship or dredge.
- Whether tidal variations could be used to modify the restriction.
- Whether ships could be lightened or topped up in a deeper area and what that would cost.
- Whether there are any plans to deepen the waterways in question.
- How often the actual restriction is encountered. It may make more sense to design a vessel with a deeper draught if the restriction seldom occurs in practice.

Restriction. Limits on the ***beam*** originating from locks, canals, bridges, port basins, ferry berth.
Ways of adapting. Check:

- Whether the information is correct.
- If it is really necessary to pass the point of restriction. Could cargo be taken on board or unloaded somewhere else? Could the port be entered by another route. Could feeder ships or lighters be used to get the cargo past the point of restriction.
- Whether planned expansion or improvement to the port will eliminate the problem.

Restriction. Outreach of loading or unloading equipment.
Ways of adapting. Supplement shore-based equipment by shipboard self-trimming devices, cranes or conveyors. In extreme cases, turn the ship at the quay.

Restriction. Limits on *length* originating from turning basins, locks, canals, quays.
Ways of adapting. Follow the advice given for beam restrictions. In addition, make the distinction between rigid constraints, such as locks, and 'soft' constraints, such as turning areas.

Restriction. Air draught restrictions originating from bridges, free height under loading/unloading booms, suspended electricity cables and pipelines.
Ways of adapting. Follow the suggestions given for beam restrictions. Check whether ballasting or heeling can be used to reduce the height. Check whether simple mechanical means (e.g. telescoping) could be used to reduce the height of bridge houses, masts and antennas.

Restriction. Limits on the *loading* and *unloading capacity* including limited capacity for moving cargo to and from the ship and limited capacity of equipment.
Ways of adapting. Supplement the equipment on shore with your own forklifts or tractors. Supplement loading/unloading equipment with ship-borne equipment. Reorganize the work on the quay and improve planning. Load or unload a part of the cargo to or from lighters.

Restriction. Limited storage capacity in ports.
Ways of adapting. Supplement shore storage by barges. Acquire additional storage capacity. Organize direct handling between ships and land transport vehicles.

Restriction. *Seasonal variation* in cargo inflow.
Ways of adapting. Check that the demand is seasonal. Moderate the effect of the fluctuations by storing the cargo when the inflow is at its maximum. Charter additional tonnage when the demand is high and charter out your own tonnage when the demand is low.

Restriction. *Tonnage restrictions.* It is often necessary to keep the tonnage below certain threshold values beyond which manning, port dues and safety precautions are increased.
Ways of adapting. Study vessels that comply with the corresponding limitations. Seek expert advice. Note that the rules for calculating tonnage were changed in 1982 and the opportunities to vary the rules in special cases are reduced.

Restriction. Restrictions on *discharges.* This is applicable to the discharge of chemicals, oil-polluted water, sewage, dust and anything which may pollute the environment. The restrictions may be found in MARPOL 1973/1978 (the International Convention for the Prevention of Pollution from Ships 1973, and the Protocol of 1978) and in the rules issued by the International Maritime Organization (IMO), the US Coast Guard and other national and port authorities. All ratified international rules are included in the Flag rules and regulations issued by the Flag Administration. In Norway this is the Norwegian Maritime Directorate.
Ways of adapting. Study the rules and regulations carefully. Vessels which are not built to the specifications given may be excluded from national waters or may have to be modified. *Clarify* the objectives of the restrictions and try to meet these objections in a better way than has been done in the past. Clear the proposed designs with the relevant authorities. Be *aware* that drafts and amendments of rules may be in preparation and be put into force in the near future. Check this with your national authority and with national representatives in international committees. *Check* with your management to see which rules and regulations not yet in force should be complied with.

Restriction. Restrictions on the *arrangement of cargo compartments* and *equipment.* These are applicable to vessels carrying dangerous cargoes, strong acids, strong bases, hydrocarbons, explosives and to special purpose vessels such as supply, stand-by and rescue vessels. The restrictions can be found in the regulations issued by the IMO, US Coast Guard, the Australian Sea Board and other national authorities.
Ways of adapting. Follow the advice for adapting to restrictions on discharges.

Restriction. Restrictions on *motion* and *position keeping.* These are applicable to drilling rigs and ships, offshore support vessels and passenger vessels.
Ways of adapting. Study the reasons behind the restrictions. Check whether movements may be compensated for by special equipment such as heave compensation and anti-rolling devices and whether the actual operations could tolerate movement in excess of the limits. *Calculate* the cost of complying with the restrictions and compare costs and benefits such as compliance versus increased downtime.

4.2.2.1 A few words of caution

The competition in shipping and offshore activities is great. Therefore, in most cases you will look for minimum cost adaptations to restrictions. However, there may be cases when it is economically justified to choose solutions that require a greater financial investment than the minimum cost adaptation. An example of this is when extra investment improves relationships with customers, produces a more reliable service and thereby increases income, and attracts good officers and crew.

More important than any consideration related to rules and regulations or adaptation to restrictions is the requirement that a ship, semisubmersible rig or other marine structure possess the capacity, speed and technical standards that will make it attractive to the market.

5

ADDITIONAL BACKGROUND INFORMATION

Most of the information needed to begin a design job has been mentioned in earlier chapters. A few supplementary items are listed below. Information related to these items should be available before you start to work on the problem.

5.1 DESIGNING TRANSPORT SYSTEMS

You need information about:

- Magnitude, fluctuations, estimated duration and the nature of the cargo inflow.
- The location of and distance between ports.
- Canals and waterways to be navigated.
- The reliability of port services.
- Shore reception facilities.
- The capacity and outreach of cranes.
- The layout of berths.
- The availability of service equipment such as floating cranes, treatment facilities for polluted ballast water, repair and maintenance services, tugs, pilots and linesmen.

5.2 DESIGNING OFFSHORE SUPPORT SERVICES

You will need information about:

- The magnitude and type of support functions.
- The estimated duration of the demand.
- The condition of the sea floor
- The depth of water.
- The distance to the base and its location.
- The endurance of the unit to be served.

5.3 GENERAL CONSIDERATIONS

You should also consider:

- The duration of daylight.
- Wind statistics
- Wave statistics
- Statistics of ocean currents
- Ice statistics
- Air temperature statistics
- Water temperature statistics
- Any particular navigational hazards.

It is important to obtain the statistical information in the form of *density distributions*. This makes it possible to estimate how the vessel and equipment should be designed in order to make them operable and accessible for a given number of days per year. For example, you will have to have a certain ice class to work in arctic regions for 11 out of 12 months, but a different ice class is required to work only for only 8 out of 12 months.

6

ATTACKING THE DESIGN TASK

6.1 INTRODUCTION

The work involved in developing a design depends on the tactics followed. It is a good idea to develop a prototype solution first, because the results of the design work may alter the underlying conditions and assumptions or even suggest reasons why the project should be discontinued. A prototype solution may indicate whether your result will be within the scope of the assumptions set at the start of the project. It can also provide a basis for deciding whether or not to go on with a project. A prototype solution will also tend to highlight the issues that are important for your design.

Some aspects of design tactics are discussed below. The underlying theme is that a design job should be discontinued at any stage if it turns out that the original objectives cannot be met.

6.2 IMPORTANT VARIABLES

There are three principal kinds of variables.

Decision variables. These are variables whose value is selected by the designer. Examples include the main dimensions, speed, the navigation system, the cargo handling capacity, the quay area and the storage capacity.

Resulting variables. These are variables whose value is a result or function of the decision variables. Examples include moulded depth as a function of draught and freeboard, displacement as a function of the main dimensions and fullness, and heave response as a function of water plane area and mass. One important type of resulting variables are the measures of merit, the criteria that measure the economic performance of a design. Measures of merit are discussed in Chapter 11.

Independent variables. These are variables which cannot be influenced or controlled by the designer. Examples of independent variables include waves, currents, ice floes, prices, currency fluctuations and actions of your competitors. Any design must take these independent variables into account.

A design may become over-specified and run into deadlock when decision variables and resulting variables are not clearly distinguished from each other. This can happen, for example, when the value of the main dimensions, the weight of cargo, or fullness, and the displacement is selected by the designer and used as input to a computer program. The designer often has the option of deciding what variables should be used as independent variables, for example whether engine power should be used instead of speed or whether displacement should be used instead of cargo deadweight.

Decision variables that have a marked influence on the merits of feasibility of a solution or which, in order to ensure compatibility with other systems, must be decided on early in the design, are the most important variables. These variables should be identified as a first step towards arriving at a solution. As a second step you should concentrate on determining their optimum values. Some rules for identifying important variables are discussed below.

6.2.1. Identifying important variables

The initial selection of important variables may be made on the basis of intuition and experience and by considering what the key problem is. To identify important variables you should consider whether the variable:

- has a major influence on the merit of the solution chosen;
- is related to the key problem;
- is crucial for solving any restriction or constraint;
- must be determined early in the design process;
- may be determined by simplifying assumptions.

If you then ask yourself whether any variable that relates to the questions given above has been forgotten, you will find that the majority of the important variables have been identified.

When you are dealing with a problem that is new or different in your experience, this simple questioning technique may not be sufficient and systematic sensitivity analysis should be used to supplement it. The measure of merit and any key condition should be checked against extreme high and low values of any important decision variables. The important decision variables should be altered one at a time. If the alteration of one variable has a major influence on the value of the measure of merit or a key condition, then the variable is an important one. Some examples of key conditions include 'provide an accessibility of 97%', 'provide an all year service', 'be able to pass through the Panama Canal', and 'be operable by a crew with little training and education'.

Sensitivity analysis is dealt with in Section 6.3. Measures of merit are discussed in Chapter 11.

6.2.1.1 Example: a check of important variables

A check list of important variables is given in the table below:

***Task*: To support a drilling operation at sea**

Variables	*Why it is important*	*To be determined at the outset?*	*Basis or methods of arriving at preliminary values*
Type of platform	Determines operation capacity and the requirements of the support functions	Yes	Number of alternative types: 3
Payload	As above *and* decisive for cost	Yes	As function of water depth, weather statistics distance to shore base
Main dimensions	Determines motion characteristics, displacement and payload	No	As function of *payload* and weather statistics
Position keeping	Determines equipment weight, mooring loads, operability, permissible water depth	Yes	On the basis of water depth and weather statistics

In this example the type of platform, payload and position keeping system are the important variables. Other variables may be important in other projects. The list below outlines other variables which may turn out to be important in various types of projects.

Ships. Important variables include type, speed and cubic or deadweight capacity. Speed and capacity may be interdependent.

Ports. Important variables include which ports will be used.

Storage. Important variables include the location of storage. The storage capacity is determined by the ship capacity.

Cargo handling. Important variables include the type and capacity.

Transport both from the point of origin to the ship and from the ship to the final destination on land. Important variables include the type and capacity.

Support vessel. Important variables include the type, deck area and bollard pull.

6.3 PRELIMINARY SENSITIVITY ANALYSIS

The procedure for carrying out a preliminary sensitivity analysis is listed below:

1. Choose a measure of merit to use to compare solutions, preferably *required freight rate or required charter hire*. These measures of merit give tbe the required income per unit capacity and make it possible to compare them with market rates.
2. Construct a simple formula to calculate the measure of merit. (See Chapter 12.)
3. Choose the most *likely values* of the variables and estimate the value of the measure of merit. Remember that some of the variables will be interdependent, for example, speed and deadweight must be related if the transport capacity is to be the same for all alternatives. The most likely values for some variables will be extreme values; for example, the largest possible deadweight might be used in order to exploit economies of scale.
4. *Increase or decrease* the value of each of the major variables by 10–15% one by one but adjust those variables which are interdependent to follow suit. For example, if a speed of 15 knots and a deadweight capacity of 150 000 tonnes produces a *required* transport capacity, an increase in deadweight by 20% to 180 000 tonnes would require a reduction in speed by roughly the same percentage, or 2.5 knots, to keep the transport capacity the same.
5. Check the effect of the variation of the major variables on the measure of merit. Rank the variables according to their effect and concentrate the design effort on finding optimum values for the highest ranking variables.
6. Check whether the optimum value of any of the major variables is in conflict with any design condition or restriction and calculate the loss which would occur if you adhere to the actual condition or restriction.
7. Estimate how much could be spent on modifying or eliminating conditions or restrictions which prevent you from obtaining the maximum return on your design. Determine whether this would be sufficient to accomplish the necessary changes and report to management to get authorization to incorporate the changes if you find it is worthwhile trying.
8. When an overall design solution has been found, check what is left of the budgeted resources for the design. Check the scope of the design work, estimate whether it would be worthwhile to continue and consult with management before you proceed. Tactics for proceeding with changes are discussed in the next chapter.

Example: Design of a very large crude carrier (VLCC)

First the simplifying assumptions will be explained, then the important variables will be listed. Next the calculations used for the sensitivity analysis will be laid out. Finally, the conclusions which may be drawn from the analysis will be discussed.

Simplifying assumptions. In this example, calculations will be based on a standard design with deadweight and speed as variables. The restrictions imposed by ports and the Suez Canal will be neglected in the first approximation. The value of the cargo and the cost of forgone interest on this value during transport will not be taken into account. When the cost of forgone interest is taken into account the economic speed may be increased by 1.5 to 2 knots.

Important variables

1. The important variables for ships are speed in knots (V), deadweight (dw) and layout. In this example assume starting values of $V = 12$ knots; dw = 200 000 tonnes; layout = segregated ballast tanks, double bottom.

2. Restrictions due to ports and straits in this example include draught less than 21 m; assumed maximum dw is 250 000 tonnes. These restrictions apply to areas such as the port of Rotterdam, Kharg Island and the Straits of Malacca.

3. Loading time. Limits on loading quantity, Q, determine the loading time, T. In this example loading time is 100 000 tonnes on the first day and 200 000 tonnes over 4 days. Thus, $T = 0.0001 \times (Q / 1000)^2$.

4. Handling. Handling is the same for all designs.

5. Hinterland transport. This is not relevant in this example.

Sensitivity analysis

1. Roundtrip distance = 13 000 nautical miles

2. Roundtrip time at sea = 13 000/24V days.
   Loading time in port = $0.0001\ (Q / 1000)^2$ days.
   Discharging time in port = 2 days

3. Annual cost (simple formula used for this example)
$3.2 \times (\mathrm{dw}/1000)^{0.66} \times (0.82 + 0.18\ (V / 12)^4)$ million Norwegian kroners (Nkr)

4. Measure of merit is the required freight rate, i.e. the cost per tonne carried.

5. The result of the calculations is cost per tonne carried (Nkr/tonne). The table below gives the result of the calculations for ships of various dw at various speeds.

	Dw in 1000 tonnes		
Speed knots	150	200	250
10	86	80	77
12	80	75	73
14	80	76	74

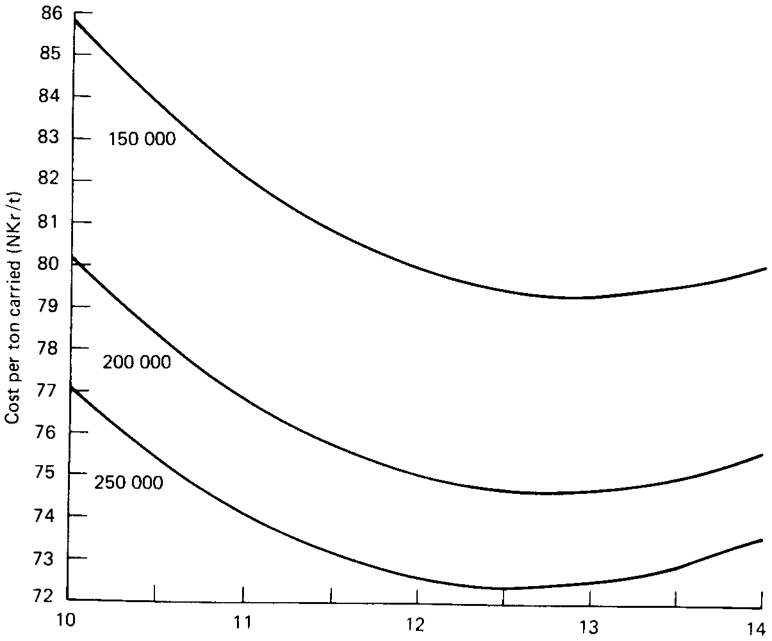


Figure 6.1 An example of a sensitivity analysis
Cost per tonne carried as function of speed for three different ship sizes

Conclusion
So far as cost is concerned, the most important variables are *deadweight* and *speed.*

The deadweight should be as great as possible. The speed, based only on economical running of the vessel, should be around or slightly more than 12 knots. When the cost of forgone interest on the cargo is taken into account, the economic speed may be around 14 knots (see example in Section 6.3).

For vessels above 200 000 tonnes d.w. the deadweight has a diminishing influence on the cost. However, it still has sufficient influence to justify a close comparison between a Suez-max and a Rotterdam-max tanker.

The remaining design resources should be spent on determining the main dimensions, configuration and economy of these two types of ship and on investigating the effect of speed variations around 14 knots on the economics. The costs related to the cost of forgone interest on the cargo to be taken into account.

6.4 USING EXISTING KNOWLEDGE

Experienced designers will have some fundamental relationships in the back of their minds and will use them to find an initial solution. This solution will usually be close to the optimal one. Some of the fundamental relationships used by experienced designers and their applications are discussed below.

6.4.1 Economy of scale

This effect is very pronounced for ships. The larger the ship, the lower the cost per tonne carried. Therefore, design the ship to be as large as port conditions, inflow of cargo and the required frequency of call permit.

This effect is also evident for other types of equipment. For example, 40 foot containers are more economical than 20 foot containers (the majority of container cargo is light); 40 tonne railway carriages are more economical than 20 tonne carriages; 20 tonne grabs are superior to 10 tonne grabs. This is all based on the assumption that there is sufficient cargo and activity to utilize fully the capacity of big units.

In summary, go for the big units in your initial design solution.

6.4.2 Energy is expensive

We have recently gone through a period of high fuel prices where the emphasis was on designing machinery plants with low fuel consumption. Some of the fuel saving devices may be too expensive in relation to the moderate fuel prices in 1987, but many of them do not require much additional investment. In any case, you should be prepared for large fluctuations in fuel prices in the future. You should consider the economics of designing machinery so that fuel saving devices and methods may be installed or put to use when a rise in fuel prices makes it profitable to do so. It is now possible to produce power at the rate of 0.18–0.2 kg fuel/kWh.

6.4.3 Choose the simple solutions

Reliability is a necessity for all marine systems. The daily turnover of money is large and stoppages will cause large financial losses. In your initial solution go for the reliable and the simple. Later more sophisticated alternatives may be acceptable if they are proven to be advantageous in cost-benefit and reliability analysis.

Simplicity is also advantageous for system solutions. Try to design identical ships for the same transport task. Keep the number of trans-shipments as low as possible. Incorporate a reasonable number of offshore support functions in one vessel to reduce the number of vessels needed. Standardize equipment and configurations. Try to create systems that can be handled under *routine* conditions and do not require exceptional solutions.

6.4.4 Avoid unnecessary items

The specifications for new ships, semi-submersibles and other marine designs are frequently based on the specifications of existing ones. Installations, outfit and features may easily be carried over from the existing design to the new design. This can also be done when they are not needed. Ask yourself whether any equipment, feature or constraint that you want to incorporate in a new design is *really* needed.

First, check what the feature or installation is used for (if anything) in the existing construction. Secondly, check whether there will be any need for it in the new construction. Thirdly, if the need exists, check whether it can be satisfied by cheaper means. You can use value analysis (as described in Section 9.4) for this type of analysis.

7

DESIGN TACTICS

The effort spent on a design must be adjusted to the importance of the task and the time available as discussed in Chapter 2, Section 2.3. However, certain tactics are necessary to tackle a design job and much work will be saved if the correct tactics are employed. In this chapter it is assumed that the work done and the time spent on each step will be related to the importance of the task. The important design tactics are discussed below.

7.1 PREPARATION

Prepare the tasks well and ensure that preparation is made as outlined in Chapters 2–6. Adjust the preparatory work according to the significance and the purpose of the design. Establish good connections and easy communication with everybody who will supply information for your work.

Begin carefully and slowly. Check periodicals, interview colleagues inside and outside the client company. Develop your own opinion of the task but be prepared to change your mind as the job progresses.

Systematize information from the very beginning. Note extracts of articles, phone conversations, and meetings with colleagues. If possible, store information on a computer for quick and easy retrieval using keywords.

7.2 CARRYING OUT THE DESIGN WORK

Solve one question at a time. Consider your initial solution to be the basis for the work to follow, even if the initial solution may subsequently have to be modified.

Begin by working through the design from beginning to end. Do not spend more than 20–25% of your resources on this first work-through. The remaining resources may be needed for reworking or adjustments to your design.

After your first work-through, review your initial assumptions and the importance of conditions and restrictions. Carry out a sensitivity analysis, then allow a little time for reflection and see how well or badly things fit together. This will enable you to see what changes can be made to improve your design. Before you spend time or other resources on changes, *calculate* their cost and effect. If actual calculations are too time-consuming or difficult, make estimates instead. Use your judgement throughout. Undertake the most promising changes first.

Note that:

- The results of the first work-through may alter the initial assumptions.
- A sensitivity analysis may reveal conditions or restrictions that should be changed in order to arrive at a good solution.
- A sensitivity analysis may identify areas where errors in calculation and estimation may be critical.
- Changed assumptions may have economic consequences and changing conditions may require other people to become involved. It may be necessary to discuss these consequences with management before proceeding (see Section 4.2).

7.3 STRUCTURING THE DESIGN WORK

7.3.1 Top level variables

Begin with the top level variables, i.e. variables that influence the total solution and variables which may form the basis for the design of sub-systems. The example below illustrates this approach.

7.3.1.1 Example: intercontinental transport

The top level variables for designing an intercontinental transport system and the decisions made based on their analysis are listed below.

1. Top level variables
   (a) *Route*: loading and discharging port, land transportation system from the point of origin to the loading port and from the discharging port to the final destination, the sea route between the ports.
   (b) *Packing*: is it bulk, unitized or break bulk?

The decisions made concerning these top level variables determines, or sets the basis for determining, many of the variables for sub-systems. Variables which relate to the sub-systems are listed below.

(a) Land transportation system: nature of the cargo inflow to the export port and the cargo outflow from the receiving port. This influences the demand for storage in ports and the interdependency between ship size and storage capacity.
(b) Export and import ports: these place limits on the dimensions of the ships and influence the costs related to exceeding these limits, storage and cargo handling. They also form the basis for determining the cost of storage and cargo handling.
(c) Sea route: places limits on ship dimensions and is a basis for determining relationships between sea speed, cargo d.w. and number of ships. It places an upper and lower limit on the acceptable frequency of service.
(d) Packing: type of ships, cargo handling gear, storage and land transportation systems.

Once the route and the packing have been determined, the conditions are set for the design of the land transportation system, storage in port, the ships and other sub-systems. These may be designed independently of each other.

7.3.2 Interfaces

Next, solve the *interface systems or variables*. These are the systems or variables that belong to, or influence, two or more sub-systems.

An example of an interface system is the cargo handling system which acts as an interface between the land transportation system and the storage system or between the storage systems and the ships. As soon as the system for transferring cargo in and out of storage has been determined, the storage, land transportation systems and ships can be designed independently of each other.

When interface variables have been determined there is a set of conditions which act as a framework for the design of each sub-system. Each sub-system can then be designed independently without affecting the other sub-systems. Necessary revisions of the framework of sub-system design can be carried out as explained below. The benefit is that individual tasks can be tackled independently of each other. A lone designer may work through one task after another. In design teams the individual tasks may be solved in parallel without the need for continuous exchange of information or discussion between team members.

In some cases individual variables are the interface between sub-systems. Some examples of this include *length* (of ships and quay), *beam* (of ships and lock gates), depth of ports and the *draught* of ships. Each of these four variables sets the design conditions for two neighbouring sub-systems. For example, length affects the design of ships and quays and beam affects the design of ships and locks.

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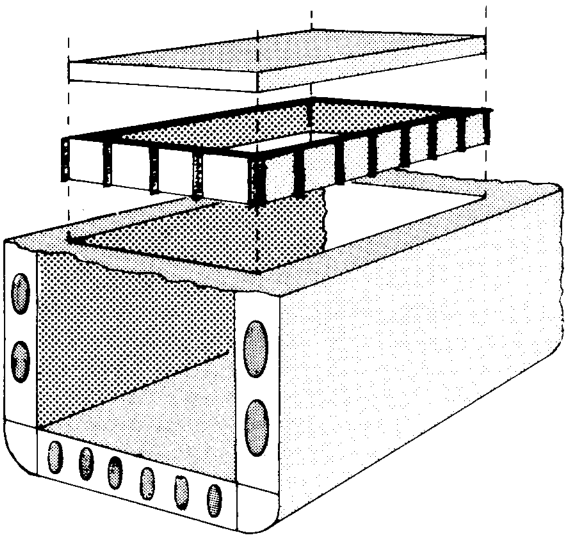

Figure 7.1 The hatch opening may be considered as the interface between the hatch coamings and the deck structure

The tactic of determining the interface systems and interface variables first and then designing the sub-systems whose conditions have been determined should be followed throughout the design job whether dealing with the overall design or small sub-systems. This does not mean that a design must be for ever tied to an initial set of interface variables. Instead, work stepwise towards a solution within the interface variables determined for each step. Often the initial solution of the interface variables requires improvement. Then it is necessary to undertake an *interface revision*. This should be made in a systematic manner at agreed points and not simply haphazardly carried out whenever design team members feel there is a need. A few simple examples of interface variables are given in the table below to demonstrate their variety. Interface revision is discussed in the next section.

Examples of interfaces	*Sub-systems or variables whose end conditions are set when the interface item has been determined*
Location of engine room bulkhead	Cargo compartments/engine room
Propeller	Thrust/required power
Dimensions of hatch opening	Hatch covers/deck structure/cargo units
Voltage	Power consumer/power generator

7.3.3 Adjusting interface variables

Before an interface variable is altered, the consequences for the interfacing systems must be evaluated. Some suggestions for evaluation are given below.

Make the interface solutions known to all concerned as soon as they are determined. Establish permanent routines for checking whether it is necessary to adjust or redesign interfaces and for making changes known. This can be done, for instance, during regular morning meetings. The nature of design is that discoveries made in the course of the work may give cause to modify interface systems and interface variables.

It is of great advantage to limit the exchange of information to scheduled meetings and established procedures. Otherwise the design work may deteriorate into information hunting.

7.4 ITERATIONS

To iterate is to do something over again. Designs must be re-done when the initial assumptions, conditions, restrictions or interfaces are changed. The re-designing may have to be carried out in loops in order to find a balanced solution, for example, for d.w. capacity weight and displacement. This is an integral feature of all design processes.

7.4.1 Iterations due to changes in the basis of the design

The basis of the design includes the statement of the problem and the assumptions, conditions and restrictions that underlie the design work.

In principle, a design problem may be solved by any imaginable solution so long as the solution satisfies the given conditions and restrictions. As a rule, however, the solution must be better than earlier solutions in order to be successful. Therefore it is necessary to use inventions, discoveries and ideas from other industries and technologies that are derived during the design work when they may improve the design.

New ideas and discoveries may change the initial assumptions and require the design to be re-done. You must then return to the stage in the design process where the initial assumptions and conditions were used for the *first* time and re-do the design from that point. This type of iteration is inherent in design work.

However, iterations consume resources; if carried out too frequently they may consume the whole design budget before a final solution is reached. To avoid this, first carry through a design based on the original statement of the problem and the original restrictions and assumptions. Perform a rough sensitivity analysis and estimate the consequences of changes in the basis of the design. If it is found worthwhile to undertake an iteration, concentrate it on those areas where the changes seem to have the greatest effect. Do not spend time and effort on routine work.

This procedure requires that everyone engaged on a design write down any suggestions, ideas or discoveries that may change the design basis as they arise and bring them up at scheduled revisions and follow-up meetings. Decisions about when to start an iteration and in which areas to concentrate should be made at these meetings.

7.4.2 Balancing iterations

Balancing iterations are iterations carried out to find a balanced solution. This type of iteration is typical in the design of marine vehicles whose dimensions are not set by physical constraints. In cases when cargo inflow is large enough to justify a ship that could be larger than the limits set by such factors as locks and water depth, the correct procedure is to set the limited dimensions at their maximum value and balance or adjust those dimensions which may have no limits.

For objects which float in a liquid, the interdependence between variables may cause the need for iterations. For example, the light weight of a vessel is dependent on the hull, outfit and machinery, while the machinery is dependent on the hull, outfit and speed. The total weight is dependent on the weight of the vessel plus the payload. Payload is dependent on

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cargo space and cargo space is dependent on the design of the hull and the machinery. In most cases these relationships cannot be expressed exactly by mathematical equations.

In the designing of ships, semi-submersibles and other vessels, the problem is solved by using empirical formulas to derive an initial solution. Other parameters such as weight, space requirements, resistance and stability are then calculated on the basis of the initial solution. The next step is to check that the calculated parameters are in agreement with the assumptions used to derive the initial solution. They are usually not in agreement and it is then necessary to adjust the initial solution and make new calculations if required. This procedure may have to be carried out several times before a balanced solution is reached. A common way of illustrating this is with the so-called design spiral shown in Figure 7.2. The examples given in the next two sections illustrate the balancing process.

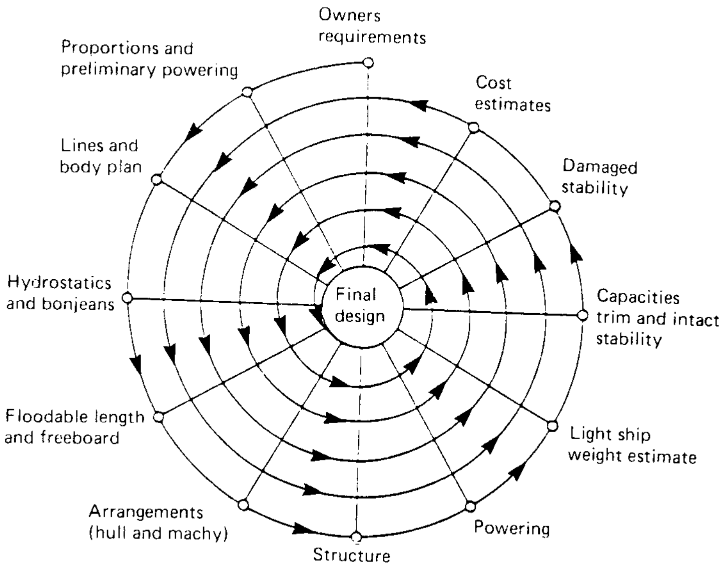


Figure 7.2 The 'design spiral' is frequently used to illustrate the sequence of calculations that are done and re-done when, starting with a set of user requirements, one determines main dimensions etc. of a ship. The illustration provokes strong objections from many experienced designers, perhaps because the assumption that one starts with a fixed set of user requirements is basically wrong. The user requirements should not be considered fixed before all possibilities of a solution have been explored. On the other hand, the determination of main dimensions etc. of a floating object is an iterative process that is well illustrated by a spiral. This particular illustration has been taken from Ship Design and Construction (Dillon, 1969).

NOTES:

1. Professor J.M. Evans introduced the 'design spiral' in his article entitled 'Basic design concepts' (ASNE Journal, Nov. 1959)

7.4.2.1 Example: design of a special purpose tanker

The design aims and initial assumptions are tabulated below. Next the first approximations for displacement and the main dimensions are shown. Finally the iterations are described and conclusions are drawn.

1. *Design aim (derived by design of the transport system)*

Cargo deadweight:	120 000 tonne
Tank volume, cargo:	147 000 m^3
Service speed, V:	12.5 knots
Length overall (LOA) not to exceed:	275 m
Draft (T), not to exceed:	15 m

2. *Starting assumptions*

Bunkers, fuel, fresh water	2000 tonnes
Draft, T	= 15 m
LOA/LBP	= 1.041
$LBP \times B \times D$	= 1.35 x (Total tank volume),
shall be as follows	
$5.30 \leq L/B \leq 6.40$,	based on comparison with similar ships
$0.78 \leq CB \leq 0.82$	from consideration of fuel economy
Ballast tank volume (segregated ballast tanks)	= 0.37 x (Cargo tank volume), based on comparison with similar ships

Light ship weight = $0.105 \times (LBP \times B \times D)$ (tonnes)

3. *First approximation*

Displacement:

$LBP \times B \times D$ = 1.35 x (Total tank volume, cargo and ballast)

$= 1.35 \times (1 + 0.37) \times 147\,000 = 271\,877\ m^3$

Light ship weight = $0.105 \times 271\,877$ = 28 547 tonnes

Weight of cargo and bunkers = 122 000 tonnes

Total displacement: = 150 547 tonnes

Say = 150 000 tonnes

Main dimensions:

Draught, T = 15 m

$LBP \times B \times 15 \times CB \times 1.029 = 150\,000$ tonnes

Specific gravity of sea water, 1.025 g/cm^3

Effect of hull plating and appendages, 4%

$LBP \times B \times CB$	$= 9718\ m^2$
LOA	≤ 275 m
LBP	$\leq 275/1.041 = 264.17$ m
Choose LBP	= $\underline{250\ m}$
Speed V	= 12.5 knots = 6.43 m/(sv)

Froude's number, $Fn = \dfrac{v}{\sqrt{gL}}$ $\qquad \dfrac{6.43}{\sqrt{9.81\ 250}} = 0.130$

Block coefficient (Ayre)

$C_B = 1.06 - 1.68 \times Fn = 1.06 - 1.68 \times 0.13 = \underline{0.84}$

C_B is set equal to 0.82 in order to confirm with restriction

$$B = \frac{9718}{250 \times 0.82} = 47{\cdot}41\ m$$

$L/B = \underline{5.27}$

$LBP \times B \times D = 271\,877 \text{ m}^3$

$$D = \frac{271\,877}{LBP \times B} = \frac{271\,877}{250 \times 47.41} = \underline{22.94}, \text{ say } \underline{23.0\text{m}}$$

Solution: LBP = 250 m
B = 47.31 m
D = 23.00 m
T = 15 m
C_B = 0.82

4. *First iteration*:

Observation: The critical capacity is *total volume*.
Dimensions should be checked against *volume*.

The following calculations are made partly with formulas and diagrams as given in Harvald (1983), Schneekluth (1980) and Henschke (1964).

Required propulsion power (Harvald, 1983):

$$L/\nabla^{1/3} = \frac{250}{(150\,000/1.025)^{1/3}} = 4.74$$

Propulsion power, P_B = 6500 kW (by diagrams)

Volume of hull up to deck at midships:

$V = L \times B \times D \times (C_B + 0.3 \times (D\text{-}T)/T) \times (1 - C_B))$ (Schneekluth, 1980),

$= 250 \times 47.31 \times 23\ (0.82 + 0.3 \times (23\text{-}15)/15 \times (1\text{–}0{\cdot}82))$

$= 23\,091 \text{ m}^3$

Volume of engine room (Henschke, 1964):

length, l = 25 m (by comparison with similar ships)

volume $= l \times B \times 0.9 D \times 0.75$

$= 25 \times 47.31 \times 0.9 \times 23 \times 0.75 = 18\,362 \text{ m}^3$

Required volume for 2000 tonnes of bunkers, 2500 m³

Volume *available* for cargo and ballast,
230 901 – 18 362 – 2500 = 210 039 m³

Required volume, 147 000 x 1.37 = 201 390 m³

Surplus 8 649 m³(4.3%)

5. *Intermediate conclusion*: the volume is also slightly too large for this approximate calculation. A reduction of volume can be obtained by reducing *LBP*, *D*, *B*, or C_B. The simplest way is to reduce *D*, the moulded depth. Before starting on more accurate calculations the moulded depth should be reduced to: 0.96 x 23 = 22.8 m. The next step would be to check the IMO ballast draught.

7.4.3 Carrying out the calculations

In practice the first rough calculations will be made by hand, but a computer should be used to do the calculations for detailed balancing. Several different combinations of main dimensions and fullness should be worked out. Measures of merit should be calculated for each combination. One computer program which is designed to do this is SHIPSHAPE (Marintek, 1987).

7.5 AVOIDING MISDESIGNS

Occasionally a ship, semi-submersible or other marine construction turns out to have a defect when taken into use. Some typical areas of misdesign and their consequences are outlined in the next section. There is no foolproof rule or theory which can prevent misdesigns, but the discussion below may help to avoid the more frequent mishaps.

When you think you have completed a design, ask yourself what may go wrong. Estimate the consequences of a failure and check that the precautions taken to avoid the failure are commensurate with the consequences. If you then think that there is any reason to suspect a weakness in the design, go over it again. Request more model testing and additional calculations in order to ascertain that the performance will be satisfactory.

The consequences of a failure should be compared with threshold values. Minimum threshold values may be taken as those laid down by authorities and classification societies for the aspects over which they have jurisdiction. Otherwise, economic considerations make it possible to develop threshold values.

The next section lists areas where misdesign may occur, the typical consequences of these misdesigns and precautions that may be taken to prevent them. The items mentioned are only examples . Do not assume that your design is defect-free after you have checked the examples in the list. The list is based on experience. Your design may be beyond experience.

New and innovative designs frequently have defects because so much attention is paid to new technology that problems in traditional areas are often overlooked and established expertise forgotten.

7.5.1 Typical misdesigns

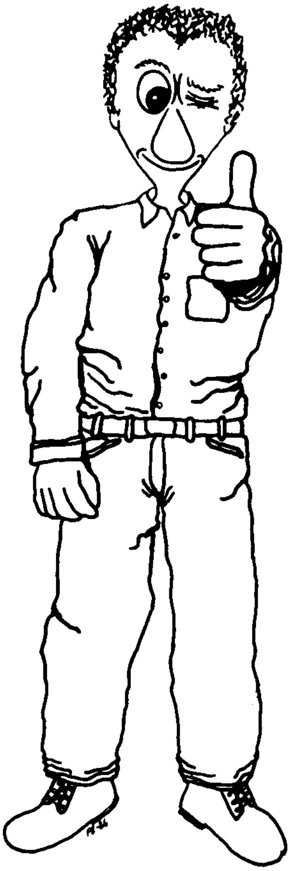
Some examples of misdesigns, their consequences, threshold values and preventive actions are listed below:

Area of misdesign:	Stability.
Consequences:	Increased ballast and reduced payload.
Thresholds:	International and national rules must be obeyed. See also the discussion on payload in Section 16.6 (Harvey, 1986 and Harris, 1986).
Preventive action:	At the design stage, make stability calculations for all important loading conditions. Make exact weight calculations. At the construction stage adhere strictly to the design weight limits. Record the weights of all items and compare with the estimated weights.
Area of misdesign:	Weight.
Consequences:	Reduced payload.
Thresholds:	See Section 16.6.
Preventive action:	Follow the same procedure as outlined for stability.
Area of misdesign:	Steering.
Consequences:	Excessive use of rudder. Change of rudder or steering engine.

Thresholds:	See Section 16.11.
Preventive action:	Model tests.
Area of misdesign:	Inclination due to moving cargo.
Consequences:	Excessive ballast pumping, reduced cargo handling speed, restrictions on using side doors.
Thresholds:	Restrictions are acceptable for a certain percentage (5–10%) of cargo handling cases and cargo handling time.
Preventive action:	At the design stage follow the suggestions given for stability and weight.
Area of misdesign:	Hatch cover/hatch coaming.
Consequences:	Leakages. Pontoons too heavy for the lifting gear.
Thresholds:	Non-containerized cargo: no leakage. Containerized cargo: leakage corresponding to normal weather exposure ashore may be tolerated.
Preventive action:	Exact calculation of stiffness of hull and movements of hatch coamings in a seaway. Compare the outreach and the SWL of the rig with the weight and stacking procedure of the hatch pontoons.
Area of misdesign:	Overload of propulsion engine.
Consequences:	Reduced speed, burnt valves and excessive wear.
Thresholds:	See Section 16.10
Preventive action:	See Section 16.10
Area of misdesign:	Cargo handling.
Consequences:	Reduced cargo handling speed or increased use of men and equipment.
Thresholds:	Schedule to be maintained. Estimated costs not to be exceeded.
Preventive action:	Simulation of loading/unloading operations and cargo flow.
Area of misdesign:	Vibrations and noise.
Consequences:	Reduced habitability, reduced earning power in the case of passenger vessels. Increased stress for the officers and crew on watch.
Thresholds:	See Chapter 16, Section 16.15.2.
Preventive action:	Thorough calculations, simulations and model tests.
Area of misdesign:	Mooring.
Consequences:	Increased time needed for mooring, unmooring and shifting. Increased manning on board or ashore.
Thresholds:	Manning rules, the manning plan, the planned schedule, estimated port expenses and prescribed equipment.
Preventive action:	Preparation of detailed mooring plan. Simulation of mooring operations.

8

ESTIMATING WEIGHTS, VOLUMES AND COSTS



8.1 INTRODUCTION

The design of marine structures is dependent on correct estimates of weights, volumes, centres of gravity, costs and capacity. The cost caluculation for the hull including superstructures and deckhouses should be based on a man-hour and weight calculation and on the price per man-hour and per tonne of material. The price per man-hour may vary greatly between countries. For many pieces of machinery and equipment the required capacity is calculated first and the cost estimation is based on this. However, preliminary cost calculations may be based on an estimate of the number of man-hours and the weight of the material.

In principle weight, volumes and centre of gravity may be calculated by four different methods:

1. General formulas, diagrams or charts.
2. Extrapolation from a known and similar object.
3. Simplified direct calculation methods based on approximate hull form and structural configuration.
4. Item by item direct calculation of the actual vessel.

The first two methods are generally used in the preliminary design. The third and fourth methods are used for the final calculations. The four methods are discussed below.

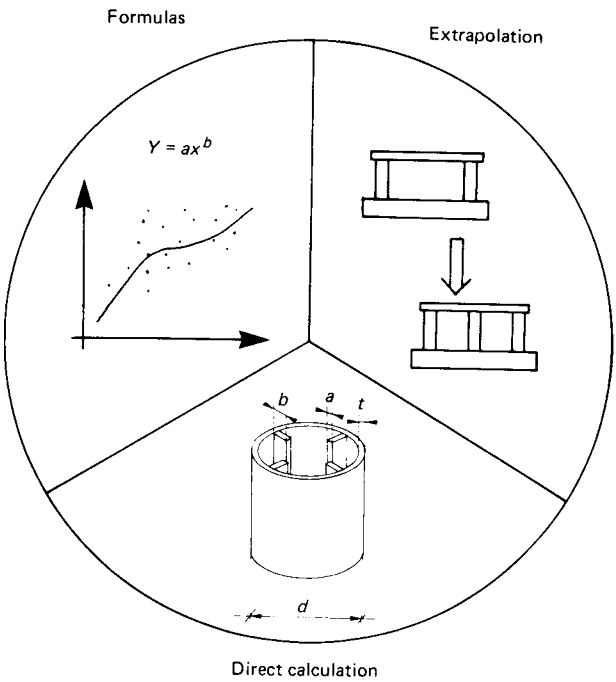


Figure 8.1 Three ways of estimating

8.2 GENERAL FORMULAS, DIAGRAMS AND CHARTS

Diagrams and charts are based on, or may be approximated by, formulas.

Formulas deal with different aspects of design ranging from the estimation of the overall weight of a complete semi-submersible to the derivation of the propulsive capacity of an azimuth thruster. A formula may be specific to only one type of vessel or to a particular set of conditions. A few general aspects of using formulas will be discussed below. In addition typical structures of formulas will be shown and some examples of different formulas will be given.

8.2.1 Critical features

For some vessels the capacity is limited by *volume* or *deck area*. For other vessels capacity is limited by *deadweight, stability* or *speed*. The selection of formulas must be based on the critical features of the design. Some formulas are based on the overall dimensions of the vessel; others are based on its deadweight, displacement or underwater dimensions. Some examples of vessels which have different critical features are shown below.

Area critical. Roll on/roll off ships; car carriers, including ferries; livestock carriers.
Volume critical. Chip carriers; container vessels; tankers, due to their requirement for ballast capacity; vessels for carrying liquefied gas; war ships.
Deadweight critical. Ore carriers; floating drilling platforms; cruise ships, including combined cruise ships and ferries; war ships; tankers for dense liquids.

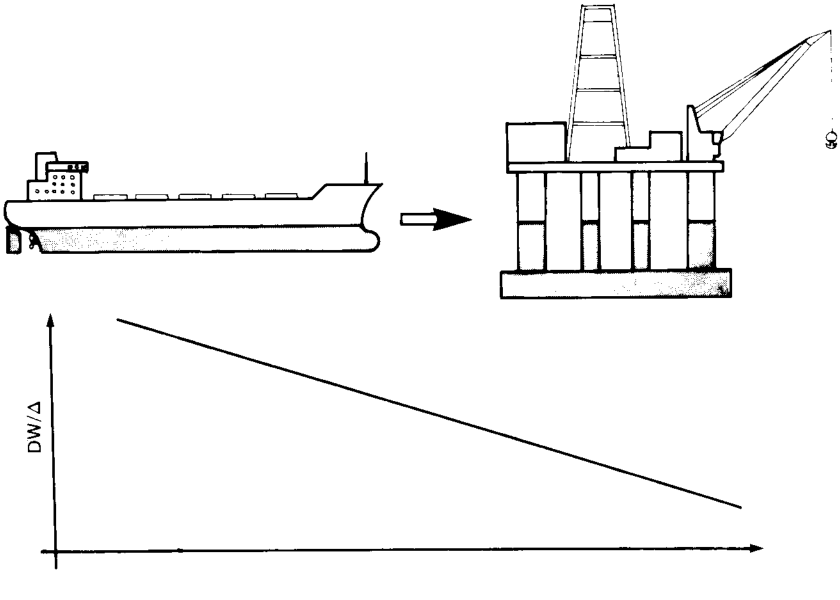


Figure 8.2 An illustration of how the payload/displacement ratio varies between different types of vessels

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Stability critical. Semi-submersibles and passenger vessels, because they must remain stable even when damaged; container vessels, because they carry deck cargo; fishing vessels, because of their low mass inertia in relation to breaking waves.
Speed critical. Patrol boats; rescue vessels, war ships.

In some types of vessels the deadweight or payload is only a small fraction of the displacement. This is the case for drilling platforms where the payload may be only 10% of the displacement. It is also true for cruise ships and modern ferries where the deadweight is around 20% of the displacement. An important feature of these types of vessels is that, as a rule, the draught is limited because the vessels must remain stable even when damaged. In these types of vessels a slight miscalculation of the light weight or stability may result in a considerable loss of deadweight or payload.

In other deadweight critical vessels, such as ore carriers, the deadweight is so large in relation to the displacement that a slight miscalculation of the light weight will not have a significant effect. Margins of uncertainty for deadweight estimates are discussed in Section 16.5.1.

In volume or area critical ships it is difficult or uneconomic to have a volume which is large enough to utilize the deadweight capacity which would be possible if the ship were loaded to its maximum permissible draught. Therefore in these types of vessels it is customary to base the design on a draught that is less than the minimum freeboard draught. Small adjustments in the freeboard draught may be made after the ship has been built.

Naval architects know the critical features of the vessels which they design and make sure to use formulas and methods adapted for the critical features.

8.2.2 The general structure of formulas

In general, costs are calculated as a function of *weight*. In a few cases costs are also calculated as functions of *volume* or *area*. Weight is usually calculated as a function capacity, i.e., deadweight, volume, area and power. Therefore, it is necessary to determine the *capacity* in some form before estimating the weight or the cost.

The most generalized formulas take a vessel as a whole and use total weight and total volume. In a more detailed design, formulas for different parts or systems of the ship are used to derive figures for weights and costs. It is common to split up in weights of the *steel, machinery, outfit* and *equipment* (sometimes referred to as *hull engineering*). The outfit and the equipment are often taken together. Figures for volume and area are split up in types of compartments, for example compartments for *cargo, passengers* or *ballast*, or *machinery bunkers*.

There are a variety of formulas. The division of sub-systems and parts may differ. Therefore it is necessary to check what is included in a formula before using it. The definitions of outfit, equipment, machinery and hull machinery cause problems most frequently but even for steel weight different definitions may be used.

Generally the *mathematical* structure of the formulas is as shown below.

$$J = a_0 + a_1 x_1^{b_1} + a_2 x_2^{b_2} + ... + a_n x_n^{b_n}$$

frequently reduced to,

$$J = a_0 + a x^b \text{ or}$$
$$J = a_0 + a_1 x_1^{b_1} + a_2 x_2^{b_2}$$

The basic philosophy behind the mathematics is that some items vary with the *mass* or *volume*, for example, the displacement or total cubic capacity. Other items vary in relation to the 'surface' of the vessel (Telfer, 1955). The cubic capacity is often expressed as the product of the three main dimensions, length, *L*, beam, *B*, and depth, *D*. This product is called the cubic number. The expression for 'surface' is derived by reducing the cubic number or the displacement by a power of 2/3.

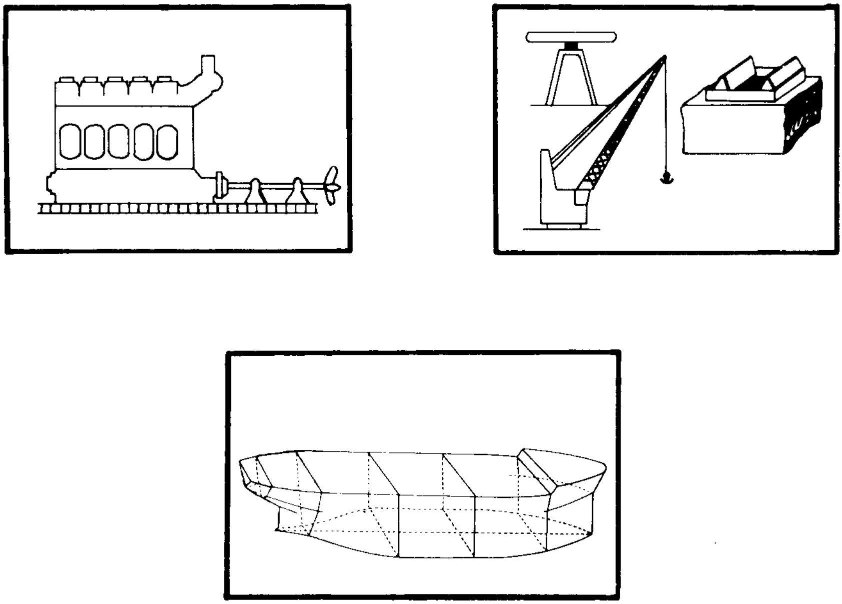


Figure 8.3 Traditional grouping of ship systems for weight calculations

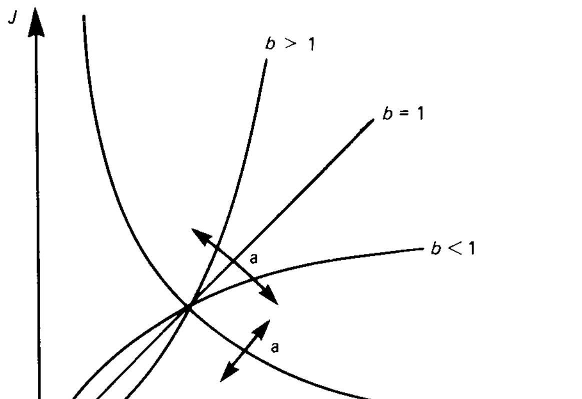


Figure 8.4 An illustration of how the graph varies with the coefficients a and b of the formula $J = a_0 + ax^b$

The formulas for the weight of the propulsion machinery, w_M, have the general form $W_M = ax^b$ where x is the power.

For *diesel* machinery the exponent b will be equal to one when all the engines are of the same type. When there is a large range of horsepower and the type of engine is changed as the power is changed b will have a value close to 0.7. The horsepower may be derived by

$$x = a_0 x_1^{b_1} \times x_2^{b_2}$$

where x_1 is the speed and x_2 is the wetted surface.

Experience has shown that formulas of this type produce crude, but basically correct, results. To reduce the range of uncertainty the formulas may be refined by adding factors that adjust the results to take into account features of the actual vessels. This is discussed below.

8.2.3 Correction factors

General formulas are based on normal or 'average' vessels. Differences between the average and the actual may be compensated for by using correction factors. Items taken into account by correction factors are usually related to:

- Number of decks;
- Number of bulkheads;
- Type of machinery, for example low, high or medium speed diesel engines or gas turbines
- Freeboard;
- The block coefficient (this may be included as a variable);
- Form of underwater hull, for example U-shaped versus V-shaped sections;
- Complexity, whether the vessel is austere or well equipped;
- Technical development, for example lighter steel structures, more complex machinery plants and more equipment;
- Material used, for example high tensile or mild steel;
- Ice reinforcements;
- Manning.

When using general formulas it is important to check what the formulas are based on and when they were derived and to make adjustments if relevant. Good sources of weight formulas include Schneekluth (1980) and Watson (1977).

In some cases correction factors are also used to adjust a general formula to make it correspond with the known values of a built vessel. This is good practice provided that the corrections are applied directly to those items where there are differences between the known vessel and the basis of the formula. For example, it may be more correct to check the part weights of steel and machinery and to use a separate correction factor for each part than to apply one correction factor to the overall weight estimate. Computer programs often ask the user for correction factors. Before supplying correction factors you should find out the procedure used in the program to adjust the calculations to fit known vessels.

It may also be important to make adjustments to a formula to take into account technical advances. This is because all formulas are based on *existing* vessels. These may be old and built to rules which differ from those which will affect your design.

8.2.4 Levels of precision

The level of precision to which the calculations are made should be adjusted according to the stage of the design work. So long as many different alternatives are compared it is acceptable to use formulas which produce overall estimates. These types of formulas calculate the total weight, volume or cost of a vessel on the basis of one or two overall variables such as the deadweight, cubic number and perhaps the speed.

More detailed formulas should be used when the number of alternatives is reduced to two or three. For instance, the steel weight may be calculated separately for:

- The hull, including, but not above, the upper continuous deck. This could be subdivided into fore and aft ends and the cargo section.
- The forecastle.
- The poop.
- Deck houses.
- Hatch coamings.

Similar categories may be envisaged for equipment, outfit and machinery. An even more detailed breakdown may be required for calculations which will form the basis of a binding offer.

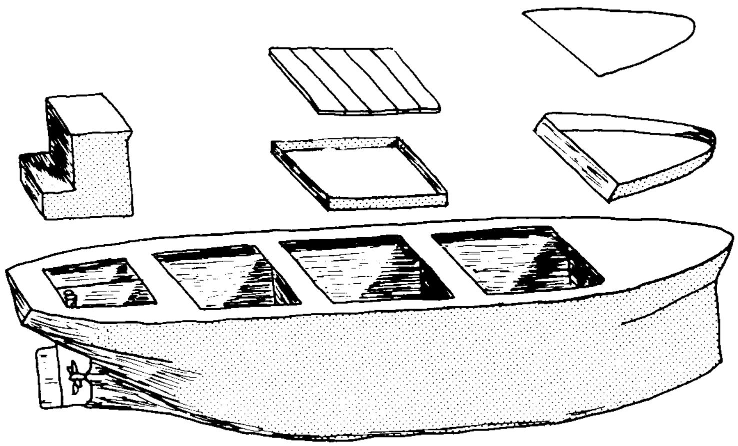


Figure 8.5 The steel weight is in most cases calculated separately for hull, superstructures, deck houses, foundations and outfit

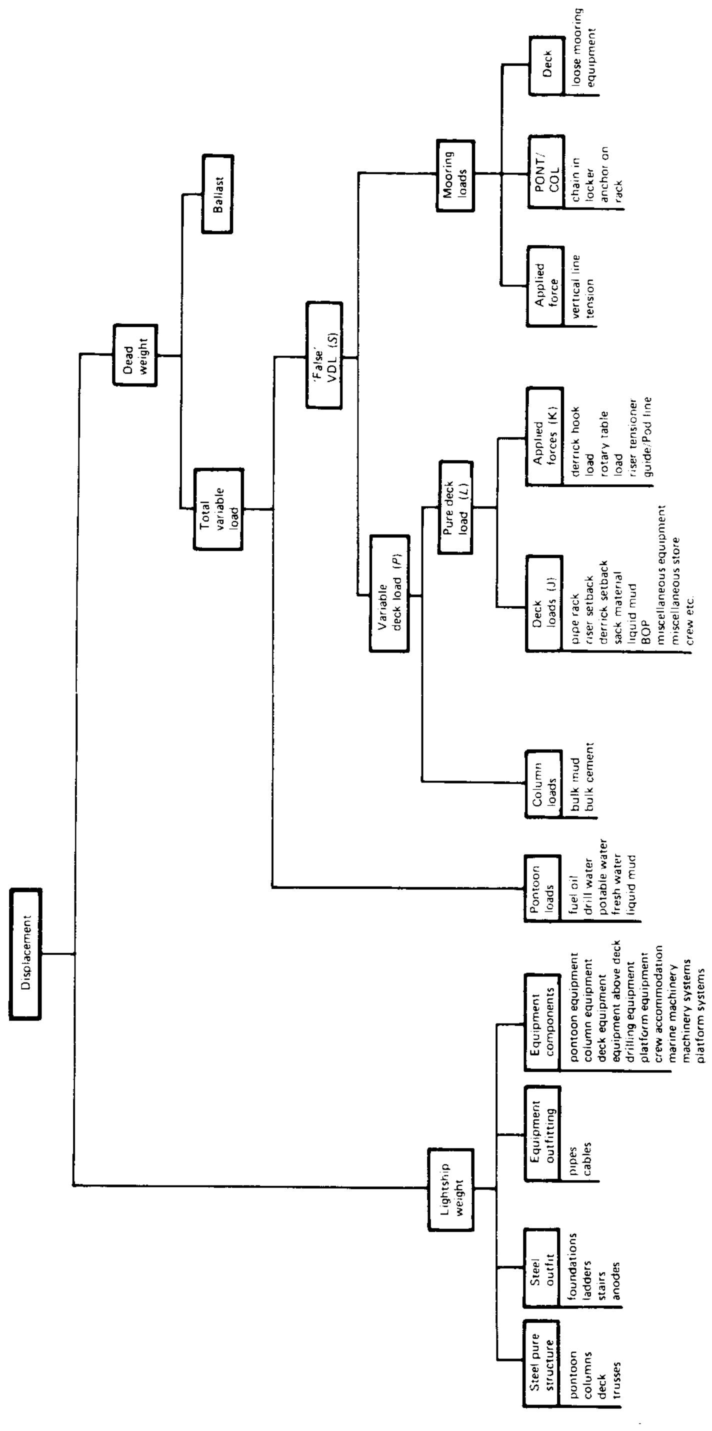


Figure 8.6 Example of weight breakdown of a semi-submersible taken from Haslum and Fylling (1985)

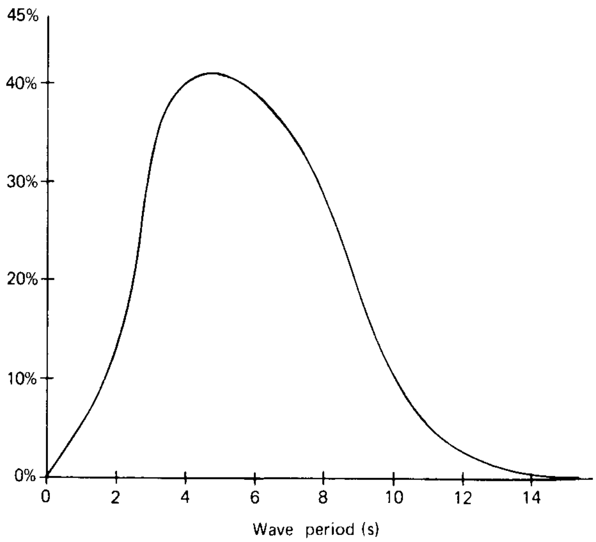


Figure 8.7 Typical wave spectrum of the North Sea (NPD76)

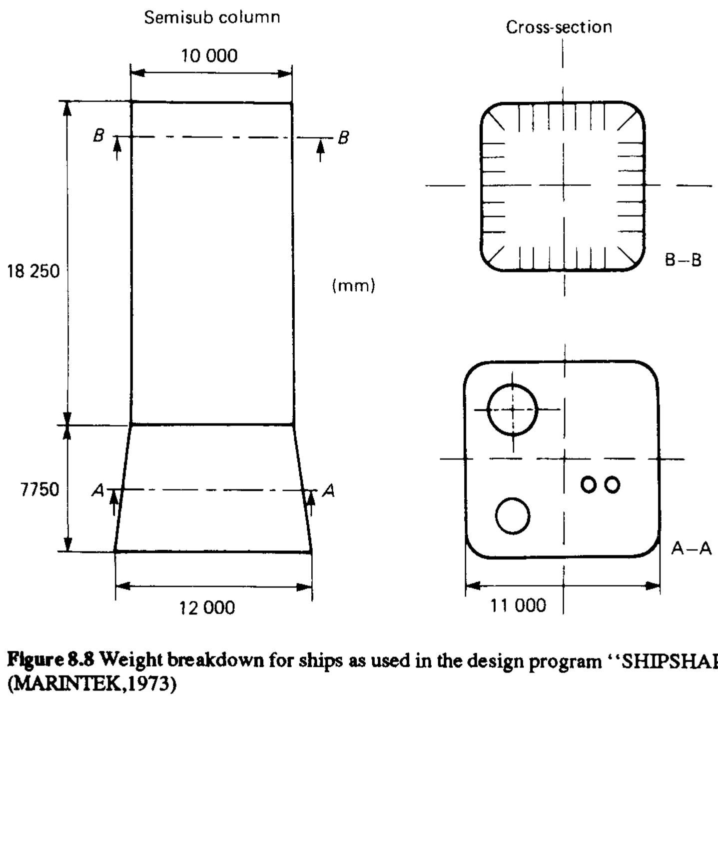


Figure 8.8 Weight breakdown for ships as used in the design program "SHIPSHAPE" (MARINTEK,1973)

8.2.5 Formulas for semi-submersibles

8.2.5.1 Example: Geometry of a two pontoon semi-submersible

The formula is based on Fagnastøl (1984).

Symbols
A_W = waterplane area of all columns taken together
Δ = displacement (tonnes)
C_{BP} = pontoon, block and waterplane area coefficient
L_P = pontoon length (m)
B_P = pontoon beam (m)
D_L = longitudinal distance centre to centre of columns
D_T = transverse distance centre to centre of columns
H_P = pontoon height (m)
K_B = centre of buoyancy
KG = centre of gravity
i_C = moment of inertia of column cross-section
N = number of columns
T = draught (m)
W = weight
GM_T = Transverse metacentric height
GM_L = Longitudinal metacentric height

Displacement = $2\,C_{BP} L_P B_P T$ for $T \leq H_P$
$2\,C_{BP} L_P B_P T + A_W(T - H_P)$ for $T > H_P$

Centre of buoyancy, (KB) $= \frac{1}{2}T$ for $T \leq H_P$

$$\frac{C_{BP} L_P B_P H_P^2 + \frac{1}{2} A_W (T^2 - H_P^2)}{2C_{BP} L_P B_P H_P + A_W (T - H_P)} \quad \text{for } T > H_P$$

$$GM_T = KB + \frac{B_P^2 + 3D_T^2}{12T} - KG \quad \text{for } T \leq H_P$$

$$GM_T = KB + \frac{Ni_C + A_W \frac{D_T^2}{4}}{2C_{BP} L_P B_P H_P + A_W (T - H_P)} - KG \quad \text{for } T > H_P$$

$$GM_L = KB + \frac{L_P^2}{12T} - KG \quad \text{for } T \leq H_P$$

$$GM_L = KB + \frac{Ni_C + A_W \frac{D_L^2}{4}}{2C_{BP} L_P B_P H_P + A_W (T - H_P)} - KG \quad \text{for } T > H_P$$

Weight and centre of gravity
Light ship weight $W_{LS} = 1.231\,\Delta_{Op}^{0.910}$

Light ship centre of gravity $(KG_{LS}) = 1.11\,H_{MDK}^{0.84}$ (m)

where Δ_{Op} is the operational displacement and H_{MDK} is the height from underside keel to main deck in m.

Period of heave $T = 2\,\pi \sqrt{\frac{m}{A_w}}$ (s) for $T > H_P$

$m = \Delta/g + a_m$ ($\frac{t}{m/s^2}$)

Where:

T = period of heave (s)
Δ = displacement (t)
g = gravitation constant = 9.81 (m/s²)

ρ = density of the fluid
a_m = added mass ($\frac{t}{m/s^2}$)
A_w = waterplane area

According to Haslum and Fylling (1985) the added mass may be set equal to the mass of the pontoons.

8.2.6 Formulas for ships

A few formulas that may be used to derive a set of main dimensions when the required capacity is known are given below. To complete a design the formulas for weight and resistance are also necessary. Because these formulas may be easily found in the literature they are not included here. However, a number of useful references are reviewed in Section 8.2.8.

The cargo hold volume, C, may be estimated by the following formulas.

Tankers:	$C = 210 \times 10^{-6} (LBD)^{1.09}$ (m^3)
Dry bulk, single deckers:	$C = 370 \times 10^{-6} (LBD)^{1.04}$ (m^3)
Shelterdeckers:	$C = 350 \times 10^{-6} (LBD)^{1.04}$ (m^3)

Formulas for geometry are based on Breda (1981). For single deck ships a regression analysis gives,

$$LBD = 1994 \times C^{0.962}$$

The length/depth (L/D), length/beam (L/B) and beam/depth (B/D) ratios vary only within a quite narrow range. Some typical values are:

$L/D = 12$
$L/B = 6.7$
$B/D = 1.8$

The L/D ratio is a basis of the requirements for the ship's longitudinal strength, and is often limited by the plate thickness in the deck. The B/D ratio is dependent on the stability requirements.

When these ratios have been determined the length may be expressed as follows:

$$LBD = L \times (L \times B/L \times (L \times D/L) = L^3/(L/B \times L/D)$$

$$L = (LBD \times L/B \times L/D)^{1/3}$$

Combining this with the regression formula we get,

$$L = 12.58\ (L/B \times L/D)^{1/3} \times C^{0.321}$$

Typical L/B and L/D ratios, for this type of ships are 6.7 and 12 giving

$L = 54.3\ C^{0.321}$ (Dry bulk, single deck)

Correspondingly,

$L = 56.9\ C^{0.306}$ (Tankers, $L/D = 12$, $L/B = 6.5$)
$L = 56.9\ C^{0.321}$ (Shelterdeckers, $L/D = 12.5$, $L/B = 7$)

The draught is determined by the freeboard regulations. A typical ratio is,

$$T/D = 0.75$$

8.2.7 Formulas for transport systems

Transport capacity;

$Q = N \times P$ in tonnes, m^3, number of units, per year

where:

N = number of ships
P = annual ship capacity (tonnes, m^3, number of units, etc.)

Ship transport capacity:

$P = C\,G\,A$

where:

C = capacity per ship (a quantitative measure)
G = loading factor, degree of utilization of ships' capacity
A = round trips per ships per year (1/(ship x year))
$A = \dfrac{365 - Z}{T}$ (1/year)
Z = time out of service (off hire) (days/year)
T = round trip time (days)
$T = T_S + T_H$ (days)
T_S = time at sea per roundtrip (days)
T_H = time in port per roundtrip (days)
$T_S = \dfrac{D}{24V}$ (days)
$T_H = 2\,CG/U + T_D$ (days)
T_D = Delays in port per round trip (days)
D = transport distance (nautical miles)
V = ship speed (knots)
2 = number of loading and unloading operations for one load of cargo
U = loading/unloading capacity (tonnes/day)

$$P = \frac{CG\,(365 - Z)}{\dfrac{2CG}{U} + TD + \dfrac{D}{24V}}$$

When required annual capacity per ship, P, is given:

$$C = \left(\frac{PD}{24V} + PT_D\right)/G\left((365 - Z) - \frac{2P}{U}\right)$$

$$V = \frac{PD}{24CG\left((365 - Z) - \frac{2P}{U}\right) - PT_D}$$

When number of days between calls, F, at the ports is also given:

$$F = \frac{365}{AN}$$

Capacity per ship, $C = \dfrac{Q}{ANG} = \dfrac{QF}{365G}$

8.2.8 References for formulas

Some references to useful formulas are briefly described below. Full reference details are given in the reference list at the end of the book.

8.2.8.1 Semi-submersibles

Fagnastøl (1984) derived the formulas for drilling platforms which were referred to in Section 8.1.5. He discusses the validity and uncertainty of the formulas and makes reference to the work of Haslum and Fylling (1985) and Penney and Riiser, 1984.

Haslum and Fylling (1985) discuss motion, position keeping and mooring as well as weight, deckloads and size optimization. They also give breakdowns of weights and costs for semi-submersibles, including equipment and well head costs.

Penny and Riiser (1984) present a review of the main dimensions of semi-submersibles and of the design procedure. They give weight formulas for steel, machinery, propulsion systems and equipment. They also discuss motion characteristics and the effect of different pontoon and column configurations.

Havig (1983) reviews the Norwegian regulations for semi-submersible structures and discusses the impact of the regulations on the design.

8.2.8.2 Ships

Breda (1981) presents a number of diagrams which show the relation between deadweight and displacement, main dimensions and deadweight, system weights and deadweight for tankers, bulkships and 'paragraph' ships. He also discusses the design of ships, main dimensions, fullness and lines, freeboard/draught relations, stability, weights, longitudinal distribution of displacement, trim, cubic capacity and compartmentation. The paper is in Norwegian.

Harvald (1983) reviews mathematical and physical models, ship resistance and propulsion, machinery–propeller interaction, model ship correlation and prediction of propulsion power. The topics are all discussed with a view towards practical use. Examples of resistance estimation by different methods are also included.

Keil (1982) discusses weight and cost estimation on the basis of weight and production costs of characteristic sections of a ship. The method is explained in Section 8.4.

Langenberg and Andersson (1977) provide a very thorough and comprehensive treatment of the design of a container ship. Their paper is an excellent discussion of the problems which often occur in design work and how to solve them.

Langenberg (1982) reviews design work and methods with an emphasis on planning and the problems associated with the establishment of a correct basis for design.

Schneekluth (1980) presents a very thorough discussion of the design of ships. His book contains many useful formulas, diagrams and definitions. It covers main dimensions, hull shape, weights, centres of gravity, general arrangements, equipment, rules, cost estimation, optimization and aesthetics. The book is in German.

Watson and Gifillan (1977) concentrate on cargo ships. They discuss the structure and development of design formulas and present actual formulas for deadweight carriers, volume carriers and linear dimension ships. Formulas are given on both a general and a detailed level. Watson's 1962 paper is taken as a starting point.

Watson (1962) presents formulas, diagrams and tables which describe the relationships between the main dimensions, speed, weight of hull, machinery and capacity. It presents a thorough discussion of the design aspects of the deadweight ship and volume carrier. An example is included.

Farstad (1985) is an 80 page book which covers all the major steps involved in the concept development, pre-planning, design and contacting of a fishing vessel. The appendix lists light ship weights and centre of gravity as a function of the cubic number of six different types of fishing vessels. The book is in Norwegian.

8.3 EXTRAPOLATING FROM KNOWN AND SIMILAR OBJECTS

The weights and costs of a known object, whether a drilling platform, ship or a part thereof, may provide data which can be used in making estimates. Because so much is dependent on correct estimates designers should try to use this type of data as often as possible. The data may be used in three different ways:

1. As a basis for using the total differential of a known formula.
2. To develop your own correction factors for known formulas.
3. To develop your own statistics.

These procedures are discussed below.

8.3.1 The total differential method

The displacement, Δ, may be expressed as a function of, for example, deadweight, dw, weight of hull, W_H, weight of machinery, W_M, and weight of outfit and equipment, W_E. The mathematics then go as follows:

$$\Delta = dw + W_H + W_M + W_E$$
$$\delta\Delta = \delta dw + \delta W_H + \delta W_M + \delta W_E$$
$$= \delta dw + \frac{\delta W_H}{\delta\Delta}\delta\Delta + \frac{\delta W_M}{\delta\Delta}\delta\Delta + \frac{\delta W_E}{\delta\Delta}\delta\Delta$$

Now, if the individual weights may be calculated by formulas of the type

$$W_i = a_i\Delta^{b_i}$$
$$b_i = \ln(W_{i1}/W_{i2})/\ln(\Delta_1/\Delta_2)$$
$$\delta W_i/\delta\Delta = a_i b_i \Delta_i^{b_i - 1} = b_i W_i/\Delta \text{ and}$$
$$\delta\Delta = \delta dw + \frac{W_H}{\Delta} b_H\delta\Delta + \frac{W_M}{\Delta} b_M\delta\Delta + \frac{W_E}{\Delta} b_E\delta\Delta$$
$$= \frac{\delta dw}{1 - \left(\frac{W_H}{\Delta}b_H + \frac{W_M}{\Delta}b_M + \frac{W_E}{\Delta}b_E\right)}$$

If a change in deadweight is desired, the corresponding increase in the displacement, Δ, will be according to the formula shown above. This formula is also known as 'Normand's number' after its inventor, J.A. Normand (see Normand, 1901). Fisher (1972) describes an application of Normand's method.

The changes in individual weight, W_H, may be derived in the same manner. Expression of the same type may also be derived when speed and main dimensions are the free variables. The expressions then become:

$$\delta\Delta = \frac{\delta dw}{1 - \frac{1}{\Delta}(W_H b_H + W_M b_M + W_E b_E)}$$

$$\delta\Delta = \frac{\delta W_H}{1 - \frac{1}{\Delta}(W_H b_H + W_M b_M + W_E b_E)}$$

$$\delta\Delta = \frac{\delta W_M}{1 - \frac{1}{\Delta}(W_H b_H + W_M b_M + W_E b_E)}$$

$$\delta\Delta = \frac{\delta W_E}{1 - \frac{1}{\Delta}(W_H b_H + W_M b_M + W_E b_E)}$$

In order to use these types of formulas it is necessary to know the displacement, deadweight and the part weights, W_H, W_M, W_B, of a vessel which is identical, except for its size, to the vessel being designed. This vessel is referred to as the 'basis' vessel below. If the basis vessel is not identical it is possible to correct for the differences. In addition, the exponents of the weight formula, b_H, b_M, b_B, must be correct.

The procedure may be used for calculating weights that vary with the dimensions, speed and endurance of a vessel but not for independent weights. Independent weights are weights which are independent of the vessel itself or its features. Their treatment is described below.

If the basic vessel lacks items which the new vessels will have, i.e., it is not identical to the new vessel, the weights of these items must be added to the weights of the basis vessel before the extrapolation is made. However, the condition is that these items vary with size and features of the vessel, i.e. that they not are independent. Examples include the weight of the bulkheads, which varies with the beam, the weight of the machinery which varies with the power and the weight of the bunker tanks which varies with the endurance.

Independent weights are weights that do not vary with the size or features of the vessel, but depend instead on some independent feature. A typical example of an independent weight is the weight of the loading/unloading equipment which varies with the capacity of the equipment. In most cases this capacity is specified based on the weight and type of the cargo and is not directly related to the vessel. Weights of independent items should be subtracted from the weights of the basic vessel before the design weights are calculated, and calculated separately. The designer should be able to distinguish between items which have *independent* and *dependent* weights.

The total differential method provides an acceptable degree of accuracy provided that the dimensions and the capacity of the basis vessel are not too different from the dimensions of the vessel being designed. An example of its use is shown below.

8.3.1.1 Example: Use of the total differential method

This example is based on a Royal Institute of Naval Architects (RINA) paper by Carryette (1978).

Ship Design: Dependent weights

$L, B, D,$ and T are constant, i.e., the basis ship and the ship being designed have the same main dimensions. A small change in ship speed, V, leads to:

Displacement change: the block coefficient, C_B is given by $C_B = k_1 V^{-0.6135}$

$$C_B = k_1 V^{-0.6135}$$

$$\frac{\partial C_B}{\partial V} = k_1 (-0.6135 V^{-0.6135-1}) = -0.6135\, k_1 V^{-0.6135}/V$$

$$= -0.6135 \frac{C_B}{V}$$

$$\delta C_B = -0.6135\, C_B \frac{\delta V}{V}$$

where V is the base speed.

With constant main dimensions it is obvious that the product

$L B T \rho = N$

is constant.

Thus the displacement, Δ, is:

$\Delta = N C_B$ and

$$\delta\Delta = N\,\delta C_B = \Delta\,\frac{\delta C_B}{C_B}$$

$$= \Delta\,(-0.6135\,\frac{V}{V})$$

Change of engine power, P

$$P = k_2\,V^3\Delta^{2/3}$$

$$\delta P = k_2\,(3\,\frac{V^3}{V}\,\Delta^{2/3}\delta V + V^3\,2/3\,\frac{\Delta^{2/3}}{\Delta}\,\delta\Delta)$$

$$\delta P = 3P\,\frac{\delta V}{V} + 2/3\,P\,\frac{\delta\Delta}{\Delta}$$

Change of engine weight, W_E

$$W_E = k_3 P$$

$$\delta W_E = W_E\,\frac{\delta P}{P} = W_E\,(3\,\frac{\delta V}{V} + 2/3\,\frac{\delta\Delta}{\Delta}$$

$$= W_E\,(3\,\frac{\delta V}{V}\,2/3\,(-0.6135)\,\frac{\delta V}{V}$$

$$W_E = 2.591\,W_E\,\frac{V}{V}$$

Change of deadweight, d.w.

$$d.w. = -(0.6135\Delta + 2.591\,W_E)\,\frac{\delta V}{V}$$

This means that an increase in speed will reduce the deadweight because C_B is made smaller and the engine weight is increased.

Independent weights

While the basic ship had two portal cranes, each weighing 176 tonnes, the vessel being designed will have three rotatable cranes, each weighing 38 tonnes. Thus 238 tonnes will be saved and this can be added to the deadweight.

8.3.2 Developing corrections and adjustments

Because they know that any general formula or diagram is based on an average of many vessels, all experienced designers use data from known designs to see how these data relate to the general formulas. A common way of doing this is to plot your own data on a chart where graphs of the general formulas have already been drawn. It is then possible to see at a glance how the general formulas differ from your own data. The necessary corrections and adjustments can then be made. Any general formula will have terms that may be used to adjust it to specific conditions or features. Study of terms may give useful indications of how to make adjustments to the formulas.

The adjustments and corrections should be based on *individual weights*. As a minimum requirement the weights should be subdivided into weights for steel, machinery, outfit and equipment. If the corrections are based only on the total weight, the real reason for discrepancies with the general formulas may be concealed and corrections could lead to incorrect results.

When developing corrections and adjustments the designer should know:

- The reasons why his own data do not coincide with data derived from the general formulas.
- How the features of the new design relate both to vessels whose particulars are known and to the vessels from which the general formulas are derived.

The example below illustrates the type of reasoning used when a general formula is applied to a known ship in order to assess how accurate the formula will be for a design which is similar to the known ship.

8.3.2.1 Example: Verification of general formulas

The *weights* of the known vessel in relation to the values derived by the general formulas are:

Steel: 5% less than the formula value
Outfit: 10% more than the formula value
Machinery: the same as the formula value

The following considerations are valid:

1. *Steel.* There has been a general tendency to reduce the requirement to section modulus of ships (see for example Lind and Erichsen, 1981 or Meek, 1985). It is therefore assumed that it is correct to estimate a steel weight of 5% less than that given by the general formula.

2. *Outfit.* There is a tendency to increase the outfit of ships. However, the known ship has much wider hatch openings and heavier cargo handling gear than the design. As a first approximation we will assume that the outfit weight of the design is only 5% higher than the value given by the general formula.

3. *Machinery.* The type of main engine and auxiliaries and the r.p.m. are the same as in the known ship. We therefore assume that the values derived by the general formula are sufficiently correct.

8.3.3 Regression analysis

Determining variables may be identified and formulas for weights, costs and other variables may be derived by regression analysis. Programs for carrying out regression analysis may be run on any personal computer. It is possible to test how well different formulas suit a set of data by running a computer program. As a rule the programs use the 'sum of least squares' to test the suitability of a formula against given data.

$S = \text{min: } \Sigma (y_i - f(x_i))^2$

where y_i is the *observed* value (a data point) and $f(x)_i$ is the corresponding value given by the formula $f(x)$.

In marine design two typical expressions of $f(x)$ are:

$f(x) = a_0 + a_1 x_1^{b_1} + a_2 x_2^{b_2} + \dots + a_n x_n^{b_n}$ and

$f(x) = a_0 x_1^{b_1} x_2^{b_2} x_3^{b_3} \dots x_2^{b_n}$

The second equation may be transformed to

$\ln f(x) = \ln a_0 + b_1 \ln x_1 + b_2 \ln x_2 + b_n \ln x_n$

Values of a and b that minimize the sum of squares can be determined by regression analysis.

A linear regression analysis will determine the *significance* of each of the variables as well as the correlation between the formula tested and the data points.

By testing different expressions and variables and retaining variables with acceptable significance and expressions with good correlation it is possible to derive formulas that are reasonably accurate. The level of significance which is acceptable must be determined separately for each case depending on the spread of the data.

This method requires much insight and expertise on the part of the designer because he must choose which variables will be independent and which formulas should be tested. Regression analysis provides only a basis for the evaluation of the designer's suggestions. It is simply an analysis of formulas suggested by the designer, but does not guarantee that the formulas analysed are the best. Thus, the use of regression analysis is in itself no guarantee that you will arrive at formulas that will produce sufficiently accurate estimates. A brief description of the use of regression analysis may be found in Chapter 13 of the book by Montgomery (1976).

A typical example of the kind of reasoning which may be applied when establishing formulas to be tested by regression analysis is discussed in Erichsen (1971). In dealing with the problem of establishing a formula for the calculation of the weight of items related to 'hull engineering' Erichsen states:

1. When the horsepower is nil, there may still be a ship, so hull engineering weights may be other than zero when the horsepower is nil.
2. When the cubic number ($L \times B \times D$) is zero, there is no ship and no hull engineering.

By this he excludes the two formulas below from consideration:

$$W_{HE} = a\,(BHP)^b$$
$$W_{HE} = a + b \times (L\,B\,D)$$

Before leaving the topic of regression analysis, it should be pointed out that *fitting a curve* through your own data points may be as good a method as any other.

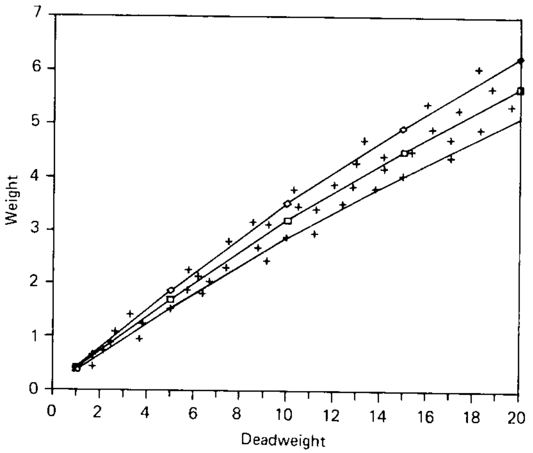


Figure 8.9 Data points of steelweight plotted against deadweight, with a 'general' curve and curves indicating the upper and lower limit of the weight

8.3.4 Your own statistics

You may have so much data from your own sources that you may wish to develop your own statistics and formulas. The first step should be to plot your data on logarithmic paper and to try to draw a straight line through the points. Logarithmic paper should be used because both weight and resistance formulas generally have the structure $y = ax^b$, giving $\log y = (\log a) + b \times (\log x)$, when the logarithm is taken. The plot of this second equation is a straight line on logarithmic paper. When plotting your data it is important to base your dependent variable, for example, outfit weight, on some logical independent variable such as, for example, the cubic number, $L \times B \times D$. This was discussed in the previous section.

One problem with this method is that it may be difficult to acquire enough data and to isolate the determining variable. However, the problem may be eased by using determining variables that are similar to those used in general formulas. Regression analysis may also be used, as discussed in Section 8.3.3.

8.4 SIMPLIFIED DIRECT CALCULATION

This method is based on the fact that all structures have a large degree of continuity. There are few abrupt changes in the volume of material and the changes that exist are easily identified. Accordingly, weight is estimated by calculating the weight per unit of length or height for typical sections. The complete weight is found by integrating over the length or height.

The structural parts that are continuous in the direction of integration or which occur at regular and frequent intervals, such as floors, are included in the weight per unit length. Members which are not continuous in the direction of integration, such as the bulkheads of ships or the decks of semi-submersible columns, must be calculated separately. The weight of any structure may be estimated in this way but in practice it is the steel structure that has the majority of longitudinal members. This method of calculation is therefore used most commonly for calculating steel weights.

In its most simple form, the calculation of the section weight is done only for the section amidships and at the forward and aft perpendicular. The midship weight per unit of length is assumed to be constant for $\pm 0.2\,L$ from amidships as is the section modulus. The weight per unit length between $\pm$ 0.2 L and the forward and aft perpendicular, respectively is assumed to vary in accordance with some mathematical expression that takes the shape of the hull and the required section modulus of the vessel into account. The required section modulus is defined by the rules of the classification societies. By these rules a vessel with the same cross-section over its entire length would have a linear decrease in weight per unit length from the $\pm$ 0.2 L midship area to the perpendiculars. A ship-shaped vessel will, however, have a steeper decrease at the ends. Usually it is assumed that the reduction may be expressed by the formula

$W_x = W_n \sqrt{ax + b}$ where
W_x = Weight per unit length between the perpendiculars and $\pm 0.2\,L$ at amidships
W_n = Weight per unit length within $\pm$ 0.2 amidships
If for example:
$W_{AP} = 0.20\,W_n$
$W_{FP} = 0.15\,W_n$ then
W_x for (AP $\leq x \leq 0.3\,L$),
$x = 0 \rightarrow W_x = 0.2 W_n$ and
$0.2\,W_n = \sqrt{b}\,W_n$ or $b = 0.04$
$x = 0.3\,L \rightarrow W_x = W_n$ or
$W_n = W_n \sqrt{a\,0.3\,L + 0.04}$ giving $a = \dfrac{1 - 0.04}{0.3L} = \dfrac{3.2}{\sqrt{L}}$ and
$W_x = W_n \sqrt{x\,3.2/L + 0.04}$
W_x for $(0.7\,L \leq x \leq FP)$
$x = 0.7\,L$ gives $W_n = \sqrt{a\,0.7L + b}\,W_n$
$x = L$ (FP) gives $0.15\,W_n = \sqrt{aL + b}\,W_n$
accordingly $1 = 0.7L\,a + b$ and
$0.0225 = aL + b$
$0.9775 = -0.3La$ $a = -3.26/L$ $b = 3.2825$ and
$W_x = W_n \sqrt{x\,(-3.26/L) + 3.2825}$

Direct calculation of individual components of the actual vessel is a method that is frequently used for final calculations. It is also used for preliminary calculations when the design is so distinctive that data or formulas from existing vessels cannot be used. The calculation may be carried out in two different ways:

1. Based on the measurements of the component in question and the specific gravity and cost of the material and labour it requires. Every part of the vessel should be taken into account.
2. Based on a characteristic dimension of the individual components and a known weight and cost per unit of the characteristic dimension.

8.5.1 Calculating every component

In principle it is simple to calculate every component. By reference to the specification, drawings, scale models and piece lists everything that is part of a vessel can be counted. Their volumes can be calculated. The weight and costs can be determined based on specific gravity and unit costs. The vessel's centre of gravity can be measured from drawings or a scale model. The problem is to remember to include all components and to correctly estimate the amount which should be added to cover details which are not included and unforeseen additionals. In any case it is only the net weight of the material that is measured. A certain amount of, for example, steel, piping and wood is lost during fabrication. This percentage must be estimated and added to the calculated net amount in order to find the total cost of the material.

If you are working this out by hand it is best to have at least two independent groups carry out the calculations. By keeping accurate accounts of purchased and built-in weights you can get a fairly accurate idea of the scrap percentage. Figures for waste and scrap percentages may also be found in the literature. See, for example, Kerlen (1985).

A computer aided design (CAD) system may make it easier to ensure that all components are taken into account. If properly used, the computer will provide information on any component associated with a vessel. It may thus be used to maintain check lists of items which have or have not been included. However, you must be absolutely certain that every component is included in the computer system before it is used for this type of calculation. In any case, the results obtained from the computer should be compared with the weights and costs of built vessels.

8.5.2 Using cost and weight per unit

This method is similar to calculating every component. A characteristic dimension of a component is calculated, measured or counted and the weight cost and centre of gravity are obtained by multiplying by some unit weight and cost. Some typical examples are:

- The number of passengers multiplied by the weight of bedclothes, tableware, luggage and estimated weight per individual.
- The inside area of tanks is determined and multiplied by the weight per unit area of coating.

The main challenge in this type of problem is to keep account of what has and has not been included. A good computer-based system is useful for this purpose. This method may be used in combination with other methods, but you must make sure that nothing is counted more than once, or (and this is more likely) overlooked.

8.6 ASSESSING ERRORS

Weights and costs are the basis of any bid, and errors in the calculations may have a decisive influence on whether the bid is economical. Every effort should be made to check that the calculations are correct. This should include making estimates by two independent methods, comparing previous estimates with real values and comparing the current estimate with previous estimates.

The reliability and accuracy of an actual estimate may be assessed on the basis of how your previous estimates have been in comparison with real values. Estimated weights, centres of gravity, costs and volumes of built components should always be checked against the actual end values.

The total weight of a vessel and its centre of gravity should be measured during the inclining experiment. Costs are calculated by the accounting department. Volumes may be, and frequently are, measured by testing the tanks. Small tanks are usually filled under controlled conditions but air is used for larger tanks. In the latter case the volume can be checked when cargo and bunkers are taken on for the first time and the loaded quanitites can be monitored by the cargo owner or a stevedore.

When comparing the estimated values with the actual end values of built components you should establish the error ratio of past estimates, E.

The check of calculated values should be made by calculating the ratio between calculated and real values. This is the error ratio, E.

$E = V_R/V_c$
V_c = calculated value
V_R = correct value

E should be plotted in a histogram as in Figure 8.10.

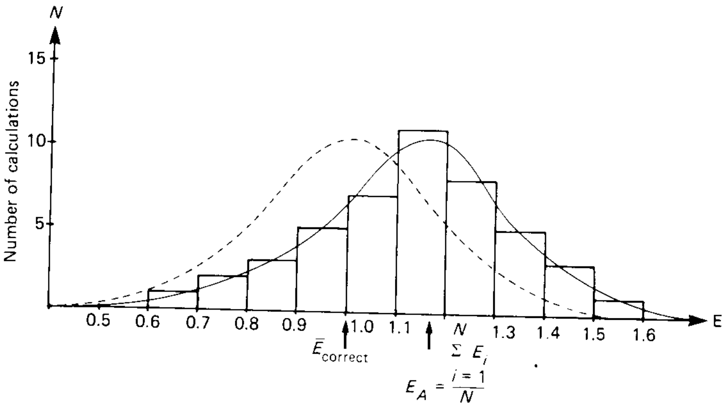


Figure 8.10 Frequency of errors in cost calculations. Number of calculations plotted against the ratio between real and calculated cost to form a histogram. Real costs have been taken from actually built vessels. The histogram is used as basis for developing a continuous error distribution function

In Figure 8.10 the *cumulative* distribution of errors is:

Error ratio:	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Total number of calculations:	1	3	6	11	18	29	37	42	45	46
Total number of calculations in %	2	6.5	13	24	39	63	80	91	98	100

The average value of E for each type of calculation should be derived,

$$E_A = \frac{\sum_{i=1}^{n} E_i}{n}$$

If E_A differs from 1, there is a systematic error in the calculation. The cause of the error must be found and corrective measures taken. If it is not possible to find the cause of the error or to make the necessary corrections, subsequent calculations must be adjusted by the average error factor, E_A. Thus:

$$V_{corr} = V_{calc} \times E_A$$

where V_{corr} is your estimated value corrected for systematic error and V_{calc} is your estimated value.

8.7 APPLICATION OF PROBABILITY THEORY

8.7.1 The risk of losing on a contract

Figure 8.10 shows the graphs of two density distributions and a histogram of the relationship between the estimated and the actual end values. The *expected* or *average* error was calculated in Section 8.6.

A density distribution of the relation between previously estimated and real costs may also be used to assess limits of the relationship between new estimates and actual costs. For example, according to Figure 8.10, the actual cost has never been more than 1.6 times the estimated cost. If the *price* should be set high enough to avoid any probability of losing on a contract, the price would have to be set at 1.6 times the estimated cost according to Figure 8.10. Correspondingly, if you can accept an 80% probability of losing on a contract, the price should be set at about 1.3 times the estimated cost.

The figures show that you may be forced to quote high prices when the relation between the actual and the estimated cost has a wide spread and you want to secure yourself against losses. In a normal situation, with stiff competition, it may be impossible to carry out such a pricing policy. Therefore, it is very important to make cost estimates as accurate as possible and to avoid a large spread between actual and estimated cost. A complete revision of the estimation procedures may be justified if the spread is greater than 10%.

9

IDEA GENERATING AND PROBLEM SOLVING

A part of the design process is to find new methods of earning money in an existing market or to create opportunities in a new market. The new market may arise as a result of a brainstorm or through systematic search, trial and tests. Some methods which may assist in this process are discussed below. An extensive survey of more than thirty different methods of design may be found in Jones (1982). Some methods are best suited for group work. Others may also be used by designers working alone.

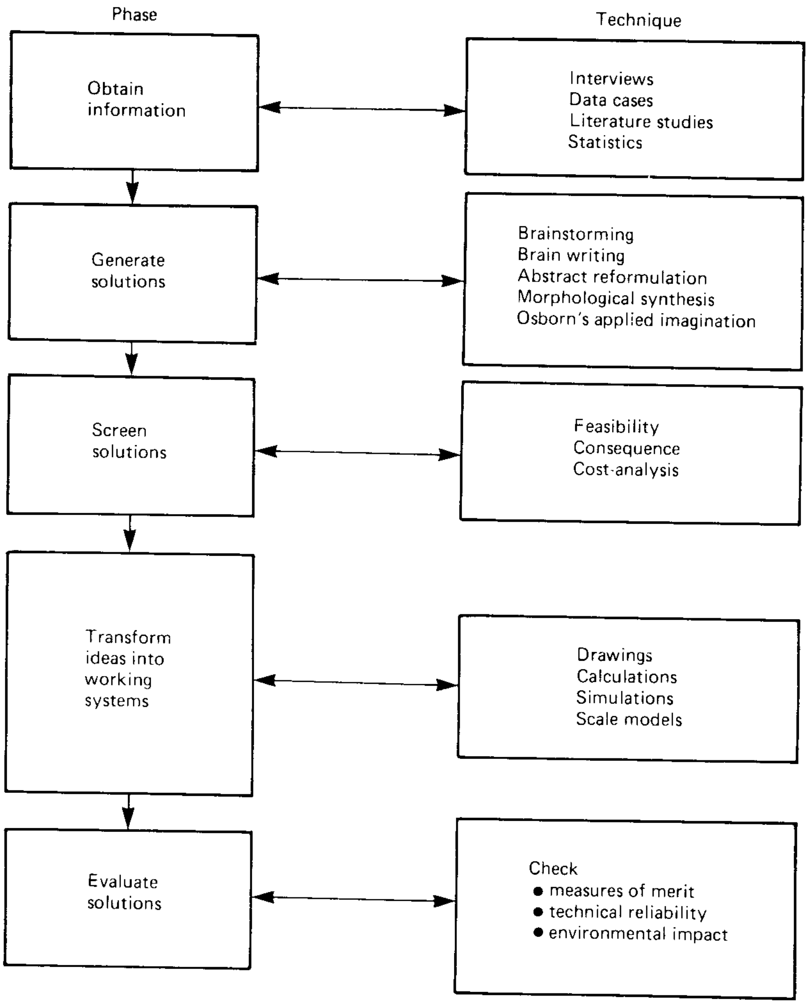


Figure 9.1 Phases and techniques in design

9.1 CLARIFICATION OF AIMS

For people who are not trained in a particular method of idea generation it is an advantage if the aim of the work is clearly defined and well understood by everyone who is taking part. One good way to start is to discuss the aim or problem to be solved. The participants in this discussion should include both those who posed the problem and those who are going to find the solution. In many cases this will mean that management, designers and, frequently, customers will have some part in the discussions.

A memorandum which contains an unambiguous definition of the aims and problems should be prepared after the discussion. Even when working alone it is a good idea to prepare a written formulation of the problem at the outset. In this way the main aim of the work can be kept in mind, even if you are distracted by side issues or unnecessary detail during the course of the project.

The formulations of aims has been dealt with in the examples given in Chapter 3. The next section continues this discussion.

9.2 ABSTRACT REFORMULATION

This subject was briefly touched upon in Chapter 3. The method works best when two or more people can work together. However, an individual working alone will also benefit from forcing himself to reformulate his problems in more abstract terms.

In general terms, abstract reformulation makes it possible to put a problem into a wider perspective and encourages solutions that involve a greater part of the totality. The following examples illustrate this.

Original formulation. Design an underwater wellhead.
Possible solutions. Assemblies of pipes, valves and control units located underwater, presumably on the sea bed.

Abstraction 1. Design a control and production system for an oil well on the sea bed.
Possible solutions Any system that can lift oil from a well located on the sea bed by any means. For example, semi-submersibles, jackets, jack-ups, ships and templates can be used as a basis for a production/processing/control-system for oil above or below the water surface.

Abstraction 2. Design a system for harvesting energy from an underwater oil well.
Possible solutions. Any system that can harvest energy contained in oil delivered on the sea bed, for example transformation of oil to electricity, heat or gas by any type of processing and support system.

Abstraction 3. Design a system for exploiting the energy contained in an offshore oil field.
Possible solutions. Any system that can transfer the energy contained in an oil field located below the sea bed to onshore facilities. Examples include underground processing plants, tunnel connections and all the solutions mentioned previously.

If the abstraction is carried too far it may open up solutions which are different from those first thought of. As a result the possible solutions become much more comprehensive. They presume the involvement of many more people and require much more time and manpower than originally envisaged. In addition, the possible solutions may become quite removed from the field of interest of the company who initiated the design work.

A way to limit abstract reformulations is to discontinue the reformulation when you have reached *one level higher* than directly corresponds to your principal's field of interest.

For example, a valve manufacturer may be very interested in developing a good wellhead design, but it may be beyond the scope of his interest to take part in the development of a new energy transfer system for offshore fields. Considerations of this kind turn the question of any high level abstraction into a management problem. For this reason management, and sometimes customers as well, should take part in the problem formulation in order to ensure that the formulation is within the scope of their interests.

If it is evident that solutions which may emerge on higher levels of abstractions will be of advantage to all concerned it is the responsibility of the designers to advise the management, and possibly the customers, of this fact.

9.3 MORPHOLOGICAL SYNTHESIS

This method is well suited both for individuals working alone and for group work. The object is to list possible solutions to part problems or subgoals, combine these solutions in a random way and then use the random combinations as a basis and stimulus for generating ideas and new solutions. The following example illustrates this method.

Aim. Find transport tasks for ultra large crude carriers (ULCCs)
Considered areas of alternatives. Cargo, packing, cargo handling.
Possible solutions in the alternative areas.

Cargo	*Packing*	*Cargo handling*
Liquids	None	Pump
Grain	Container	Lift
Coal	Pallet	Walk
Passengers	Bags	Roll
Cars	Strapped	Float
Ore	Preslung	Blow
Wood	-	-
Pulp	-	-

Examples of combinations and their consequences

A. Wood + Bags + Pumps

1. The wood should be liquid to be pumped
Liquid wood or paper pulp may be carried in bags. It may be 'Dracones' towed behindf the ship and pumped ashore.
Bags may be carried on deck.
Liquid pulp may be carried in the tanks.
2. Why not produce the pulp on board?
Offer ULCCs as platforms for wood processing.

B. Liquid + Strapped + Pumped

1. In order to be strapped the liquid has to be frozen, to be pumped it should be a liquid. Examples include:
Transport of ice from a cold region to a warm region.
Ice chunks stored on deck, melting water led into tanks and pumped ashore on arrival.

C. Cars + Container + Float

Cars preloaded in floating multi-storey parking structures that are:

Floated over a submerged deck.
Straddled over a submerged deck.

The total number of possible combinations based on the list is 8 x 6 x 6 = 288. Some of these solutions may be obvious, for example the idea that Ore + None + Lift leads to rebuilding a tanker into an ore carrier. Sometimes it is difficult to investigate all possible combinations. In that case you should look into the most unusual solutions first because these will lead your thoughts away from traditional ideas and into new concepts.

The reason for putting a suggestion aside should be recorded in the form of a condition that must be changed before it is worthwhile considering the suggestion again. For example:

Idea. Carry liquid pulp in tanks.

Set aside because: there are too many stiffeners inside the tanks to make it possible to discharge the liquid over a reasonable timespan.
Re-evaluate if: there are changes in tank design or discharge time is not important.

9.4 VALUE ANALYSIS

This method may be used both by individuals working alone and when two or more people are working together. The method is perhaps best suited for detailed design.

Value analysis means to analyse the function a design should have, check the general market cost of components which perform these functions and finally use these costs as a measure of an acceptable 'value' of the design. By this it is meant that the value of the components of your design must not be greater than the cost of buying a simple solution in the open market. This creates pressure to come up with a design which is simple and reasonable.

Although this method is best suited to detailed design, the philosophy behind the method may be, and frequently is, applied to general questions. An example of this is the assessment of the value of large tankers. Today this is done on the basis of the value of the stock of laid up VLCCs and ULCCs. New tanker designs must be competitive with this in mind.

More specific examples include:

- Smoke detectors for domestic use as a measure of the value of a smoke detecting system.
- Domestic freezers and refrigerators as a measure of the value of built-in refrigeration equipment and cold stores for provisions.
- A harpoon gun as a measure of the value of equipment for throwing a line ashore.
- Walkie-talkies as a measure of the value of a small scale communication system.

In actual detailed design the basic functions to find a solution for include:

- Support. Value = the cost of a piece of steel.
- Fix. Value = the cost of a bolt and nut or, perhaps, glue.
- Separate. Value = the cost of a gasket and lid.

Some of the examples mentioned above are in common use today. However, when they were introduced it was on the basis of value analysis thinking.

9.5 BRAIN STORMING AND BRAIN WRITING

These methods are designed for group work and function best for groups. However, individuals may use the method as an impetus to write down ideas.

There are three main steps in brainstorming:

1. Statement of the problem to be solved.
2. Generation of ideas for the solution.
3. Evaluation and selection of ideas.

The statement of the problem to be solved has been discussed in Chapter 3 and in Chapter 9, Section 9.1.

The generation of ideas is carried out in a group. Individuals suggest solutions to a chairman or administrator. The chairman writes down the suggestions so that everyone can see them. This generation of ideas by several people stimulates thinking. There will be a good production of ideas, especially at the beginning of a session.

It is important that the participants make no negative comments during the idea generating session. Negative comments may discourage other participants from coming forward with suggestions. Anyone who ridicules any idea should be asked to leave the session.

After a while the idea generation may slow down or the chairman may feel that enough solutions have been generated. The generation session is then brought to a halt, at least temporarily. As a next step the administrator suggests *combinations* of some of the generated ideas and takes down proposals based on these combinations. However, sooner or later it is necessary to shift to the *evaluation* of the ideas which have been generated.

The evaluation should also be carried out by the group. During the evaluation ideas for solving problems linked to special solutions may come up. Evaluation may be carried out on the basis of the *consequences*, *feasibility*, *cost*, or the *time required for implementation* of the solutions. The evaluation should be carried out in the sequence indicated by these four points. This will make it possible to discard many suggestions without too much work. Evaluation of solutions is discussed in Section 9.9.

One tactic used in this type of session is so-called *negative brain storming* in which participants try to discover or invent as many negative sides to a suggestion as possible. The suggestions that survive this criticism with the fewest negative points may be candidates for further development. Negative brain storming may also generate ideas as to how negative features of a solution may be overcome.

At the end of the evaluation session a clear ranking of the solutions may emerge and a clear understanding of who is to carry on the work and when it will be completed may be reached.

In principle, *brain writing* is the same as brain storming. It differs only in that suggestions are written down on cards and are not put forward verbally. Each participant takes a card and writes down his solutions to the previously defined problem. After one to two minutes the idea writing is halted and each participant passes his or her card to the next person. The participant reads the ideas on the card they have received and adds new ideas of their own.

The intention is that participants will be stimulated to generate additional suggestions by reading the suggestions of other participants. The cards may be passed on from one participant to the next, four or five times before the writing is discontinued. The cards are then collected and the suggestions copied on to a blackboard or otherwise displayed to allow everyone to see what has been generated. From this point, on the procedure is the same as for brain storming.

Brain writing is suitable when the group is so large that it may be difficult to keep the idea generation under control if proposals are made verbally. For groups larger than 10–15 people brain writing may be used instead of brain storming. Brain writing makes it easier to make shy people, who do not like to speak in public, take an active part.

9.6 REMOVING MENTAL BLOCKS

This method is suitable for both group work and individuals working alone. This method may help to get the design work to continue in the right direction if inspiration fails or the problems seem insurmountable. It may also help designers to see things from a different point of view than they are accustomed to in their daily work.

One basic approach is to pose questions that stimulate re-thinking (Osborn, 1963). For example, in relation to an object or an obstacle, consider how to:

- put it to other uses
- adapt
- modify
- minimize
- substitute
- re-arrange
- reverse
- combine.

Another approach is to use Roget's Thesaurus (1966) to find terms that are related to each other but inspire new ideas. For example, there are a large number of words which are associated with the verb *to move*. These include: go, glide, trail, cruise, stir, deviate, wave, remove, swing, operate, float, jerk, sling, agitate, leap, impel, roll, draw, drift, convey, slide, transport and interchange.

Yet another technique is to ask questions such as:

- *Why* a requirement is as it is.
- *Why* a particular solution has been selected.
- *Why* the design was initiated.

There are many other techniques for removing mental blocks. A more extensive survey may be found in Jones (1982). In addition, De Bono (1977) has published interesting ideas on how to stimulate thinking in a different way (lateral and vertical thinking) as have McKenney and Keen (1974).

9.7 DISCUSSING THE PROBLEM WITH SOMEONE WHO IS NOT INVOLVED

This kind of discussion may be taken up by a lone designer as well as by a design group. If a design group is involved it is important that the group as a whole take part in the discussion.

One of the simpler, but in many cases, very efficient, ways of stimulating thinking and idea generation is to discuss the problem with somebody else. Preferably this should be somebody who is not involved in the problem solving, but has some understanding of the subject. It is an advantage if this person does not know the problem area too well because you are then forced to explain the problem in detail and in a way that can be understood. In doing this you are put in to a situation where you have to consider the problem from new points of view. In most cases this will be sufficient to open the mind to new ways of looking at the problem and will lead to the generation of new solutions.

Discussions with people who are not involved with the problem are more fruitful when they occur *after* other methods of problem solving have been tried. By taking this approach the problem solvers will be familiar with the problem area before the discussion starts and will know of a great many solutions that can be kept out of the discussion. It may be best to postpone this type of discussion until you feel that other methods have been exhausted and there seems to be no other way of progressing. It is important for this type of discussion to be carried out at least once for any problem solving task that is not simple routine work.

9.8 HOW LONG TO CONTINUE IDEA GENERATION

We know that a systematic approach to idea generation will further the generation of ideas. We also know that humans easily feel exhausted, especially when it comes to intellectual work such as idea generation.

As a consequence, you should not discontinue generating ideas simply because you feel exhausted and unable to produce further solutions. As a minimum requirement idea generation should continue until at least one systematic method of idea generation has been carried through. It is also advisable to thoroughly discuss the problem with someone who is not involved in the work before discontinuing idea generation.

If time permits, it is a good idea to temporarily stop your consideration of solutions and to reconsider the problem formulation. This will allow your brain to subconsciously work towards a solution. The duration of your halt may range from thirty minutes to a day or two, depending on the time available and the importance of the problem. In any case, it is a good idea to try to get started on problem solving *before*, not after, a regular break; that is *before* lunch, *before* the end of a day, *before* a vacation and even *before* the next cigarette if you happen to be a smoker.

9.9 FROM CONCEPT TO SOLUTION

Any normal idea generation session will create many more ideas or concepts than can be thoroughly dealt with. The next task is to sort out only as many promising ideas as there is time available for their further development.

To save time each concept should first be evaluated on the basis of its

- Consequences.
- Feasibility.
- Time required for implementation.
- Costs.

The most radical concepts should be evaluated first. The evaluation should be based in the sequence outlined above. In this way many alternatives may be discarded without too much effort. Although discarding some ideas is necessary in order to obtain reasonable progress, don't forget that the best solutions are often those that overcome restrictions and obstacles by some means.

9.9.1 Consequences

The purpose of examining the consequences of ideas is to find out whether they require actions or precautions or may lead to situations that will be unacceptable to the company. Such an evaluation should be based on overall considerations and details should not be taken into account.

A good way of revealing the consequences of an idea or a concept is to ask what it would require in terms of total resources, cooperation with other people, political acceptance or stability, duration of an engagement, precautions to reduce risks or anything else which concerns the policy of the company.

It may turn out to be that too much of the company's resources would be concentrated in one area; the company would lose too much of its independence by becoming involved in the type of cooperation required; the necessary political stability is not available; the engagement would reduce the freedom of action of the company for too long a period or the proposed country of registration would not be acceptable to the company policy.

After screening on the basis of consequences, a feasibility check should be carried out.

9.9.2 Feasibility

The feasibility check should should concentrate on:

- Technical systems and solutions.
- Commercial arrangements.
- Consent required from other people.
- Political consent.

Technical systems may be regulated by laws and restrictions that make a concept unfeasible. A design concept may be based on technical developments that are not yet feasible in practice. In addition capacities and dimensions may be interlinked in a way that makes the proposed solution unfeasible. Union rules, demarcation agreements and divided jurisdictions may also make it impossible to find practical solutions.

Commercial arrangements may be difficult to carry out in practice because of the traditions of a trade, regulations concerning the flag of registration, tax laws and national jurisdictions.

Consent required from other people may concern the standardization of operation, joint ownership or management, changes in existing organizations and changes in delivery patterns. The attitude of the other interested parties should be ascertained before any effort made to develop a solution beyond the concept stage. Political consent may be required in relation to the base port, flag of registration, manning and the tax system.

9.9.3 Time required for implementation

The solution must ultimately satisfy the demand. Therefore, it is important to consider the time required to implement a solution. Some concepts may have to be discarded because they cannot be implemented in time to meet the demand.

9.9.4 Costs

Rough cost estimates should be prepared for the ideas that still seem feasible after screening on the basis of consequences, feasibility and time required for implementation. If the ideas involve relatively high costs in relation to the benefit, they should be discarded.

9.9.5 Comparing competing alternatives

After screening, only a few alternatives will merit further investigation and comparison. Comparison should be based on quantitative evaluation. The economic criteria discussed in Chapter 11 are the best basis for comparison. If it is impossible to obtain sufficient data to analyse the economic criteria, the grading method described below should be used.

First write down the *essential features* required for a solution, rank them according to their relative importance and assign weighting numbers. A feature that is considered to be absolutely necessary should be given a high weighting number. Agreement on the ranking should be established both within the design team and between designers and the management *before work proceeds*. It is an advantage to constrain the weighting by requiring that the sum of the weighting numbers equal one. This will make it necessary to grade the individual features against each other.

The next step is to consider each alternative in relation to each of the features and grade it according to its performance. Assign grades ranging from 0 to 5. The alternatives can then be compared by raising each grade to a power equal to its weight number and taking the product of the grades.

For example, compare ship A with ship B. The critical features, weight numbers and grading are shown below.

Feature	*Beaching*	*Training*	*Ease of operation*
Weight number:	0.4	0.2	0.4
Grades:			
Ship A	0	5	4
Ship B	3	1	1

For ship A the performance number is:

$0^{0.4} \times 5^{0.2} \times 4^{0.4} = 0$

For ship B the performance number is:

$3^{0.4} \times 1^{0.2} \times 1^{0.4} = 1.55$

This example illustrates the efficiency of the method. Ship A has a performance number of zero because the critical feature, beaching, has a zero grading. Ship B has a positive performance number because it does not lack any of the critical features. Ship B will probably be acceptable, ship A will not.

If the goal fulfilment were 100% the performance number would be

$5^{0.4} \times 5^{0.2} \times 5^{0.4} = 5$

The degree of goal attainment can be measured against this value as shown below.

For ship A: $0/5 = 0$
For ship B: $1.55/5 = 0.31$

A more thorough discussion of this method may be found in Starr (1963).

Another basis for comparing alternatives is to compare their performance in the feature in which they have the lowest grade. In the example given above the lowest grade for ship A is 0 (for beaching) and the lowest grade for ship B is 1 (for training and ease of operation). Thus ship B would be preferred. This type of decision is an application of the maximum or minimum principle, which aims to choose the candidate that has the highest score for the feature where its performance is at its minimum.

Frequently there is a minimum performance requirement for the critical features. For example, it may be essential to unload and load cargo within 12 hours, to continue drilling in Beaufort sea state 9 or to be maintainable by yards within a restricted geographic area. If an alternative does not satisfy the minimum requirement for a feature it should be graded zero for that feature.

Another alternative method of evaluation is to develop weighting *functions* instead of weight numbers and to use 'fuzzy' mathematics to compare the functions. This method makes it possible to express critical requirements in an indistinct way yet still arrive at a clear enumeration of the different alternatives. Bruce Nehrling (1985) illustrates how this method works by comparing ships with different accommodation space. His article is recommended for those who find it difficult to express the importance of a requirement by an exact number.

There should be agreement between designers and management or clients on the weighting of features and the grading of alternatives. It is a good idea to note down the reasoning behind the rankings. This makes it easier to reach a consensus and to make sure that no important points are forgotten when the different features are compared. It also makes it possible to go back and check the reasons behind a ranking if the comparison results in an unexpected conclusion.

The example which follows shows how weight numbers are assessed and explains the considerations behind the assessments.

9.9.5.1 Example: comparison of different riser configurations for a floating platform for oil exploration and processing

Features considered	*Weighting number*
Availability	0.20
Reliability	0.22
Safety	0.3
Easy Maintenance	0.20
Cost	0.18
Sum	1.000

The considerations behind the assignment of the weighting numbers are listed below:

1. The reason for installing the production platform is to *produce oil*. The *availability* of the riser system is essential for production. It should therefore be the most important feature.
2. *Reliability* is security against a breakdown. It should be ranked high enough so that the sum of the weighting numbers for reliability and availability will be higher than the weighting number for safety. It should be also be ranked higher than maintenance and cost.
3. *Safety* must be ranked above any individual feature, but below the sum of the two production related features, availability and reliability.
4. *Maintenance* is not as important because the expenses related to maintenance will be small compared with the losses that may be suffered due to breakdowns and non-availability.
5. *Costs* should be kept low, but not at the expense of reliability and availability. The weighting should be 1/2 to 1/3 of the combined weightings of availability and reliability.

The alternatives are: Not integrated riser (NIR), articulated tower (AT), submerged tower (ST), submerged buoy (SB)

			Grades		
Feature	*Weight*	NIR	AT	ST	SB
Availability	0.28	2	2.5	2.75	2.-
Reliability	0.22	2.75	2.4	2.4	2.5
Safety	0.3	2.3	2.50	2.6	2.6
Maintenance	0.02	3.0	2.25	2.25	2.5
Cost	0.18	3.5	3.0	1.75	2.-

Ranking:

1. Articulated tower: $2.5^{0.28} \times 2.4^{0.22} \times 2.5^{0.3} \times 2.25^{0.02} \times 3^{0.18} = 2.55$
2. Not integrated riser, $2^{0.28} \times 2.75^{0.22} \times 2.3^{0.3} \times 3^{0.02} \times 3.5^{0.18} = 2.49$
3. Submerged tower, $2.75^{0.28} \times 2.4^{0.22} \times 2.6^{0.3} \times 2.25^{0.02} \times 1.75^{0.18} = 2.41$
4. Submerged buoy, $2^{0.28} \times 2.5^{0.22} \times 2.6^{0.3} \times 2.5^{0.02} \times 2^{0.18} = 2.24$

It is important to note down the considerations made when assessing the weighting of each feature as was done in the example. Some people may object when they see the results of the grading and ranking. As a rule they object because the result does not coincide with their preconceived opinion or their intuition. In these cases it is a great advantage to be able to review the reasons behind the assessment. Reviewing the reasons behind the assessments will turn the discussion toward the importance of individual features and thus serve to reduce tension between personalities.

9.10 IDENTIFYING DISCARDED ALTERNATIVES

In the course of design work conditions may change and assumptions may have to be reconsidered. Therefore it may become appropriate to reconsider alternatives which were discarded for good reasons earlier in the project.

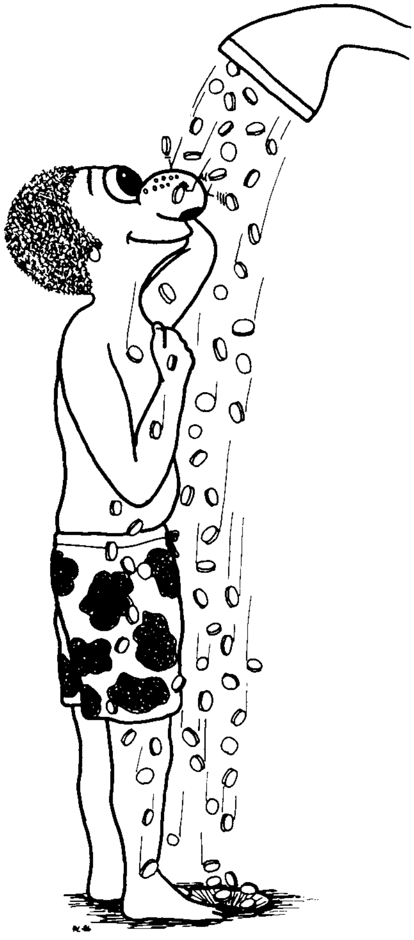
For this reason, it is important that it be possible to easily identify discarded alternatives in order to reconsider them. Therefore, before an alternative is discarded, collect all notes, calculations, information, documentation, computer printouts and anything else that is documented. Store this collection in an envelope or folder labelled with the name of the alternative, the reasons why it was discarded and the conditions and assumptions that must be changed to make it worthwhile reconsidering.

For example, the folder or envelope which contains the information relating to the alternative of using a submerged buoy in the floating platform project discussed in Section 9.9.5.1 should be labelled:

Alternative:	Riser system for oil Submerged buoy
Discarded:	Because of low availability
Reconsider if:	Submerged loading is adopted or more easily accessible connections between the buoy and surface are developed.

If a computer system is available for design support this type of identification may be stored in a data base for easy retrieval using keywords.

INCOME



Income and costs are decisive factors in the final selection of alternatives and should be calculated for all alternatives that are being considered in the final comparison. Income is discussed in this chapter. Costs are discussed in Chapter 11.

Providing that the design results in a unit or system that is attractive to users and customers, income is dependent on:

- Availability, e.g. days on hire.
- Capacity.
- Capacity utilization.
- Compensation received for the use of capacity.

It is the designer's responsibility to ensure that his designs maximize income generating features.

10.1 AVAILABILITY

Availability is defined as *average availability* which is the fraction of a given period of time during which a component will be in operable condition. Availability must be assessed for all alternatives. The following table of average figures may be taken as a guide.

Semi-submersible drilling platforms	95%
Offshore loading buoys	95–98%
Pipelines with boosting stations	98%
VLCCs	93–97%(340–360 days/year)
Ships in general	97%(355 days/year)
Loading ramps	98%
Container cranes	97%
Port cranes	96%

System availability is a function of the availability of the individual parts. A system consisting of a loading buoy, a tanker and an oil terminal would have a system availability of 0.96 x 0.95 x 0.98 = 89% if the availabilities were 0.96, 0.95 and 0.98 respectively. Simulation may be used to find system availability as explained in Section 12.3.3.

10.2 CAPACITY

The capacity for semi-submersibles and ships is measured by *payload* or *deadweight*, *volume* and sometimes, *area* or *length of lanes* for ships to carry trucks, cars or railcars. For semi-submersibles the payload includes consumables such as drilling pipes, mud, cement, fuel and fresh water as well as anchors and the vertical component of the anchor tension and riser tension. However, it does not include ballast water. Traditionally volume is measured in cubic feet, bale or grain, i.e. space, measured to the inside of the frames and skin plating, respectively. A frequently used unit of volume for modern cargo ships is TEUs, which stand for twenty foot equivalent units (twenty foot containers). Sometimes FEU, or forty foot equivalent units, are used.

The real *capacity* of semi-submersibles and ships may correspond to the specified capacity, but it may be reduced because of stability requirements.

The storage, installation and area capacity in a port is given in the same way as it is for ships. Weight may be a critical factor in quays and warehouses which are usually designed for a certain load per unit area.

The capacity of *lifting equipment* is usually specified by the maximum permissible weight of a lift, by the volume of lifting containers or grabs, by a lifting range and by number of cycles per unit of time. Manufacturers usually publish capacity figures based on the full utilization of both the weight and volume capacity and on a theoretical maximum obtainable number of cycles per unit of time. As a general rule, you may assume that the average daily real capacity is about 50–55% of the capacity indicated by the manufacturer's figures.

Pumps are also rated by a capacity based on theoretical assumptions. Their capacity must be corrected for the necessary reduction of the suction head when discharging from tanks that are beginning to become empty. Low and wide tanks will have a greater reduction of capacity than will high and narrow ones. The capacity reduction is between 15 and 20%.

Pipelines with booster stations will have a capacity which is very close to the theoretical maximum.

To calculate the money earning capacity you must know the *limiting factor*. This could be, for example, weight, volume or lane length.

10.3 CAPACITY UTILIZATION

Capacity utilization is defined as the percentage utilization of the *critical* capacity. Capacity utilization is seldom 100%. The most common reasons for this are:

- Service items such as drilling mud, pipes, cement, fuel oil and fresh water are continually consumed.
- Variation in cargo inflow by season.
- Ballast voyages.
- Weather downtime.
- Breaks due to shifts, meals, holidays and shifting berths.
- Improper stowage.
- Stability requirements.
- Required separation of different cargoes.
- Parcel sizes which do not match the capacity of the ship or her compartments.

10.4 COMPENSATION

Payment for use of capacity is generally received on the basis of:

- The period of time hired, for example, time charter parties
- Speed.
- Quantity of cargo handled, stored or moved.
- Special requirements imposed by the cargo, such as refrigeration, heavy lifts and care of live animals.
- Inconvenience caused by the capacity users, such as demurrage.

For design purposes, the income should be estimated on the basis of speed, availability, capacity, capacity utilization and the expected market rate for the service being designed. Figures for capacity utilization and availability should be taken from existing similar services, if possible. Some average figures of availability are shown in Section 10.1.

Income estimation should be based on realistic premises and should be neither too optimistic nor too pessimistic. Sensitivity analyses (see Chapter 13) should be carried out to clarify the consequences of variations in capacity utilization, availability and rates. The consequences of these variations should be clearly explained when a design solution is presented or a project is proposed.

10.5 STANDARD FORMS AND AGREEMENTS

The earning capacity of a vessel is sold in accordance with a few standard agreements. Those which are frequently used are discussed briefly below. A more detailed, but condensed, description of standard forms and agreements is given in Alderton (1980) and Branch (1982).

10.5.1 Charter contracts

The simplest form of charter contract is the *bareboat charter*. This means that the vessel is hired as is, with no manning, maintenance service or anything else which contributes to the operation of the vessel. The charter hire is usually paid monthly in advance. Standard forms of contract have been issued by the Baltic and International Maritime Conference (BIMCO). A bareboat charter may be combined with a vessel management contract. For a pure bareboat charter the cost to the owner is the cost of recovering the money invested in the vessel.

A *time charter* is an agreement to hire a fully manned and operable vessel for a specified period of time varying from a few weeks up to 15–20 years. The hire is paid per day or week for vessels on short time charters. More often it is charged per tonne dw per month. The vessel's ability to continue operation up to the agreed weather limit is crucial for *fulfilling* the contract. Vessels that fail to function as agreed come *off hire* and lose their hire until their ability to function according to contract is restored. There are several standard forms for time charter parties (Alderton, 1980, see also Chapter 11, Section 11.3.7).

A *voyage charter* is a contract to hire a fully manned and operable vessel for a specified voyage. The hire charge may be based on the voyage or per unit of cargo carried. The contract may be for a series of consecutive voyages. As a rule the owner covers all the costs in this type of charter, but he receives additional payment (demurrage) if the time in ports exceeds a stipulated time. His payment is reduced (he gets 'dispatch') if the port time is shorter than stipulated. In other words, he has to return a part of the payment due to quick dispatch.

Contract of affreightment is a type of contract where the payment is per tonne of bulk cargo transported between two specified ports. Within limits, the owner is free to use the ships which are convenient. In some cases this includes ships taken on charter. The payment may be adjusted according to the time spent in ports as for voyage charters.

10.5.2 World scale

Charter rates for tankers are always referred to the world scale, for example WS 52. WS 100 is a set of per ton dw freight rates based on a standard vessel of:

- Summer dw 19 500 long tons (1016 kg).
- Average speed 14 knots.
- Bunker consumption 28 ton per day, heavy fuel (1500 s) at sea; 5 ton per day, heavy fuel (1500 s) in port.
- Estimated port time 96 ± 3 hours per voyage.
- Fixed hire element, $1800 per day.
- Brokerage 2.5%.

Twelve further hours are taken into account for each additional loading or discharging port. Twenty-four hours are added for a transit of the Panama Canal and 30 hours are added for a transit of the Suez Canal. In addition, a differential per ton is added for certain ports. The world scale (WS) index is published for voyages between most combinations of ports and is revised as cost levels change. The world scale is calculated and updated by the

International Tanker Nominal Freight Scale Association, New York and London and published jointly by World Scale Association (London, Ltd) and World Scale Association NYC Inc., New York.

Because the index is based on a small tanker, large vessels will earn a sufficient hire income at WS which are much below 100. However, actual rates vary with the market. According to Branch (1982), the monthly weighted average spot market fixtures ('dirty') for the Arabian Gulf to Northern Europe were WS 313.30 in September 1973 and 19.4 in June 1978.

10.5.3 Liner trade

In the liner trade the freight is as a rule paid 'per ton weight or measurement' (i.e. per longton (1016 kg), shortton (907 kg) or metric ton (1000 kg) for the weight, or per 40 cubic feet for the volume) whichever gives the highest freight. Each commodity has its own rate. The rates are based partly on the value of the commodity — the freight cost that it can carry — and partly on the cost of transportation. In the container trades the tariff may be based on the container, weight or measurement.

10.5.4 Off hire

Whenever a vessel does not function in accordance with what is specified in the contract, the charterer has the right to either discontinue the contract or reduce payment. A charterer will always monitor the performance of the vessels he has on charter and demand off hire as soon as a vessel fails. Off hire periods can be as short as half an hour. Some examples of misperformance are listed below because they have such a great influence on income.

Cause. Ballast pumping slower than specified.
Consequences. Ship off hire until ballast discharge keeps pace with the loading.

Cause. Gangway not rigged when the vessel is alongside the quay.
Consequences. Ship off hire until longshoremen can get on board.

Cause. Breakdown of electrical generator, reduced cargo pumping capacity.
Consequences. Hire reduced in accordance with the extra time spent at the discharging terminal.

Cause. Deadweight less than specified.
Consequences. Hire reduced in accordance with the reduced transport capacity.

Cause. Specified speed not maintained.
Consequences. Hire reduced in accordance with reduced transport capacity.

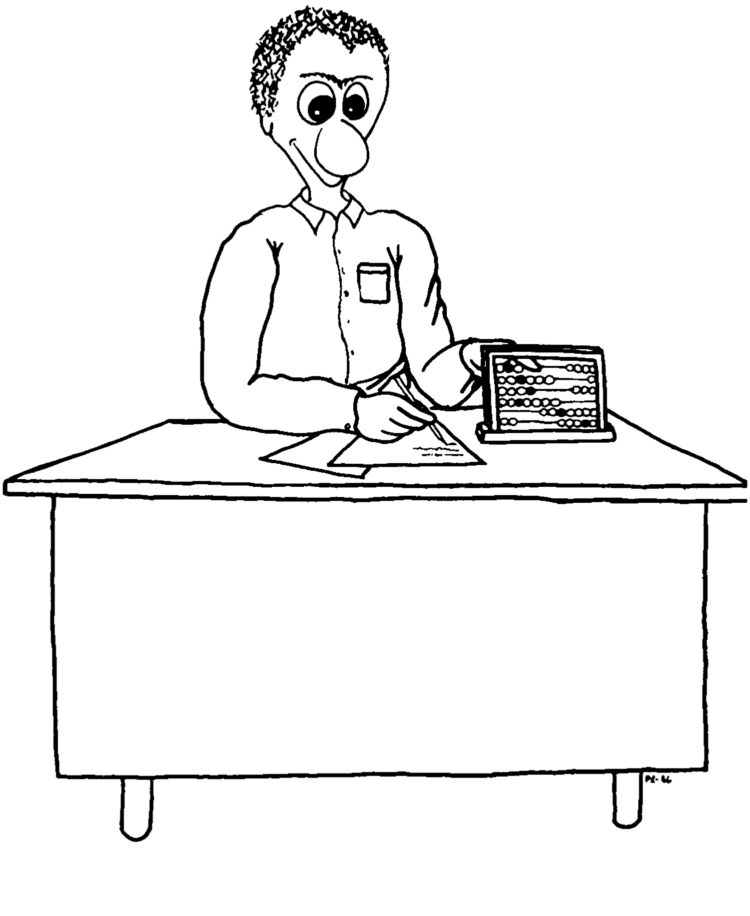
Cause. Loading ramp stuck in the open position.
Consequences. Ship off hire until the loading ramp is closed and the ship is ready for sea.

Cause. Ship arrived at the grain loading terminal with traces of the last cargo in some of the holds.
Consequences. Ship off hire until the hold is cleaned and the grain loading certificate is obtained.

Cause. Drilling operation discontinued because heave is too great, weather better than the agreed cut off limit.
Consequences. Semi-submersible is off hire as long as the weather remains below the agreed limit and drilling is not resumed.

11

ECONOMIC MEASURES OF MERIT



11.1 INTRODUCTION

The choice of a solution from many alternatives must be made on the basis of one or more criteria. In the marine industries the criteria are generally based on economic considerations and called *measures of merit*. It is necessary to know the criteria and understand how they may be used and interpreted in order to compare different solutions. Only a basic discussion of the criteria is presented in this book. All items discussed here are treated more thoroughly elsewhere. For more complete information see Benford (1957, 1958, 1963, 1967a and b, 1970), Buxton (1972, 1976 and 1982), Goss (1976) or Grant *et al.* (1982).

11.2 NOMENCLATURE

Symbol	*Units*	*Definition*
A	US$	Annual earning (R–C)
AAC	US$	Average annual costs
$AARR$	none	Average annual rate of return (derived CR)
$ACCR$	US$	Annual cost of capital recovery
ARR	%	Annual rate of return
A_{AC}	US$	Accumulated cost of charter
C	US$	Annual cost
C_B	US$	Interest paid on borrowed money
C_{Ch}	US$	Equivalent annual cost of charter
CCR	US$	Cost of capital recovery
C_F	US$	Annual fuel cost
CF	US$	Cash flow
CFB	US$	Cash flow balance
C_j	US$	Annual cost j
CR	$	Capital recovery factor
CVI/CVO	none	Cash value in/cash value out (ratio)
D	US$	Amount of depreciation
d	none	Depreciation rate
DCF	US$	Discounted cash flow
dw	tonnes	Deadweight capacity
EAC	US$	Equivalent annual cost
EAI	US$	Equivalent annual income
e	none	Annual rate of inflation
F	$	Future value
i	none	Interest rate
IRR	none	Internal rate of return
j	none	Item number
LCC_N	US$	Life cycle cost
LCC_{Ch}	US$	Life cycle cost, charter
n	year	Year number
N	years	Life time
NPV	US$	Net present value
$NPVI$	none	Net present value index
On/Total	none	On hire time/total time (ratio)
PBP	years	Pay back period
P_C	none	Number of charter periods per year
P_0	US$	A single initial amount; also investment
P_{0E}	US$	Equity part of money
P_N	US$	An amount originating at the end of year N
PV	US$	Present value
PWC	US$	Present worth of all costs
Q		Annual transport capacity
R	US$	Annual revenue

Symbol	*Units*	*Definition*
RFR	US$/ton	Required freight rate
RCR	US$/ton month	Required charter rate
S	none	A sum
TCR	years	Time of capital recovery
t	none	Tax percentage
u	none	Transport capacity utilization
WAIRR	none	Weighted average internal rate of return
'		superscript indicating value after tax

11.3 CRITERIA BASED ON COST

Criteria based on costs should be used when the income is unknown or when it is the same for all competing solutions, including cases, such as naval craft, where income is zero. In those cases you must look for the minimum cost solution.

11.3.1 Cost of investments

Investments are made to earn money and their costs can be measured in terms of the required future earnings. In addition to direct outlays there is the cost of interest which is forgone on the invested money. Therefore the eventual earnings should cover both the cost of regaining the money invested and the forgone interest on any money that is not yet recovered. Note that the cost of regaining *borrowed* money is the instalments and interest paid to the lender.

The purchase of both new or second-hand vessels is an investment. Money spent on second-hand vessels must be recovered over a shorter time than money invested in new vessels.

It is customary to assume that future earnings and costs originate at the end of each year. If the cost of forgone interest is expressed by an annual rate of interest, i, and an investment P_0 is left intact for N years it will increase with interest to

$$P_0(1+i)^N$$

If a project earns an amount, A, at the end of each year, after N years these amounts will have accumulated with interest to a sum F according to the equations:

$$F = A(1+i)^{N-1} + A(1+i)^{N-2} + \ldots + A$$

$$F = A\,\frac{(1+i)^N - 1}{i}$$

In order for the invested sum, P_0, to be regained with interest,

$$F = P_0(1+i)^N$$

or

$$A\,\frac{(1+i)^N - 1}{i} = P_0(1+i)^N$$

or

$$A = P_0\,\frac{(1+i)^N \times i}{(1+i)^N - 1}$$

Where A is the annual cost of capital recovery, *ACCR*

The expression

Symbol	*Units*	*Definition*
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RCR	US$/ton month	Required charter rate
S	none	A sum
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or

$$A\,\frac{(1 + i)^N - 1}{i} = P_0 (1 + i)^N$$

or

$$A = P_0\,\frac{(1 + i)^N \times i}{(1 + i)^N - 1}$$

Where A is the annual cost of capital recovery, *ACCR*

The expression

$$\frac{(1+i)^N \times i}{(1+i)^N - 1}$$

is called the capital recovery factor (*CR*). It is the factor by which an invested amount, P_0, has to be multiplied in order to find the amount, *A*, that must be earned at the end of each year in order to regain the total invested amount, P_0, with an annual rate of interest, *i*, during a lifetime of *N* years. A table showing the capital recovery factor as a function of time to recover the investment and rate of interest, is included at the end of this chapter. Thus

$$ACCR = P_0\, CR$$

The annual cost of capital recovery is the invested amount multiplied by the capital recovery factor. For a given rate of interest, *i*, and a given time for capital recovery, *N*, the capital recovery factor is written $CR\ (i\%, N)$.

In the preceding, P_0 may be termed the present worth of the future amount, $P_N = P_0\,(1+i)^N$.

11.3.2 Selecting the rate of interest

The following considerations apply when selecting the rate of interest:

- As a minimum requirement, the purchasing power of my money should be maintained. Therefore, the rate of interest should not be less than the rate of inflation.
- Part of my investment is in loans and I should not earn a lower rate of interest on the investment than the interest I have to pay on the loans.
- In new investment opportunities, the rate of interest should not be less than the interest gained on existing investments. The weighted average internal rate of return can be used as a measure of earnings on existing investments (see Section 11.4.4). The rate of interest offered on bank accounts should be considered the minimum obtainable on other investments. The market conditions may change; if a slow-down is expected, it may be advisable to use a *lower* interest rate in calculations than the current rate. If an up-turn is in sight, you should look for a *higher* interest rate.

The rate of interest is the critical element in assessing the present worth of future amounts and in calculating the cost of capital (see also Section 11.3.3). The cost of capital is a critical factor to consider when deciding for or against a project. If the rate of interest is low it will increase the value of future amounts. A high rate of interest will decrease their value. Therefore, the selection of interest rates should be made by management. To aid in this decision you should always explain why a particular interest rate has been used in your design calculations and whether the choice of another interest rate would cause you to rank the alternatives differently.

11.3.3 The influence of the rate of interest

Because investments are made at one time and the earnings to recover them originate later, it is very important to consider the rate of interest when comparing investments and earnings. A low rate of interest gives a higher value to future earnings than does a high interest rate. This is expressed in terms of the present worth of future earnings. As an example, the present worth of 100 Nkr after ten years at various rates of interest is shown in the table below. The present worth has been calculated based on the equation

$$P_0 = 100\,(1+i)^{-10}$$

Rate of interest, i, %	*Present worth (NOK)*
0	100
5	61.4
10	38.6
15	24.7
20	16.2

Correspondingly, the annual earnings required to recover an invested amount with interest will increase as the rate of interest goes up. If an investment is to recover 100 Nkr over 10 years by equal, annual amounts, the annual cost of capital recovery will vary with the rate of interest as follows:

Rate of interest, i, %	*Capital recovery factor, CR (i%, 10 yr)*	*Annual cost of capital recovery (NOK)*
5	0.13	13
10	0.163	16.3
15	0.199	19.9
20	0.239	23.9

The reduction of future amount to present worth is called discounting. Accordingly, the rate of interest is frequently called the discount factor.

11.3.4 The real and nominal rate of interest

Because of inflation, the value of money decreases steadily. If the annual rate of inflation is e %, an amount originating after N years must be multiplied by a factor of $(1+e)^{-N}$ to find its purchasing power in terms of the present value of money. Correspondingly, an amount that has earned interest over a period of N years and increased to $P_0\,(1+i)^N$ will have a real value at year N of:

$$P_0\,\frac{(1+i)^N}{(1+e)^N} = P_0\left(\frac{1+i}{1+e}\right)^N$$

If we set

$$1+r=\frac{1+i}{1+e}$$

where r may be termed the *real* rate of interest, that is the interest measured in terms of money whose purchasing power is not reduced by inflation.

Interest earnings may be further reduced by taxation. This is discussed in Section 11.6.

11.3.5 Total costs and equivalent annual cost, *EAC*

The previous discussion was related to the cost of the investment *only*. In any project the cost of fuel, operations, manning, maintenance, repair, administration, insurance, profit and taxes are additional costs. The total costs can be calculated as shown below.

$$C_n = P_o\,CR + \sum_{j=1}^{m} C_{jn}$$

Where C_n = total costs of year n and C_{jn} = cost of item j in year n.
Over the life time the annual costs with interest will become

$$LCC_N = \sum_{n=1}^{N} C_n\,(1+i)^{N-n}$$

at end of life time. This is called the life cycle cost.

The present worth of the life cycle cost is:

$$LCC_0 = LCC_N (1 + i)^{-N}$$

If C_n does not vary from one year to another. This is a hypothetical case, but all the same a case frequently assumed in preliminary calculations. You may replace C_n by C for each year and

$$LCC_N = C\frac{(1+i)^N - 1}{i} = \frac{C}{CR\ (N,i)}\quad (1+i)^N$$

Correspondingly, if a fluctuating flow of costs has resulted in an accumulated value LCC_N, and you want to find an equivalent annual cost, EAC,

$$EAC = LCC_N \frac{i}{(1+i)^N - 1} = \frac{LCC_N \times CR\ (N,i)}{(1+i)^N}$$

11.3.6 Required freight rate, *RFR*

If the annual transport capacity is known, the freight rate required to cover the cost may be found by:

$$RFR = \frac{EAC}{u \cdot Q},$$

where Q is the annual transport capacity, u is the capacity utilization factor and $Q \times u$ is the volume that will actually be carried. Q may be given in tons, m^3, ft^3, containers, passengers, tonne-miles or any other unit.

The factor, u, accounts for ballast voyages, low capacity utilization, off hire, seasonal fluctuations in cargo inflow and other circumstances which prevent the available capacity from being used.

The *RFR* is the absolute minimum unit rate that must be earned in order to cover costs, including profit and taxes. As a rule, the capacity of a transport system will never be fully utilized over a whole year. therefore you must use a capacity utilization factor which is less than one in your calculations.

The *RFR* should be compared with the general rates in the market. If the RFR is greater than the market rate, the design must be improved or the project abandoned. The *RFR* and the required charter rate, *RCR*, are widely used as criteria for the selection of the best designs. The *RFR* is particularly useful to consider when dealing with relatively simple trading patterns such as the transport of bulk material.

11.3.7 Required charter rate, *RCR*

Freight contracts for many types of ships are based on charter rates. Therefore, the cost of a project should be calculated in terms of the required charter rate, *RCR*. The charter rate is generally based on deadweight capacity but it could be based on any capacity indicator. The calculations used to determine the *RCR* based on the deadweight capacity are given below.

$$RCR = \frac{C_{Ch}}{dw\, P_c \times \text{On/Total}}$$

where:

C_{Ch} is the equivalent, annual cost of charter.
RCR is the required charter rate,
d.w. is the deadweight capacity,
P_C is the number of charter periods per year ($P_C = 12$ when the charter hire is paid by the month; $P_C = 360$ when the hire is per day),

On/Total is the on hire time/total time ratio.

$$C_{Ch} = C - C_V$$

C_V is that part of the annual cost that is covered by the charterer:

$$C_{Ch} = LCC_{ChN} \frac{CR\,(N,i)}{(1+i)^N}$$

where LCC_{ChN} is the accumulated cost of charter.

$$LCC_{ChN} = \sum_{n=1}^{N} C_{Chn} \times (1+i)^{N-n}$$

The *RCR* should be compared with the general rate of the market in the same way as the *RFR*.

The costs covered by the charterer depend on the contract. For time charter parties, all voyage dependent costs, such as fuel, port and canal dues and overtime due to port operations, are covered by the charterer. For trip charters, where the ports are specified, the owners may have to cover the voyage dependent costs. When using the *RCR* as a cost criterion, use a charter period that is typical of the trade in question. (See also Section 10.5).

11.4 CRITERIA BASED ON INCOME AND COST

Whenever income can be predicted with some degree of confidence you should used criteria which take income into account. The income may be assessed by checking the rates in the relevant markets, by preliminary negotiations with prospective customers or by checking previous contracts. Criteria based on income *and* costs give a better basis for evaluating risk, cash balance, growth of wealth and recovery of investments than do criteria based on costs alone.

11.4.1 Net present value, *NPV*

Providing an annual rate of interest, i, an amount, P_0 will after N years have grown to:

$$P_N = P_0 (1+i)^N$$

and correspondingly, the future amount, P_N, will have a present worth

$$P_0 = \frac{P_N}{(1+i)^N}$$

The future amount, P_N, is discounted to its present value, P_0. The net present value, (*NPV*), is found when discounting is applied on all future costs and incomes, and the discounted values are added together. The formula is:

$$P_0 = \sum_{n=0}^{N} \frac{A_n}{(1+i)^n}$$

where

$$A_n = R_n - C_n$$

where:

NPV is the present worth of all incomes and costs.
A_n is the net income of year n.
R_n is the gross income of year n.
C_n is the costs of year n.
i is the annual rate of interest or discount factor.

N is the lifetime of the project in years.
It is assumed that incomes and expenses originate at the end of each year for the sake of simplicity.

Frequently one has an opening investment, P_0, and starts to generate other expenses and income from year 1 and onwards. The formula may then be written:

$$NPV = \sum_{n=1}^{N} \frac{A_n}{(1+i)^n} - P_0$$

In preliminary, economic calculations the net income, A, may be assumed to be the same for each year,

$R_n - C_n = A$

for all years, and

$$NPV = \sum_{n=1}^{N} \frac{A}{(1+i)^n} - P_0$$

$$= \frac{A}{CR\,(i\%, N)} - P_0$$

where CR (i%, N) is the capital recovery factor corresponding to a life time of N years and a discount factor, i.

The NPV criterion measures the growth of wealth in terms of *present value*. The magnitude of the NPV is dependent on the discount factor. A low discount factor will favour projects with late incomes and early costs. A high discount factor favours projects with early incomes and delayed costs. Therefore, never accept and never present the value of the NPV criterion to management without making sure that everyone knows which discount factor has been used and how it affects the calculations.

The NPV does not measure the growth of wealth in relation to the investments. This is measured by the annual rate of return.

11.4.2 Annual rate of return, *ARR*

The annual rate of return is the net annual income divided by the investment. For year n

$$ARR_n = \frac{R_n - C_n}{P_0}$$

If it is assumed that

$R_n - C_n = A$

for all years, $AARR = \dfrac{A}{P_0}$,

The $AARR$ is the *average* annual rate of return. The $AARR$ may be compared with the capital recovery factor, CR . The $AARR$ is a measure of what a project yields. The CR is a measure of what a project must yield to regain invesments with interest. A table of CR as a function of interest rate and lifetime N, may be used to check the rate of interest that a specific $AARR$ would produce for a given lifetime and vice versa.

11.4.3 The pay back period, *PBP*, and time of capital recovery, *TCR*

In principle, the pay back period, PBP , is the time it takes to get back your investment. However, the issue is confused by the question of whether the cost of the forgone interest on the investment should be taken into account.

Frequently the cost of forgone interest is *not* taken into account. Therefore, if an investment of 100 Nkr earns 10 Nkr per year, and the earnings are not reduced by tax, the *PBP* is 100/10 = 10 years. This is a considerably shorter period than would have been required if the cost of forgone interest had also been taken into account. Taking an interest rate of 5% after tax, the annual income after tax would have to be 12.95 Nkr, or close to 30% more, in order to recover the invested money over 10 years. Thus an income of 10 kr per year would require a *PBP* of a little more than 14 years.

This illustrates the importance of clearly stating whether the cost of forgone interest has been taken into account when *PBP* is used as a criterion. It is difficult to justify the practice of ignoring the cost of foregone interest, especially in times of high inflation and correspondingly high interest rates.

The *TCR* , the time of capital recovery, *does* take the cost of forgone interest into account. It expresses the time it takes to *recover* the investment with interest. If the initial investment is P_0,

$$P_0 = \sum_{n=1}^{TCR} \frac{A_n}{(1+i)^n} \text{ , or}$$

the *NPV* of the annual net earnings, A_n, must be equal to the opening investment. The time it takes to accomplish this is denoted by the *TCR*. As before, *NPV* is dependent of the interest, or discount, rate.

In order to determine the *TCR*, you must find a *TCR* such that:

$$P_0 = \sum_{n=1}^{TCR} \frac{A_n}{(1+i)^n}$$

If A_n is replaced by A for each year, then

$$P_0 = \sum_{n=1}^{TCR} \frac{A}{(1+i)^n} = \frac{A}{CR\ (i\%, TCR)}$$

or

$$CR\ (i\%, TCR) = \frac{A}{P_0}$$

That is, for any A/P_0 ratio there is a capital recovery factor of equal value. With a given rate of interest, i, this capital recovery factor corresponds to the *TCR*. This is illustrated below

Investment, P_0 = 100 MNKr
Annual net earning, A = 14.68 MNKr
$A/P_0 = 0.1468$

The rate of interest, i, is 12%
$CR\ (12\%, TCR) = 0.1468$
TCR = 15 years (Table 11.1)

For an interest rate of 10%, the time of capital recovery would be close to 12 years.

The *TCR* is a useful criterion in the evaluation of risk. It indicates how long it takes to recover invested money with interest, i.e., how long there may be a risk of losing money. This time should be compared with the period of time for which it is possible to make reliable forecasts of income and costs.

11.4.4 Internal rate of return, *IRR*

The internal rate of return, *IRR*, is the rate of interest that is earned on the investment. As for the time of capital recovery we have:

$$P_0 = \sum_{n=1}^{N} \frac{A_n}{(1+IRR)^n}$$

but here we are seeking the rate of interest, that for a given lifetime, makes the present value of the net earnings equal to the investment.

If we assume that

$$R_n - C_n = A$$

for each year then

$$P_0 = \frac{A}{CR\ (N, IRR)}$$

$$CR\ (IRR\%, N) = \frac{A}{P_0}$$

For a given A/P_0 ratio there is a CR of equal value. With the lifetime, N, given, there is a rate of interest, IRR, corresponding to the CR.

For example, the investment, P_0, is 200 NOK, the net annual earning, A, is 39.74 NOK. Therefore

$$A/P_0 = 0.1987$$

The estimated lifetime is 7 years

$$CR\ (IRR\%, 7) = 0.1987$$
$$IRR = 9\%$$

Table 11.1 Capital Recovery Factor, CR, as function of rate of interest and time of capital recovery.

n	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
1	1.0100	1.0200	1.0300	1.0400	1.0500	1.0600	1.0700	1.0800	1.0900	1.1000
2	.5076	.5155	.5226	.5305	.5376	.5455	.5529	.5606	.5685	.5760
3	.3401	.3466	.3534	.3604	.3671	.3741	.3811	.3880	.3951	.4021
4	.2564	.2625	.2691	.2755	.2820	.2886	.2952	.3019	.3086	.3155
5	.2062	.2121	.2183	.2246	.2309	.2374	.2459	.2505	.2571	.2638
10	.1056	.1113	.1172	.1233	.1295	.1359	.1424	.1490	.1558	.1627
15	.0721	.0778	.0838	.0899	.0963	.1030	.1098	.1168	.1241	.1315
20	.0554	.0612	.0672	.0736	.0802	.0872	.0944	.1018	.1095	.1175
25	.0454	.0512	.0574	.0640	.0710	.0782	.0858	.0937	.1018	.1102
30	.0387	.0447	.0510	.0578	.0651	.0726	.0806	.0888	.0973	.1061
50	.0255	.0318	.0389	.0465	.0548	.0654	.0725	.0817	.0912	.1009

n	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%
1	1.1100	1.1200	1.1300	1.1400	1.1500	1.1600	1.1700	1.1800	1.1900	1.2000
2	.5839	.5917	.5994	.6074	.6150	.6231	.6308	.6388	.6467	.6545
3	.4092	.4164	.4236	.4308	.4380	.4453	.4526	.4599	.4673	.4747
4	.3223	.3292	.3362	.3432	.3503	.3574	.3646	.3717	.3790	.3863
5	.2706	.2774	.2843	.2913	.2983	.3054	.3126	.3198	.3270	.3344
10	.1698	.1770	.1843	.1917	.1993	.2069	.2146	.2225	.2305	.2385
15	.1391	.1468	.1547	.1628	.1710	.1794	.1878	.1964	.2051	.2139
20	.1256	.1339	.1424	.1510	.1598	.1687	.1777	.1868	.1960	.2054
25	.1187	.1275	.1364	.1455	.1547	.1640	.1734	.1829	.1925	.2021
30	.1150	.1241	.1334	.1428	.1523	.1619	.1715	.1813	.1910	.2008
50	.1106	.1204	.1303	.1402	.1501	.1601	.1701	.1801	.1900	.2000

n	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%
1	1.2100	1.2200	1.2300	1.2400	1.2500	1.2600	1.2700	1.2800	1.2900	1.3000
2	.6625	.6705	.6785	.6865	.6944	.7025	.7105	.7187	.7266	.7348
3	.4822	.4897	.4972	.5047	.5125	.5199	.5275	.5352	.5429	.5507
4	.3936	.4010	.4085	.4159	.4234	.4310	.4386	.4462	.4539	.4616
5	.3417	.3492	.3567	.3642	.3719	.3795	.3872	.3949	.4027	.4106
10	.2467	.2549	.2632	.2716	.2801	.2886	.2972	.3059	.3147	.3235
15	.2228	.2317	.2408	.2499	.2591	.2684	.2777	.2871	.2965	.3060
20	.2147	.2242	.2337	.2433	.2529	.2626	.2723	.2820	.2918	.3016
25	.2118	.2215	.2313	.2411	.2510	.2608	.2707	.2806	.2905	.3004
30	.2107	.2206	.2303	.2404	.2503	.2603	.2702	.2802	.2901	.3001
50	.2100	.2200	.2300	.2400	.2500	.2600	.2700	.2800	.2900	.3000

n	31%	32%	33%	34%	35%	36%	37%	38%	39%	40%
1	1.3100	1.3200	1.3300	1.3400	1.3500	1.3600	1.3700	1.3800	1.3900	1.4000
2	.7429	.7510	.7591	.7673	.7755	.7838	.7920	.8002	.8085	.8167
3	.5584	.5662	.5780	.5818	.5896	.5975	.6055	.6134	.6214	.6293
4	.4694	.4772	.4850	.4929	.5008	.5087	.5167	.5246	.5327	.5408
5	.4185	.4264	.4344	.4424	.4505	.4585	.4667	.4749	.4831	.4913
10	.3323	.3413	.3502	.3593	.3683	.3774	.3866	.3958	.4050	.4143
15	.3155	.3250	.3347	.3443	.3539	.3636	.3733	.3831	.3928	.4026
20	.3114	.3213	.3311	.3410	.3509	.3608	.3707	.3806	.3905	.4005
25	.3104	.3203	.3303	.3402	.3502	.3602	.3701	.3801	.3901	.4001
50	.3101	.3201	.3301	.3401	.3500	.3600	.3700	.3800	.3900	.4000

This example is a simplification. When returns vary from one year to the next, the *IRR* may be found by trial and error using the formula given in this section. The *IRR* is a good measure of the worth of an investment. The *IRR* may be compared with:

- Interest on bank accounts. If the *IRR* is lower it is better to put the money into the bank.
- Interest on loans. If the *IRR* is lower than the interest that must be paid on loans the project will not earn enough money to service the loans.
- The weighted average internal rate of return, *WAIRR*. If a business upturn is expected, the *IRR* should be higher than the *WAIRR*. If a business downturn is expected, a lower IRR could be accepted. (see Section 11.4.4.1).

The *IRR* may also be used to compare projects. In principle, the project with the highest *IRR* should be preferred, provided that the magnitude of the investments and the risks are about the same for all projects. This is because the *IRR* measures the specific return on money. For example, compare the two alternatives below.

1. An investment of 100 MNkr earning an *IRR* of 25% which produces an annual gain of 25 MNkr in addition to recovering the investment.
2. An investment of 200 MNkr earning an *IRR* of 20% which produces an annual gain of 40 MNkr in addition to recovering the investment.

Which is better? If the first alternative excludes the possibility of investing in the second alternative, because half of the money required for alternative 2 has been used in alternative 1, you must choose between an investment of 100 MNkr producing 25 MNkr and 200 MNkr producing 40 MNkr.

If you happen to have exactly 200 MNkr available for investment and the two alternatives are the only investment opportunities available, you may prefer the second alternative although its *IRR* is lower.

11.4.4.1 The weighted average internal rate of return, WAIRR

The weighted average internal rate of return, *WAIRR*, is the weighted average of the rates of return produced by the various investments made by a company. An example is shown below.

Project	*Investment,* P_0	IRR	*Earning*
Bank account	100	0.12	12
Part of drilling platform	135	0.15	20
Tanker	100	0.02	2
Management Co.	10	0.50	5
Total	245		39

WAIRR = 39/245 = 0.16

In general terms,

$$\text{WAIRR} = \frac{\sum_{j=1}^{J} P_{0,j} \, x \, IRR_j}{\sum_{j=1}^{J} P_{0,j}}$$

where the summation is to be made over all investments. The investments are expressed at their market value, or what may be obtained by selling them.

The above table may also be used as a basis for determining a realistic *IRR* for future projects. Some types of existing investments may be excluded from consideration. Others may be given more weight. If for example, it is assumed that low earning investments such as the tanker project will not come up in the future, the *WAIRR* would increase to 37/145 = 0.255. This should be a target *IRR* under certain circumstances.

11.4.5 The net present value index, *NPVI*

This criterion measures the net present value in relation to the investment as calculated below.

$$NPVI = \frac{NPV}{P_0}$$

When the income, A, is the same for every year:

$$NPV = \frac{A}{CR\ (N, i)} - P_0$$

$$\text{then } NPVI = \frac{A}{P_0 \times CR\ (i\%, N)} - 1$$

In order for the *NPVI* to be positive, the net earnings must be greater than the investment multiplied by the *CR*, which is based on the lifetime, N, and the discount rate, i. Projects with a negative *NPVI* do not satisfy the capital recovery requirement and cannot carry the specified *CR*. Therefore, they should be rejected. The *NPVI* has the same weaknesses and strengths as the *IRR* as a criterion for choosing an investment. However, the computation of the *NPVI* is simpler when incomes and costs vary from one year to the next, as is the case in real life. When 100% of the investment is equity, the *NPVI* is equal to the cash value in/cash value out ratio.

11.4.6 The cash value in/cash value out ratio, *CVI/CVO*

This ratio measure the cash value produced at the end of a project in relation to what the value of the investment would have been if it had earned interest in the general market. Only the part of the investment which represents the firm's own money (equity) is taken into account. The *CVI/CVO* is calculated as shown below.

$$CVI/CVO = \frac{(NPV + P_{0,E})\,(1+i)^N}{P_{0,E}\,(1+i)^N} = \frac{NPV + P_{0,E}}{P_{0,E}}$$

When the income, A, is the same for every year:

$$\frac{A/CR\,(i\ \%, N)}{P_{0,E}}$$

$P_{0,E}$ is the equity part of the investment. When

$P_{0,E} = P_0$

CVI/CVO = NPVI + 1

The *CVI/CVO* ratio gives a good indication of the growth of the firm's cash. Projects with a negative *CVI/CVO* ratio should be rejected. The ratio should be used with caution. Every owner will want to know how well his equity is faring but for investment analysis purposes evaluations should be based on the total investment.

11.4.7 Cash flow, *CF*, and discounted cash flow, *DCF*

A company cannot survive without cash. Therefore, it is necessary to know how a project will consume and generate cash and how this will vary over time. The cash flow, *CF* , should be predicted for the lifetime of a project and presented in a table based on regular time intervals. In the preliminary design phase a year is usually taken as the time interval. In the final comparisons of projects a month, or even a week, may be used if the project is one that will require a large cash turnover and cash is critical for the company. An example of a cash flow table is shown below.

11.4.7.1 Example: Cash flow analysis

Cash flow table

Investment:		
	Equity (Own money)	M$ 20
	Borrowed money	M$ 80
	Residual value after 12 years	M$ 20
Loan expenses:		
	Repayment M$ 8 per year (10 years)	
	Interest 10%	
Annual operating expenses, first year:		
	Wages, supplies	M$ 0.5
	Fuel	M$ 1
	Port dues and similar	M$ 0.2
	Insurance	M$ 0.1
	Maintenance and repair	M$ 0.1
	Other expenses	M$ 0.1
	Total annual operating expenses	M$ 2
Annual net freight income, first year:		M$ 21
Annual inflation		5%

For years two through twelve, income and expenses vary as given by the summary of cash flow shown below.

Summary of cash flow

Estimated annual cash flow, 5% inflation assumed, values in M$. The year's results are calculated to the year end.

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Income:													
Freight sale of ship		21	22	23	24	25	25	26	26	26	26	26	26
Expenses:													
Own investment	20												
Installations		8	8	8	8	8	8	8	8	8	8		
Interest		8	7.2	6.4	5.6	4.8	4.0	3.2	2.4	1.6	0.8		
Operating expenses		2	2.1	2.2	3	2.3	2.5	2.6	3.5	3	3.1	3.2	2
Cash:													
Surplus		3	4.7	6.4	7.4	9.9	10.5	12.2	12.1	13.4	14.1	22.8	44
(Deficit)	(20)												
Accumulated net cash flow	(20)	(17)	(12.3)	(5.9)	1.5	11.4	21.9	34.1	46.2	59.6	73.7	96.5	140.5
10% interest on accumulated cash		(2)	(1.9)	(1.6)	(1.1)	(0.5)	0.4	1.5	2.9	4.4	6.2	8.2	11.3
Accumulated cash + interest		(19)	(16.2)	(11.4)	(5.1)	4.3	15.2	28.9	43.9	61.7	82.0	113.0	168.3

Maximum estimated cash deficit: M$ 20

Year 4 is the first year with a positive accumulated cash balance. Estimated cash surplus at end of project life time with interest taken into account is M$ 168.3.

The *CVO/CVI* ratio at 10% interest is:

$$\frac{168.3}{20 \times 1.1^{12}} = \frac{168.3}{62.8} = 2.68$$

$$NPV\,(10\%) = \frac{168.3}{1.1^{12}} = 53.6$$

A cash flow analysis should be made as in the cash flow table. This gives information about the actual cash flow each year. When interest is taken into account, the cash flow table also shows the costs of keeping money available to make up for a cash deficit and the gains associated with using cash produced by a cash surplus.

If the *discounted* cash flow, *DCF*, that is the cash flow discounted to present worth, is used in an economic analysis this would be as follows for the cash flow shown above (i =10%):

Year	0	1	2	3	4	5	6	7	8	9	10	11	12
Cash flow:	(20)	3	4.7	6.4	7.4	9.9	10.5	12.2	12.1	13.4	14.1	22.8	44.0
Discounted cash flow:	(20)	2.7	3.9	4.8	5.1	6.1	5.9	6.3	5.6	5.7	5.4	8.0	14.0

$$\text{Net present value} = \sum_{n=1}^{12} DCF_n - 20 = 53.6$$

The discounted cash flow gives the cash balance for each year *discounted* to present worth. It does not show the actual cash balance.

11.5 WHICH CRITERIA TO USE

There is no one criterion which can be used as a single exclusive measure of the merit of a project. The economics of a project must be evaluated from different points of view. Consequently, it may be necessary to calculate many different criteria when you carry out an economic evaluation. The table below summarizes which criteria to use when different types of information is sought.

Information requested	Criteria to use
1. The projects standing in relation to market	*RFR* (required freight rate) *RCH* (required charter hire), to be compared directly with going and expected rates in the market
2. The risk involved	Time of capital recovery *(TCR)*, to be compared with the time horizon of your forecasts, and the influence of time on income and costs
3. Influence on your cash	*Cash flow* to be compared with the forecasted cash flow of the company as a whole
4. Return on your money	The internal rate of return *(IRR)*, to be compared with your weighted average annual rate of return, and with returns obtainable on competing investment opportunities
5. Contribution to wealth	The net present value *(NPV)*

The selection of projects is a decision for management. Therefore, it is the responsibility of the management to decide which criteria should be examined. In any case, the cash flow, *IRR*, and time of capital recovery should be calculated.

11.5.1 Comparing alternatives

Each of the criteria emphasize different aspects of the economics of a project. Therefore, one alternative may appear to be the most favourable based on one criterion but another alternative may appear more favourable when a different criterion is taken into account. The effect of examining various criteria when comparing alternatives is summarized below.

11.5.1.1 Minimum cost solutions.

When examining minimum cost solutions the criteria to consider are the average annual costs, (*AAC*), the required freight rate (*RFR*) and the required charter rate (*RCR*). These criteria do not address the project lifetime. The purchase of a second-hand vessel may, for example, give minimum cost but the lifetime may be short. A project based on new vessels may have higher costs but provide income over a much longer time. This suggests that even when the income is not known, it is not always best to simply seek the minimum cost solution.

One way to establish a basis for comparison on equal terms is to assume that the short-lived alternatives are repeated over time so that the sum of their lifetimes equals the lifetime of the long-lived alternative.

11.5.1.2 Net present value (NPV)

The *NPV* puts the emphasis on creating wealth. It should be used when there is an ample cash surplus. When the discount rate is low, the *NPV* makes future amounts more important than when the rate is high. A change in the discount rate may change the ranking of alternatives. An example is shown below.

	Alternative 1	Alternative 2	Best alternative
Investment	100	100	
Net income per year	20	15	
Lifetime	10 years	20 years	
NPV (8%), $20/0.149 - 100 =$	34.2	$15/0.11 - 100 =$ 36.4	2
NPV (15%), $20/0.199 - 100 =$	0.5	$15/0.16 - 100 =$ 6.3	1

This example also points out another weakness of using *NPV* as a criterion; the lifetime of the project is not taken into account. In principle, only alternatives with equal lifetimes should be compared. This can be done by assuming a reinvestment opportunity for the money invested in the project which has the shortest lifetime. The return on the reinvestment may then be set equal to the return on the alternative which has the longest lifetime. This is a conservative approach.

Goss (1976) and Buxton (1976) present another way of comparing alternatives which have different lifetimes. The net present value is transformed by a capital recovery factor into a series of equivalent annual incomes (*EAI*). For the alternatives 1 and 2 shown in the table above this would mean:

Discount rate 8%

Alternative 1: *CR* (8%, 10 years) = 0.149, $EAI = 34.2 \times 0.149 = 5.1$

Alternative 2: *CR* (8%, 20 years) = 0.110, *EAI* = 36.4 x 0.110 = 4.0

Thus, alternative 1 would be the best.

Another disadvantage of using the *NPV* criterion is that it measures the growth of value in absolute terms and not in relation to the investment. Thus a project with a relatively small return on invested money may appear to be the best only because the investment is large and produces a large net income by virtue of its size. This is acceptable only when there is no shortage of money.

11.5.1.3 Time of capital recovery (TCR) *and pay back period* (PBP)

Using the *TCR* as a criterion gives priority to the projects which will recover the investment with interest in the shortest time. It will favour the alternatives in which the net income comes early. It should be used when there is a possibility that the income may be less than forecasted or the costs higher than expected and when money for investment is scarce and must be recovered as early as possible. A high rate of interest (discount factor) gives a long *TCR*, a low rate of interest gives a short *TCR*. The shortest possible *TCR* occurs when a zero rate of interest is used in the calculations. Two examples illustrating the choice of alternatives based on the *TCR* are shown below.

Example 1.	Investment	100	
	Annual net income	25	
	TCR (5%) = 4.4 years	*TCR* (10%) = 5.7 years	*TCR* (15%) = 6.6 years
		Alternative 1	Alternative 2
Example 2.	Investment	100	100
	Annual net income	25	18
	TCR (10%)	*5.7 years*	11.5 years
	Life	8 years	20 years
	NPV (10%)	33.7	*53.8*
	IRR	*18.6%*	17.25%

The characteristics of the best alternative are shown in italic.

11.5.1.4 Internal rate of return, IRR

The *IRR* favours the alternative which has the highest return on the investment. It should be used as a criterion when money is scarce. The *IRR* measures the income in relation to the investment but does not take into account the amount earned. In this respect it is the opposite of the *NPV*. The exaggerated example below illustrates its weakness.

	Alternative 1	Alternative 2
Investment	10MNKr	100MNKr
Annual net income	3.2	20
Lifetime	10 years	10 years
IRR	30%	15%

Alternative 1 comes out best although its investment opportunity is only 10% of alternative 2. It may be more advantageous to earn 15% on an investment of 100 MNkr than 30% on an investment of 10 MNkr.

You should make sure that each alternative has the same investment opportunities when using the *IRR* as a criterion for comparison. This can be done by adding smaller alternatives together so that the sum of their investment opportunities matches the investment opportunity of the largest alternative. The weighted average rate of return (*WARR*) for the combined smaller opportunities is then calculated to make the comparison with the larger investment opportunity.

11.5.1.5 The net present value index, NPVI

The *NPVI* leads to the same ranking of alternatives as does the *IRR*. It has the same weaknesses and strengths as the *IRR*, but is easier to calculate.

11.5.1.6 Cash balance

No company can exist without cash. A cash balance should always be worked out before a project is brought forward for a final evaluation.

The cash balance or cash flow are criteria which can be used to compare alternatives in light of the cash situation of a company as a whole. The demand for cash may prevent a company from investing in projects that would otherwise have been of interest. This may be the case when, for example, the most promising project entails a large cash demand at a time when the company is already expected to run into a cash deficit. On the other hand, an inferior project may be preferred because it will produce cash at a time when it is badly needed. There may also be cases when a project is preferred because it offers an opportunity to invest surplus cash at the right time and thereby offer the opportunity to increase tax free depreciation.

The cash balance is unique as a criterion because it may completely change the ranking of alternatives regardless of how they are ranked based on other criterion. This is because cash is so important to a company.

11.6 THE INFLUENCE OF TAXES

In a preliminary economic analysis tax considerations may be ignored. However, tax considerations may have an impact on the final selection of alternatives. Taxes should always be accounted for in the final evaluation of a project because it may greatly reduce the net income.

11.6.1 How to calculate taxes

Tax reduces the income by the amount,

$$t\,(A - P_0 d)$$

where t = tax rate, A = gross income deducted for expenses due to operation, fuel, port and canal dues, maintenance and repair, manning, loading and unloading, administration, insurance, interest on loans (in the majority of countries) and any other item that is required to keep the operation or service going.

P_0 = the total investment,
d = depreciation rate.

The depreciation allowance is the amount which is exempt from tax. It is calculated on a year by year basis. In principle this allowance should make it possible to recover the money that has been invested in an object, such as a drilling platform or a ship, without having to pay tax on it. Rules for determining the depreciation allowance vary from country to country. In many cases investments made for one project may be used to augment the depreciation in another project. In its most simple form, the depreciation allowance corresponds to the total investment divided by the lifetime counted in years,

$D = P_0/N = P_0 d$

As as a rule, the depreciation allowance is based on the sum that has been invested. Inflation and the cost of forgone interest are not taken into account.

The detailed rules for depreciation will not be dealt with here. However, it is important to remember that the depreciation allowance is only an amount that may be earned without paying tax. It has nothing to do with the cost of an investment or the cash flow except that is a way of reducing tax.

Income after tax, A^1, may be calculated by:

$$A^1 = A - t\,(A - P_0 \times d)$$
$$= (1 - t)\,A + t \times d \times P_0$$

When the project has loans, the net income will be further reduced by the instalments on the loans.

11.6.2 The influence of tax on economic criteria

Economic criteria are derived in the same way whether or not taxes are taken into account. The only difference is that income is reduced or costs are increased by the amount paid as taxes. Taxes will increase the required freight rate and the required charter rate. They will also increase the cost and time of capital recovery and reduce the net present value and the internal rate of return. The effect of taxes on the cost of capital recovery is shown as an example below. Values marked with a prime (^{1}) represent after tax values.

When there is no tax

$$ACCR = CR \times P_0$$

When tax is introduced

$$ACCR' = CR' \times P_0 + \text{Tax}$$
$$\text{Tax} = t\,(ACCR' - P_0 d)$$
$$(1\text{-}t)\,ACCR' + t \times dP_0 = CR' \times P_0$$
$$ACCR' = \frac{P_0\,(CR' - td)}{1 - t}$$

CR' should be based on expected lifetime, N, and the interest corrected for tax, $i' = (1 - t)\,i$.

For example, if:

$CR\,(15\%, 10) = 0.20$
$P_0 = 100$ NOK
$d = 0.1$
$t = 0.5$

Before tax,

$ACCR = 0.2 \times 100 = 20$ Nkr

introducing 50% tax:

$i' = 15\,(1 - 0.5) = 7.5\%$
$CRF'\,(7.5\%, 10) = 0.1457$

$$ACCR' = \frac{100(0.1457 - 0.5 \times 0.1)}{1 - 0.5} = 19.14 \text{ NOK}$$

The difference is not great. The reason is that the interest after tax, i', is used in establishing the capital recovery factor after tax, CR'.

11.7 THE EFFECT OF BORROWING MONEY

Money is borrowed to reduce initial investment expenses. In return, instalments have to be paid over a period of time. The effects of borrowing money may be summarized as follows:

- A reduced equity requirement which may lead to more ambitious capital investments.
- A change in cash flow.
- A reduction in taxes (this depends on the country).
- An increased dependence on a regular income to cover the instalments and thus, an increase in risk.
- An increased return on equity if the project is profitable.
- A change in the ranking of projects in some cases.

The cost of borrowing money is usually reduced by the taxes. A tax rate of 50%, which is quite common, will reduce the cost of loan interest by 50%. In most cases this will increase the return on your own money. In some cases it may also change the ranking of alternatives. The example below illustrates this.

11.7.1.1 Example: The effect of part financing by loans on the ranking of alternatives.

	Alternative A	*Alternative B*	
Opening investment, P_0:	200 MNKr	200 MNKr	
Number of years with income:	5	9	
Net income per year, after tax:	55.5 MNKr	40.4 MNKr	
Residual value of investment at end of the income producing period:	0	0	
Case 1: 100% equity (own money):			
			Better alternative
Internal rate of return, *IRR*	12%	14%	B
Time of capital recovery at 10% discount rate, *TCR* (10%)	4.75 years	7.2 years	A
Time of capital recovery in relation to number of years with income	0.95	0.8	B
Net present value at 10% interest, *NPV* (10%)	10.4 MNKr	32.7 MNKr	B
Case 2: 80% of the investment by loans:			
Loan rate of interest after tax, 5%.			
Instalments, 40 MNKr per year through 4 years.			
Measures of merit calculated on the basis of *own* money, i.e., 20% of the investment.			
IRR	26%	22%	A
TCR (10%), *own money*	4.2 years	6.32 years	A
TCR in relation to lifetime	0.84	0.702	B
NPV (10%)	27.00 MNKr	50.26 MNKr	B

The benefits of borrowing money are apparent from this example, but the disadvantages are not. If money is borrowed instalments must be paid at regular intervals. It becomes necessary to produce a surplus each year, otherwise your company may go bankrupt.

When all the investment is equity capital there is an implied cost of recovering the money, but no requirement to pay predetermined amounts at fixed times. The investor using his own money will be satisfied if his money is recovered over the lifetime of a project. He is not dependent on a regular surplus and is in a much better position to take risks and operate in a market than is the person working with borrowed money.

11.8 THE EFFECT OF INFLATION

Inflation causes wages and prices to increase from one year to the next but in a preliminary economic calculation this is generally not taken into account. It is assumed that all cost and income items will increase at the same rate and the increases will thus cancel each other out. This assumption is conservative because loan expenses remain fixed in money terms if the agreed rate of interest is not changed, and are paid using money which is steadily decreasing in value.

Inflation should be taken into account, as shown in the cash flow calculations in Section 11.4.7, in the detailed economic calculations which should be done before a project is finally accepted.

One effect of inflation that is not generally taken into account is the increased cost in money terms of renewing objects, such as ships and drilling platforms, when they are worn out. These costs may vary with market conditions but there is an underlying tendency for prices to increase due to inflation. When calculating this effect, the cost of renewing worn out components should be considered as follows:

If the annual rate of inflation is e%, the cost of a drilling platform or ship will after N years have increased by a factor of

$$(1+e)^N$$

If the intention is to acquire a ship or drilling rig of roughly the same type and capacity after the original one has worn out, the cost in terms of the original investment, P_0, will be

$$P_0(1+e)^N$$

This is the minimum required for reinvestment; the cost of forgone interest is not taken into account. It has to be earned after tax. If calculating with a stream of net income consisting of annual amounts of A'_n after tax, then

$$\sum_{n=1}^{N} A'_n (1+i')^{N-n} = P_0(1+e)^N$$

where: P_0 = the original investment
A'_n = net income after tax in year n
i' = annual rate of interest, *earned on* net income after tax (assuming the annual net earnings to be reinvested in projects having an *IRR* after tax of i')
e = annual rate of inflation

$$A'_n = R_n - t\,(A - \sum_{j=1}^{k} C_{j,n} - C_{B,n} - P_0\, d)$$

R_n = gross income, year n
t = tax rate
$C_{j,n}$ = expense j in year n
$C_{B,n}$ = interest paid on borrowed money, year n
d = depreciation rate
P_0 = the opening investment

If you make the simplifying assumption $A'_n = A'$ for each year:

$$\sum_{n=1}^{N} A'(1+i')^{N-n} = P_0(1+e)^N$$

$$\frac{A'(1+i')^N}{CR\,(i\,\%, N)} = P_0\,(1+e)^N$$

$$A' = CR\,(i'\%, N)\,P_0\left(\frac{1+e}{1+i'}\right)^N$$

A' is the minimum annual net earning after tax to secure the required money for reinvestment, cost of forgone interest not taken into account.

For example if:

$P_0 = 100$ MNKr
$e = 0.07 = 7\%$
$i = 0.10 = 10\%$ before tax obtained on net earnings
$t = 0.50 = 50\%$
$i' = i\,(1-t) = 0.10\,(1-0.50) = 0.05 = 5\%$
$N = 12$ years
$CR'\,(5\%,12) = 0.113$

Then:

$A' = 0.113 \times 100\,(1.07/1.05)^{12} = 14.7$ MNKr

That is, in order to be able to recover the money required to reinvest after 12 years at 7% inflation, and assuming an income on net earnings corresponding to 5% interest after tax, it is necessary to have a yearly net income after tax of 14.17 MNKr when the original investment is 100 MNKr.

The cost of forgone interest on the invested money has then not been reckoned with.

With no inflation and foregone interest equal to $i'\%$ after tax, the investment should grow to

$P_0(1+i')^N$

Assuming that the real value of this amount not to be influenced by inflation, a year by year rate of inflation of $e\%$ would require the amount to be equal to

$P_0\,(1+i')^N(1+e)^N$

correspondingly,

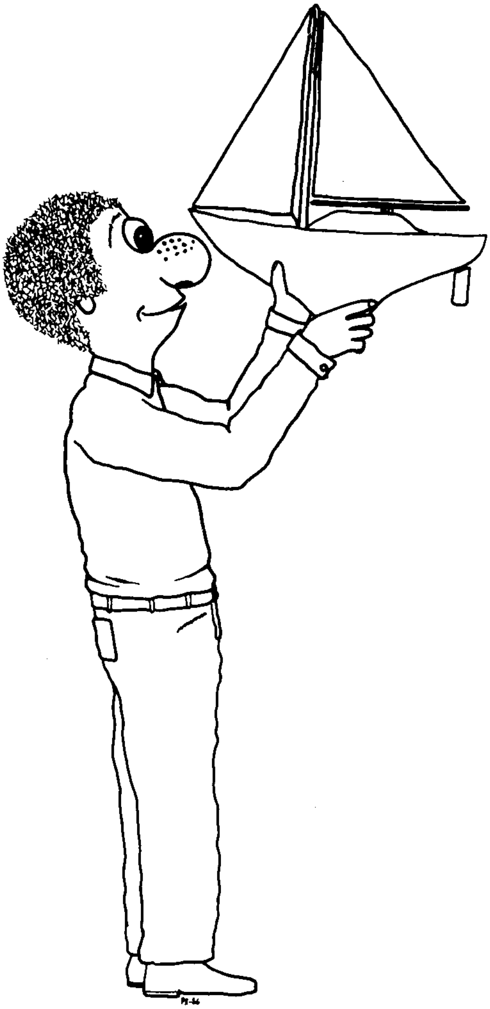
$A' = CR\,(i', N)\,P_0\,(1+e)^N$

Using the figures shown in the example above,

$A' = 0.113 \times 100 \times 1.07^{12} = 25.45$ MNKr

12

MODELS AND OPTIMIZATION



12.1 INTRODUCTION

The use of models is inherent in design. In fact, the use of models for experimentation, displaying of solutions and checking of spatial conditions is fundamental in industrial development. The development of craftsmanship was hampered by the fact that experimentation was carried out on actual constructions and not on models. Rapid industrial development occurred when the use of drawings and other inexpensive representations of the actual constructions which could be used for experimentation were introduced (Jones, 1982).

Anyone who is involved in marine design will be familiar with the use of models and many of these people construct their own. Therefore, the discussion below will be limited to brief reviews of the major types of models. Only models which have been developed recently will be discussed in more detail. There are two main categories of models: models which are a physical representation of the real thing and those which are an abstract representation.

12.2 PHYSICAL MODELS

The types of physical models and their uses are outlined below.

Drawings and sketches. These can be used for displaying solutions, for example, a general arrangement. They can serve as the basis for estimating weights, areas, volumes, centres of gravity and the amount of material which will be needed. They can also serve as a basis for production planning and production.

Scale models. These can be used to display solutions, for example, complete models of a vessel with its superstructure can be built. Engine room models can also be used to check space, areas, piping arrangements and passages. Hull models are used for determining resistance and seaworthiness. Scale models of structures can be used to test strength.

12.3 ABSTRACT MODELS

All abstract models described here are models that do not directly depict actual constructions. Mathematical models are one type of abstract models.

12.3.1 Diagrams

Diagrams are abstractions of real systems. Various types of diagrams and their uses are described below.

Schematic representations: These are used to visualize elements of a system and to show how the various elements are interdependent. See Figure 12.1.

Flow charts: These are used to visualize a sequence of operations, and for document handling, processing and procedures and to show how different components or elements depend upon each other. A flow chart outlining the design process is an example of flow chart.

Some flow charts have been developed for special purposes. These include:

Gantt diagrams: These are used to display production time and the workload of men and machines and to plan allocation of jobs.

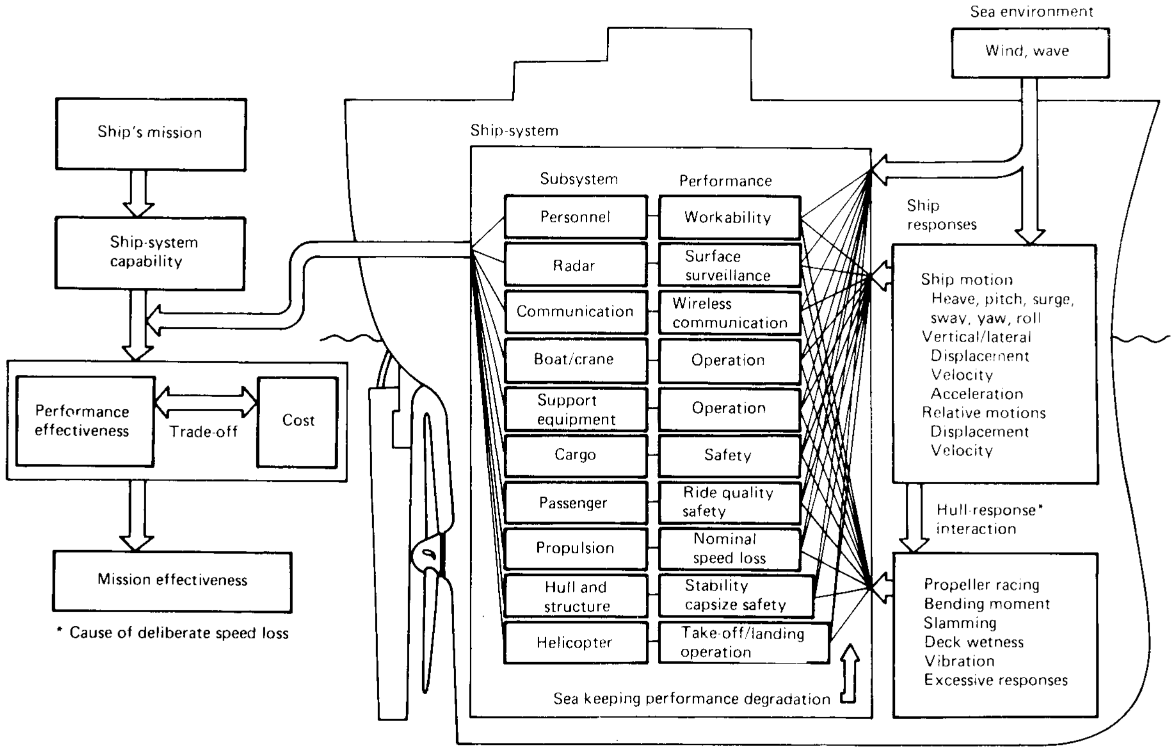


Figure 12.1 A schematic representation of interrelations between a ship's subsystems, its seakeeping performance and mission effectiveness. From Hosoda et al.'s study of seakeeping performance of patrol/rescue boats (Hosoda, 1985).

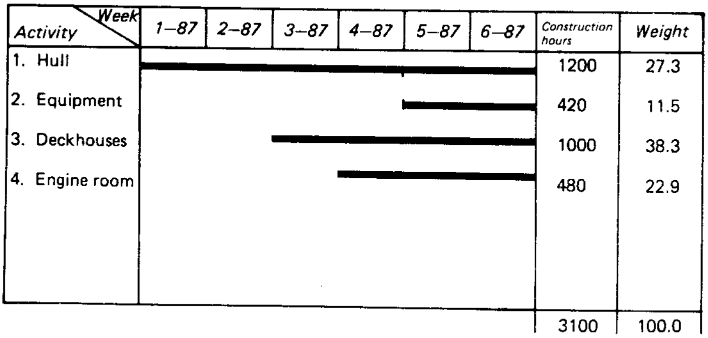


Figure 12.2 Gantt representation.

PERT (Programme Evaluation and Review Technique) diagrams: These are used to review the interdependency of suboperations, to estimate the total production time and develop a job sequence and allocation that will minimize production time. PERT is an abbreviation of Program Evaluation and Review Technique.

PERT has a technique for establishing density functions. This technique may be applied to many different cases (Figure 12.3). For example, to develop a density function for the crossing time of a voyage.

To do this, experienced captains are asked to give their opinion on:

a, shortest possible (most optimistic) crossing time
m, most likely crossing time
b, longest imaginable crossing time.

Expected crossing time, t_e, is expressed by

$$t_e = 1/3\,(2m + 1/2\,(a + b))$$

and the variance is

$$s^2 = (1/6\,(b - a))^2$$

The formula for the expected time rests on the assumption that the crossing time is distributed as a β distribution, which has a shape shown in Figure 12.4. By varying m and

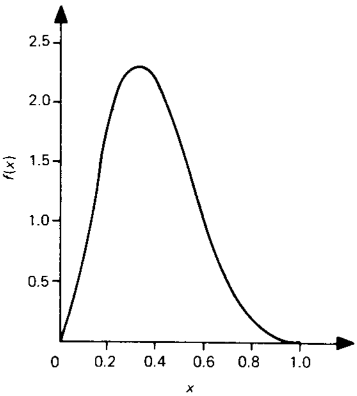


Figure 12.4 A β-distribution skewed to the left and typical of the distribution of crossing time ($\alpha = 2, \beta = 4$)

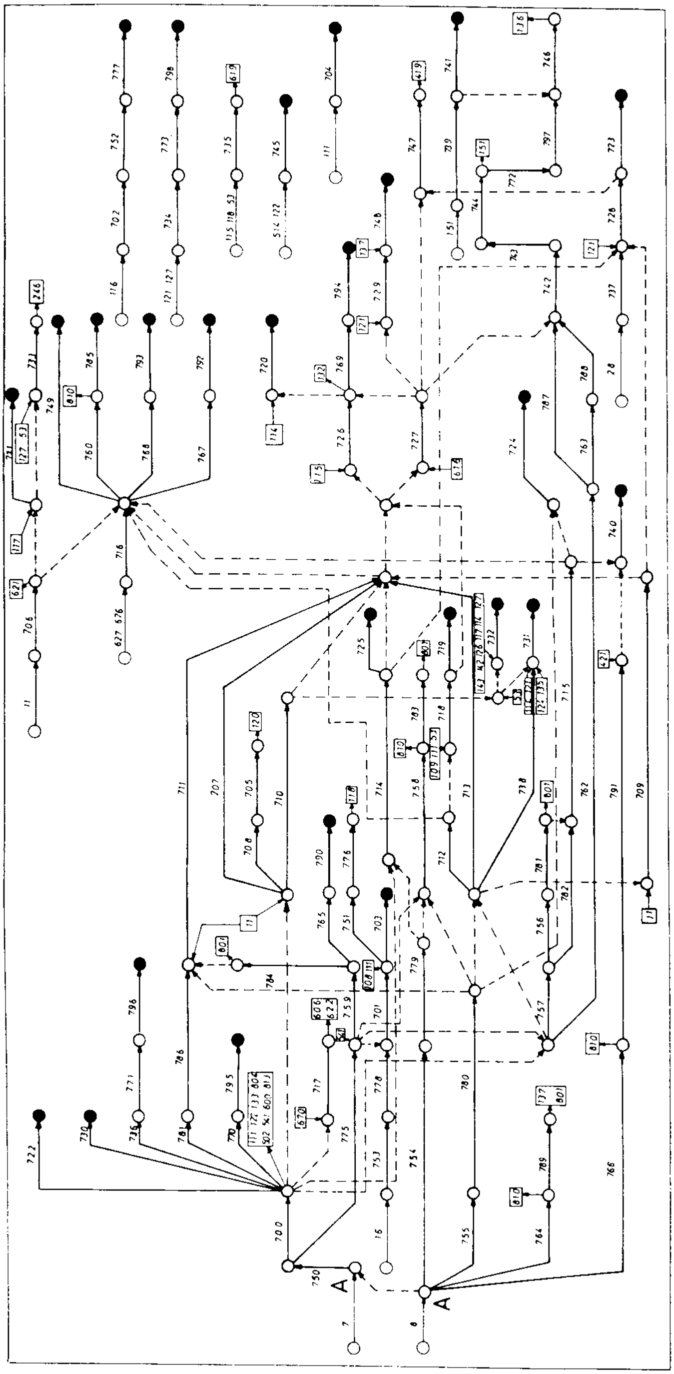


Figure 12.3 A typical PERT diagram. The nodes represent job dependencies, the arcs jobs. The density of arcs indicate high job density, ie much work to be done at the same time. (Kløvstad, 1965).

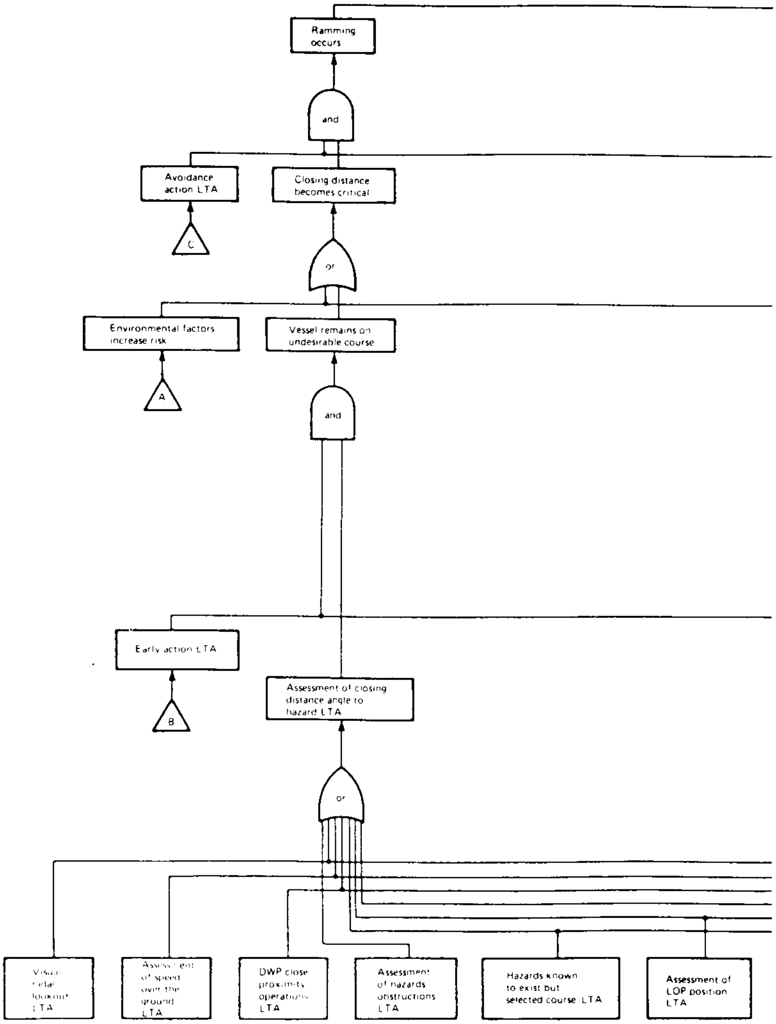
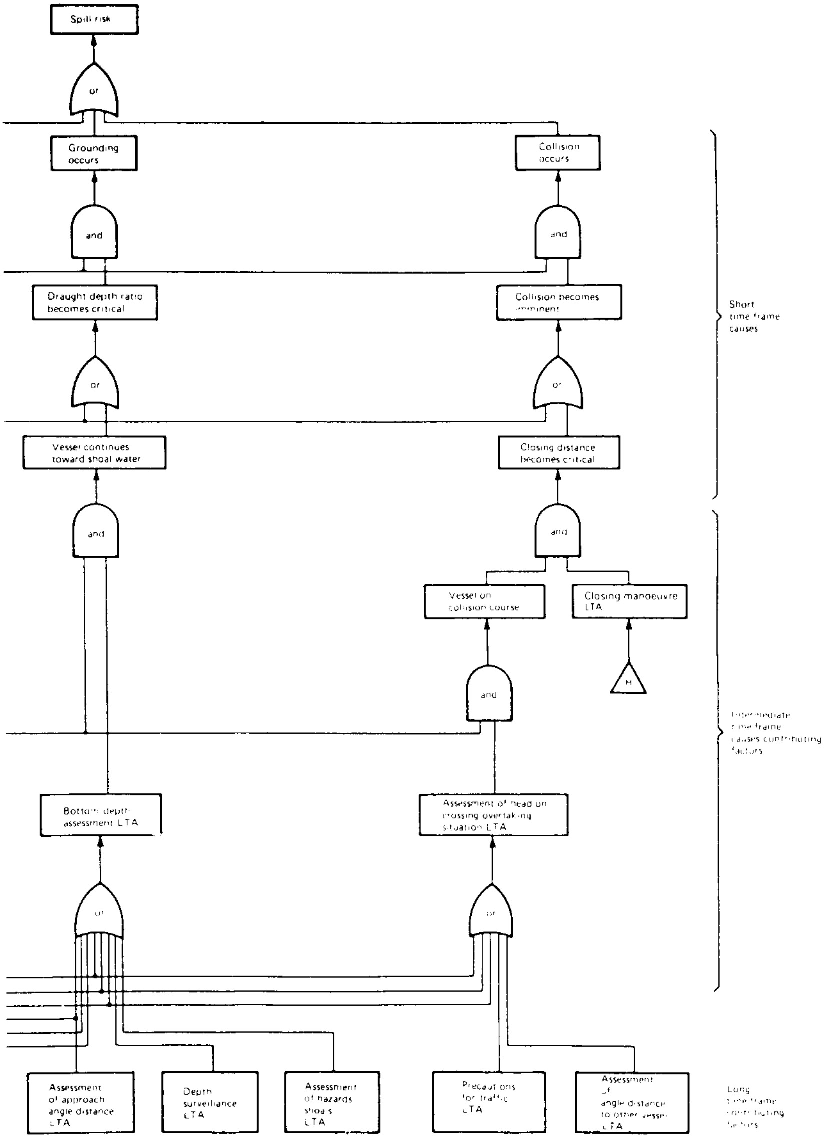


Figure 12.5 Example of a model of causes and conditions that can lead to a risk of oil spill. This type of model is called a *fault tree*. On the lowest level are the basic *less than adequate* (LTA) performances which can lead to LTA assessments. How the LTA assessments in turn can lead to a situation of risk of oil spill is in the diagram shown by "and" and "or" gates or conditions (U.S.C.G.-79)


Spill risk
or
Grounding occurs
Collision occurs
and
and
Draught depth ratio becomes critical
Collision becomes imminent
Short time frame causes
or
or
Vesser continues toward shoal water
Closing distance becomes critical
and
and
Vessel on collision course
Closing manoeuvre LTA
H
and
Intermediate time frame causes contributing factors
Bottom depth assessment LTA
Assessment of head on crossing overtaking situation LTA
or
or
Assessment of approach angle distance LTA
Depth surveillance LTA
Assessment of hazards shoals LTA
Precautions for traffic LTA
Assessment of angle distance to other vessel LTA
Long time frame contributing factors

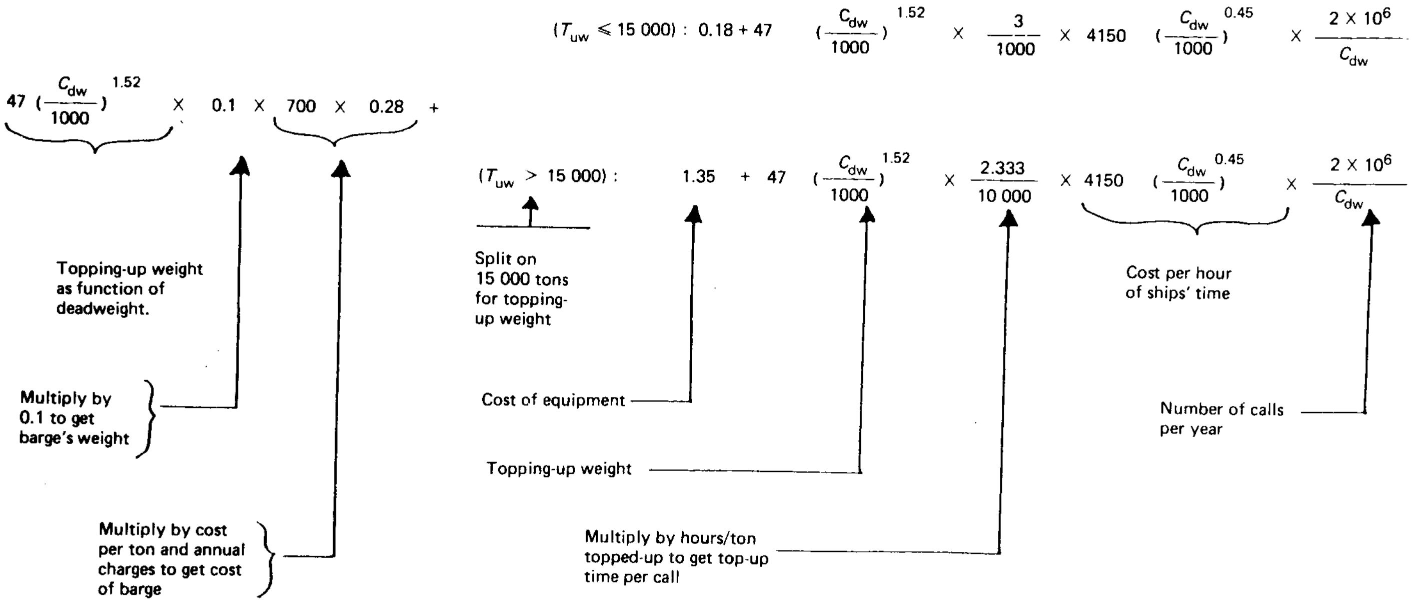


Figure 12.6 Calculation model. A model composed of arithmetic operations and a conditional branching. The purpose is to calculate the cost of topping up bulkers that load in a port with restricted draft

n the distribution may be given a suitable form. The formula of the β distribution is

$$f(x, \alpha, \beta) = \frac{(\alpha + \beta + 1)!\, x^{\alpha} (1-x)^{\beta}}{\alpha!\, \beta!} \quad 0 \leq x \leq 1$$

Fault trees: These are used to analyse a system of interdependent devices and/or actions and to determine the consequences of failures of different combinations of components. An example of a fault tree is shown in Figure 12.5.

12.3.2 Calculation models

Calculation models are used to perform either straightforward calculations, for example $\Delta = C_B \times L \times B \times T$, or calculations which involve conditional branching. Figure 12.6 is an example of a model used to calculate the cost of 'topping up' a bulk carrier which cannot be fully loaded at the quay because its draught is too deep. The functions of the different terms used in the model are explained in Figure 12.6.

Often, available models are not applicable to the case in hand and it is necessary for the designer to develop a new model, as was done in Figure 12.6. A calculation model produces one answer for each set of input variables. Developing your own models is discussed in Section 12.5.

Nowacki et al. (1970) used calculation models to undertake a systematic exploration of the solution space and the effect of constraints. Figure 12.7 shows the result of this type of exploration.

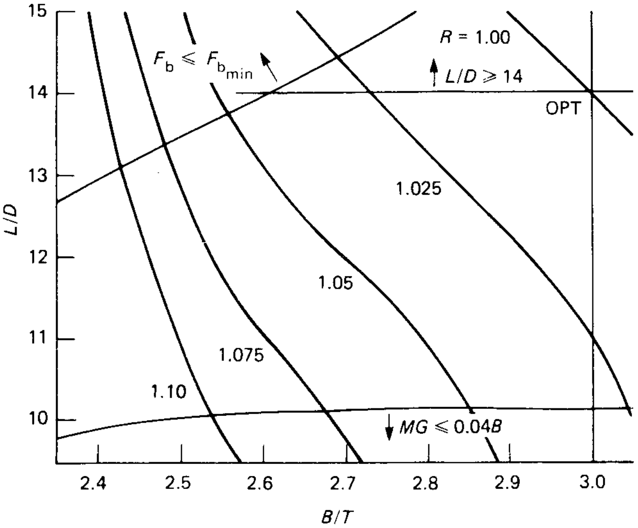


Figure 12.7 Visualization of the effect of constraints on an optimization. The example is based upon (Nowacki 1970)
L/D = length/depth ratio. B/T = beam/draft ratio
L/D has to be less than 14, the freeboard greater than $F_{b\,min}$,
B/T between 2.4 and 3.0, and the MG greater than $0.04B$

12.3.3 Simulation models

Simulation models are used to simulate randomness, either of nature, for example weather, or time required for man controlled non-automatic operations. Simulation models are used when design conditions become so complicated that it is no longer practical or possible to develop deterministic calculation models.

The simulation of randomness is generally done by using a computer to obtain pseudo-random numbers and allowing each number to generate the event that is to be simulated. Figure 12.8 illustrates how this process can be used to simulate time spent at a rig by a set of supply vessels. Because there is the same probability that the random number will have any value between 0 and 0.999, it is the slope of the graph of the cumulative distribution which determines how frequently visits of various lengths will take place. The slope of the graph directly reflects the observed frequency, as is apparent from a comparison between the histogram and the cumulative distribution.

One random number generates one event. This event may be anything with the observed limits (within 0–35 hours in the case shown in Figure 12.8). Therefore, one event is usually not representative of the case studied and it is necessary to run a simulation model many times (at least 25 times) to ensure that the events generated will have a mean value and spread similar to real life.

In some cases a simulation model may have to be run for some time in order to reach a stable situation. When the model is first started no events have been generated and the simulated system is 'empty'. A stable situation is reached when the system has generated a normal population of events. For example, the system could be said to have reached a stable situation when the population of events includes a fleet of supply vessels which is in accordance with general practice, normal amounts of supplies on board a drilling vessel and when the simulated routines are similar to those in daily operation.

A complete run of a simulation model produces results only for a specific set of input variables. The model must be re-run each time the input variables are changed.

The simulation model may contain simulations of many different actual events. As a rule it is not possible to compare simulation outcomes with actual events as was done in the case above.

Simulation is commonly used as a tool to support decision making in offshore operations. Simulations are used, for example, to forecast such things as delays and shut offs. The input variables include the performance of the rigs, tugs and supply vessels as a function of wind, waves and swell as well as the statistics, observations and time series of wind, waves and swell.

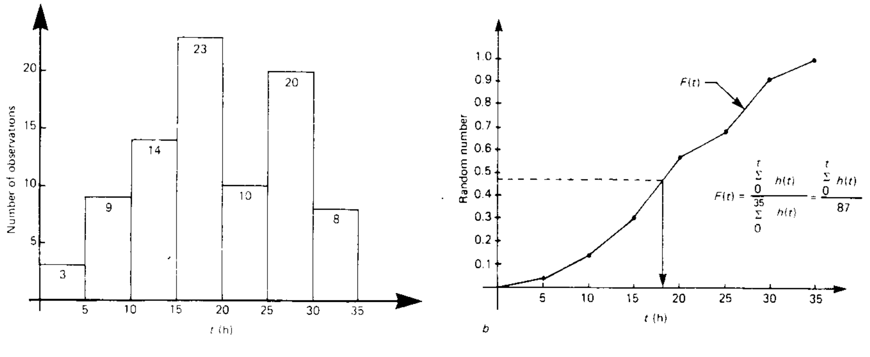


Figure 12.8 a) Histogram of time spent at a rig for supply vessels, and b) function of cumulative time distribution derived from the histogram. In simulation, a random number, n, between 0 and 1 is generated, eg, $n = 0.475$, and the corresponding time spent at rig found on the basis of the cumulative function, eg 18.33 h

Simulation is used both for acquisition decisions and for operational decisions. Deciding whether vessels and equipment should be acquired for a future operation is an example of an acquisition decision. Deciding whether a lifting operation which requires 24 hours of good weather should be started under the prevailing weather conditions is an example of an operational decision. In operational decisions observations of recent wind, wave and swell conditions are used along with statistics of past conditions as part of the basis of the simulation. The purpose is to produce a time series which describes the weather parameters and to examine the consequences of different decisions made on this basis. This use of simulation models is discussed by Ruud and Olsen (1983).

Provided the input is relevant and the models used for the purposes they were planned for, simulation can be a useful tool. However, misleading answers may result for the following reasons:

- The generation of random numbers was faulty.
- The same random number was used for the generation of different events.
- The model was run for too short a time period.
- The model has defects.
- The input parameters are irrelevant or have not been varied over a sufficiently wide spectrum.

For these reasons the results of a simulation should be judged carefully.

12.4 OPTIMIZATION

Design engineers are frequently presented with the results of optimization programs. Optimization programs are most commonly run on a computer. Optimization is a systematic change of design variables in accordance with rules which ensure that the variables are altered in a way that will improve the design. An example of an optimization routine is shown below.

Input variables:
Column diameter, d
Distance between columns, c
Pontoon cross-section, a

Starting point (first calculation):
$d = d_1$
$c = c_1$
$a = a_1$
Cost/Benefit $= R_1$

Change
$d = d_1 + \Delta d$
$c = c_1$
$a = a_1$
Cost/Benefit $= R_2$

Check $R_2 < R_1$
If *yes*: Keep $d = d_1 + \Delta d$
If no: Try $d = d_1 - \Delta d$

After the effects of changes of column diameter have been investigated, the procedure is repeated for the distance between columns and the pontoon cross-section. If, for example, it turns out that the cost/benefit value is improved by the following values of variables:

$d = d_1 - \Delta d$
$c = c_1 + \Delta c$
$a = a_1$ (no improvement obtained, no change)

a change of all three variables simultaneously may be tried, as shown below:

$d = d_1 + \mathrm{f}\,((d_1 - \Delta d) - d_1)$
$c = c_1 + \mathrm{f}\,((c_1 + \mathrm{D}\,c) - c_1)$
$a = a_1 + \mathrm{f}\,(a_1 - a_1)$

Then check the cost/benefit ratio again to see if it has been improved.

The addition to the variables, for example, $\mathrm{f}((d_1 - \Delta d) - d_1)$ for d, is calculated as a function of the difference between the new value of the variable (in this case, $d_1 - \Delta d$) and its former value, d_1. In many cases the function is merely a multiplication. For example, if $d_1 = 10$ m and $\Delta d = 0.2$ m, d would become

$d = 10 + 3\,((10 - 0.2) - 10) = 9.4$

A comparison of the calculations and the cost/benefit ratio can be made when the variables are altered one at a time (a local search) or when all the variables are altered at once (a global search). These search operations are carried out using a computer. It is possible to get a printout of the search values, but often there are so many steps in the search that it is easier to do without the printout. Interpretation of the printout can be time consuming.

12.4.1 Dealing with constraints

Penalty functions may be used to prevent a search from entering a constrained area. A penalty function is a function added to or subtracted from the objective function. The penalty function is designed so that it increases its value drastically when the search approaches a constraint. If, for example, draught is constrained to be less than 10 m and a minimum cost solution is sought, the penalty function might be as follows:

Original problem (with constraint)

Minimum $\mathrm{f}\,(L, B, T, D, C_B)$
Subject to: $T \leq 10$ m

Unconstrained problem:

Minimum: $\mathrm{f}\,(L, B, T, D, c_B) + \dfrac{1}{(T - 10)^2}$

If the value of T approaches 10 m, the value of the term $1/(T - 10)^2$ will move towards infinity and the search for a *minimum* value will change direction. The problem is that the term $1/(T - 10)^2$ approaches infinity whether T approaches 10 m through values that are greater than or smaller than 10 m. If the search started with a value of T greater than 10 m, it would also *end* with a value greater than 10. This problem can be avoided by designing penalty functions which steadily increase in value when a constraint has been violated. However, users of computer programs should bear in mind that penalty functions may have different effects outside and inside a feasible area. You should always ensure that a search begins with values that are feasible.

The constraint, $T \leq 10$ m may be said to be smooth. On its own it will not create any problems in a search that starts within the feasible area. In some types of problems many constraints may be active or some constraints, in themselves, create boundaries between feasible and infeasible areas which are not smooth (Figure 12.9). In these cases certain techniques can be used to prevent the search from approaching the constraints to begin with. One way of doing this is to multiply the penalty function by a weighting factor which is comparatively large at the beginning of the search but which is given increasingly smaller values as the search approaches a final value. This is called the sequential unconstrained minimization technique (SUMT). Gisvold (1971) gives some examples of its use.

SUMT is described in mathematical terms below:

First step, Min $f(x) + r_1\, p(x)$
Second step, Min $f(x) + r_2 p(x)$
Step n, Min $f(x) + r_n\, p(x)$

such that $r_1 > r_2 > .... > r_n$

A new r is chosen whenever the search has stagnated with a value of $f(x) + r_i p(x)$ that cannot be improved.

The use of penalty functions and the sequential reduction of their weighting factors will make the search end in a true optimum in most cases. However, a search may end in a false optimum (a sub-optimum or local optimum) if the the function on which the search is performed and the restrictions on its variables do not satisfy certain requirements at the outset. These requirements are illustrated in Figures 12.9, 12.10 and 12.11.

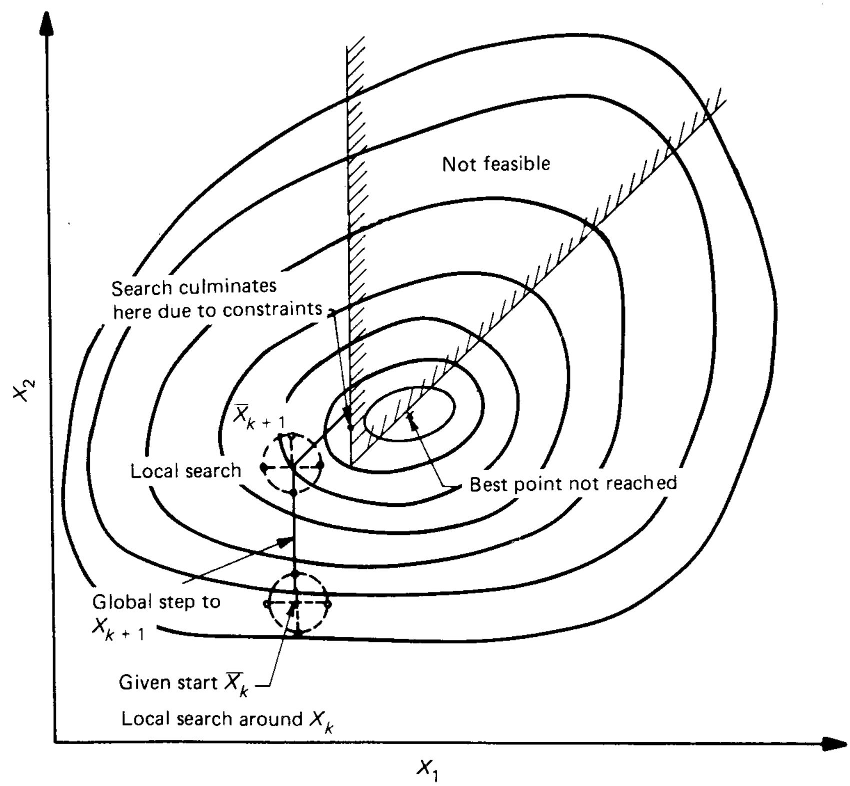


Figure 12.9 Visualization of how an *awkward starting point* may prevent the search from ending in the real optimum

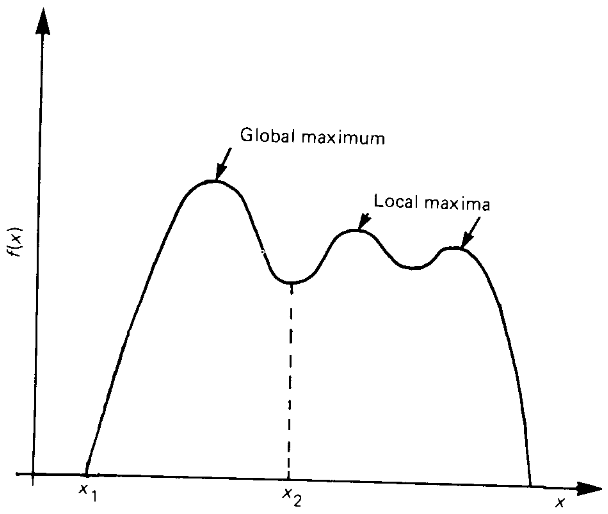


Figure 12.10 A graph of a function with one global and two local maxima. A search starting with a value of X, $X_1 < X < X_2$, would end in the global maximum; a search starting at $X > X_2$ would end in one of the local maxima

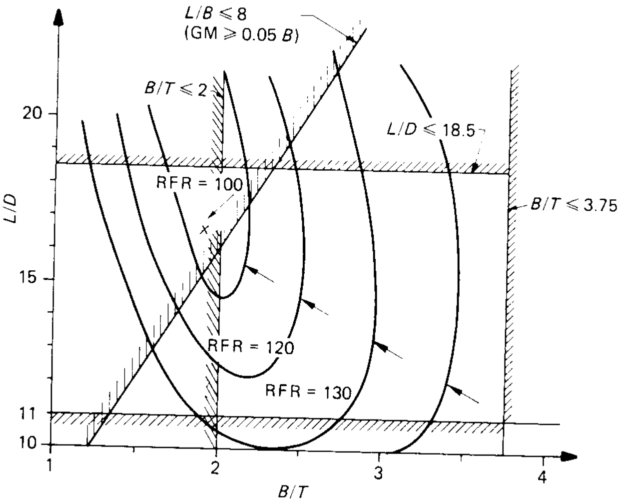


Figure 12.11 Effect of constraints on ship dimensions. The unconstrained optimum is at RFR = 100, but restrictions demanding the length/beam ratio, L/B, to be less than or equal to 8, and the beam/draft ratio, B/T, to be greater than or equal to 2, allow no better solution than that at RFR = 104. The illustration is based on one of Nowacki's investigations of effects of constraints on ship design (Nowacki, 1970)

12.4.2 Safety precautions

Marine design functions tend to have only one optimum and to have constraints which do not force the search to end before it reaches as close to the optimum as possible. There are sometimes exceptions to this rule in cost/benefit functions related to the design of steel structures (Gisvold, 1971) or when restrictions on stability or economy are used as constraints on design functions.

A design engineer who develops his own functions and constraints will certainly be aware of these facts. However, many designers make use of results given to them by consultants or contractors. They should keep in mind the sources of error illustrated in Figures 12.8, 12.9 and 12.10 as well as the points listed below.

- The search routine is applied to a function with local optima.
- Restrictions on the variables prevent the search from ending at a global optimum.
- The selection of starting points for searches may be awkward.
- The search technique may be unsuitable for the problem.
- The variables may be badly adjusted to the restrictions (see Figure 12.12).
- The search may have been applied to functions of irrelevant variables because the relevant variables may have been discarded.
- The computer printout routines may be faulty.

As a minimum precaution against errors, the search should be started at different points and the results compared. In addition, one or more of the constraints should be left out of consideration for several of the searches in cases where the results of searches do not correspond well. It may also be necessary to request a few printouts of the values of the objective function for different stages of the search, for example for each global step.

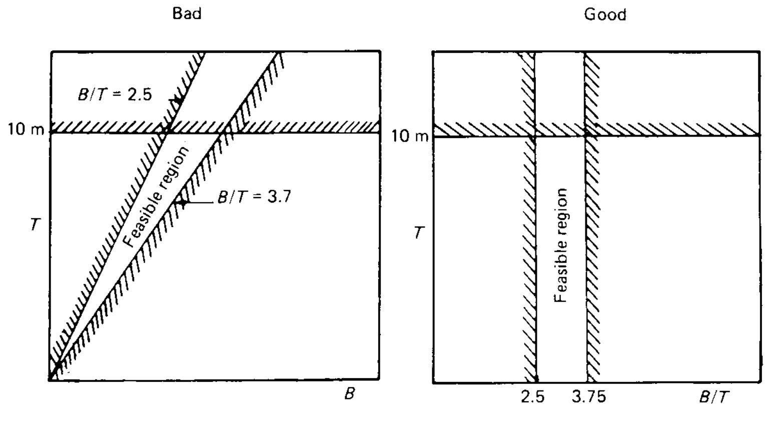


Figure 12.12 Example of how a suitable selection of variable (B/T against T) makes the feasible region more convenient for a search. Restrictions: $2.5 < B/T < 3.75, T \leq 10$

12.5 ESTABLISHING YOUR OWN MODELS

A design engineer will be so familiar with the setting up of calculations and the preparation of drawings, sketches and, possibly, physical models, that there is not much need to give much consideration to the problem of developing his own models here. However, before preparing a model you should understand its purpose and know which are the important variables. The examples below may give some guidance:

Purpose: To demonstrate the effects of constraints and expensive requirements.
Type of model: A diagram like that illustrated in Figure 12.11 and presentation of the economics with and without constraints.
Important variables: Constraints, main dimensions and capacity.

Purpose: To illustrate the proper sequence of a job or operation.
Type of model: Flow chart.
Important variables: Operations, jobs, part jobs, job dependencies.

Purpose: To make sure a schedule is adhered to.
Type of model: Gantt diagram, flow chart.
Important variables: Work load, time

Purpose: To investigate spatial conditions.
Type of model: Physical model.
Important variables: Room partitioning, installations, furniture, equipment and its location.

Purpose: To compare the costs and benefits of different solutions.
Type of model: Calculation model.
Important variables: Main dimensions, capacity, time.

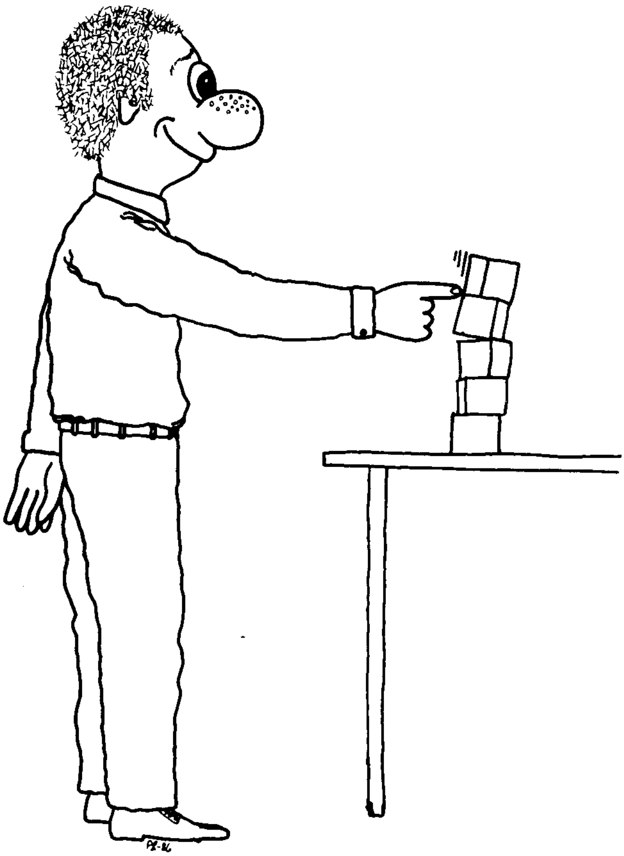
Purpose: Physical experimentation.
Type of model: Physical model in accordance with model laws.
Important variables: Main dimensions, shape, capacity.

Purpose: To investigate the effects of uncontrollable events.
Type of model: Simulation model.
Important variables: Main dimensions and particulars, capacity, time.

Purpose: To verify a hypothesis.
Type of model: Simulation models, physical models for experimentation.
Important variables: Major variables and conditions of the hypothesis.

13

SENSITIVITY ANALYSES



It is important to investigate how basic assumptions and parameters influence the outcome of a design. Variables and assumptions should be systematically altered and the outcome of each case should be noted.

To start with only one variable or assumption should be changed at a time. When the crucial variables and assumptions have been revealed in this way two or more variables may be changed at the same time in order to discover their combined effect. It is best to check how relatively drastic changes of assumptions and variables will influence the outcome first. If the drastic changes have a marked influence, the calculations should be repeated for less drastic changes. Except for very simple cases, a computer-based calculation model is necessary to complete this job within a reasonable amount of time.

13.1 USES

A sensitivity analysis may be used to:

- Discover the extent to which variables can be changed without creating an unacceptable outcome; to determine the break-even points.
- Identify the important assumptions and determine how much they can change before an unacceptable result is produced; to determine the break-even points.
- Investigate how much variables and assumptions may change before a chosen alternative becomes inferior to another alternative.
- Systematically explore the solution space in order to clearly see the interrelationship between variables, assumptions, constraints and outcome. Figure 13.1 illustrates this approach.

A sensitivity analysis provides much insight into where to concentrate further design work and how to reduce the effects of errors in assumptions. The two examples below illustrate the use of a sensitivity analysis.

13.1.1 Examples

13.1.1.1 Example: Exploring the effects of changes in basic assumptions

The table below lists some basic assumptions.

Item	*Assumed value*	*Break even limit*	*Limit of acceptable deviation in per cent*	*Per cent change of net earnings per 1% increase of assumed value*
Freight Rate	70 $/t	66.5 $/t	− 5	12
Cargo Volume	500,000 t/year	450,000 t/year	− 10	10
Fuel Price	120 $/t	180 $/t	+ 50	−1.3
Cargo Related Costs	20 $/t	25 $/t	+ 25	− 3
Operation Cost	2 M$/year	4 M$/year	+ 100	−0.7
Miscellaneous	2 M$/year	4 M$/year	+ 100	−0.7
On Hire	360 days/year	342 d/year	− 5	12
Building Price	70 M$	84 M$	+ 20	− 5
Salvage Value after 12 years	14 M$	Nil	−100	1
Round trips per Year	12	11.4	− 5	20

Basic assumptions are ranked below in accordance with their influence on the surplus.

1. *Freight rate*: A margin of only 5% is too small to go on with the project. A rate reduction will most probably occur at the same time as a reduction in cargo volume.
Try to: reduce costs and secure long term freight contracts. Drop the project if the assumed income cannot be secured or the costs cannot be reduced.
2. *Round trips per year*: The margin is small. Check the weather statistics and further investigate the relationship between hull shape and fullness and propulsion power and speed under different weather conditions. Company policy demands that if the probability of dropping below 11.4 round trips per year is larger than 2% the project should be dropped.
3. *Time on hire*: The time on hire depends on company policy. It has never been below 342 days per year. This limit is acceptable.
4. *Cargo volume*: A marign of 10% would be acceptable were it not for the fact that a reduction in cargo volume would, in nine out of ten cases, come at the same time as a fall in the freight rates.
Try to: Secure a sufficient cargo inflow or freight rate by long term contracts. Otherwise, drop the project.
5. *Fuel price*: The margin is acceptable.
6. *Building costs*: The margin is acceptable if there are no changes in currency values.
Try to: Secure the rate of change of the currency by contract.
7. *Operation costs*: The margin is acceptable.

This example demonstrates that renegotiation of terms and reworking of the design may be necessary after a sensitivity analysis. However, conditions that are under your own control can be treated with a higher degree of confidence than conditions which are influenced by outside forces such as other people or nature.

13.1.1.2 Example: Adapting to changing conditions

Frequently the choice is between one solution which is extremely well suited to one particular set of assumptions but which is not very suitable under other conditions, and a solution which does not fit any particular set of assumptions but is not particularly bad under any other conditions.

Figure 13.1 illustrates a case where the optimum deadweight of a freighter has been calculated for several different sets of assumptions. The amount by which the deadweight may be changed in relation to the optimum without increasing the required freight rate by more than 2.5% has also been determined. Figure 13.1 shows that if a deviation of up to 2.5% from the optimum is accepted, it is possible to find a solution that will remain within this limit for almost any set of assumptions.

When you don't know how things will develop, as is usually the case, it is better to seek a solution that will produce a reasonable outcome for any set of conditions than to select a solution that is very good under one particular set of conditions but not very good under other conditions. It is often better to design for versatility and easy conversion than to design for a close fit.

13.2 TRADE-OFF ANALYSIS

Trade-off analysis is a special kind of sensitivity analysis by which you can investigate how much may be gained or lost on one component by either spending money or economizing on another component. For example:

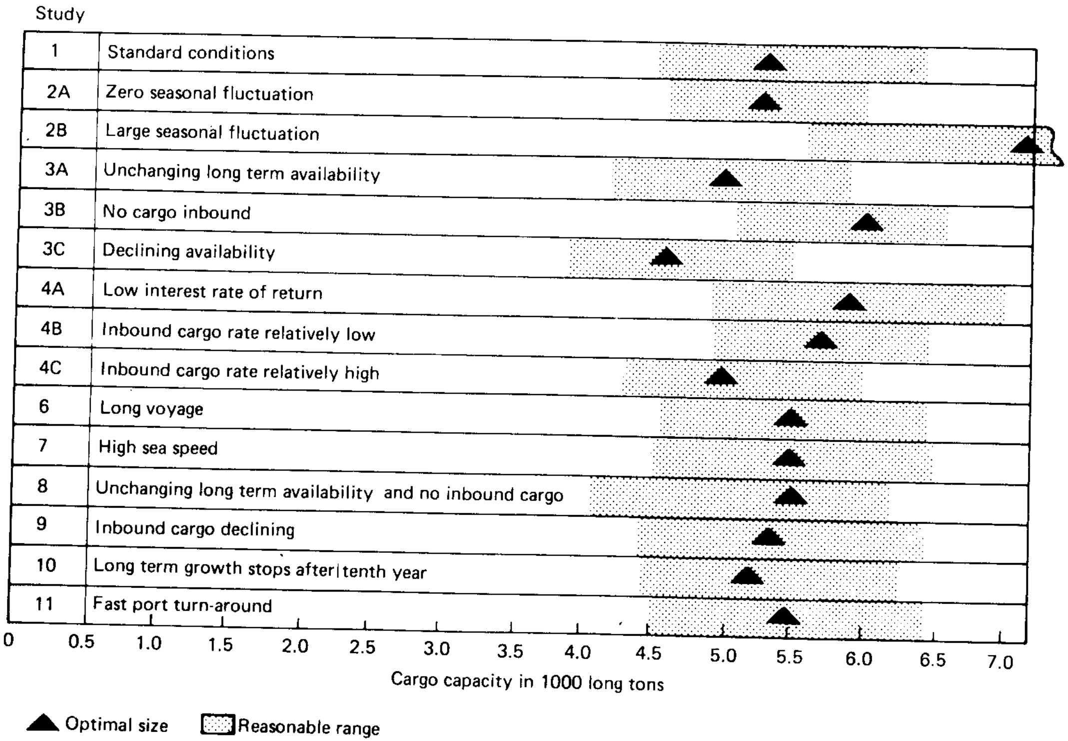


Figure 13.1 Sensitivity Analysis by Benford (Benford 1967). Reasonable ranges of DW as functions of changing basic conditions. Within a margin of ± 2.5% of the optimum (the 'Reasonable Range') it is possible to find a capacity that will fit 14 out of the 15 cases.

- What is the cost of doubling up the drilling equipment on a drill ship versus the gain in the resulting reduction in downtime?
- What is the cost of increasing or decreasing the speed by one knot versus the income gained by a shorter round trip time or the loss incurred by a longer round trip time if the speed is reduced?
- How much extra would customers be willing to pay for added luxury items on a cruise ship?

Marine vehicles are built according to various specifications (see Chapter 16). As a rule the specifications of recently built vessels are used as references while you gain experience with the vessels. Often the specifications are altered when a mishap occurs in order to prevent the accident from happening again. This may lead to a specification with so many added components that the cost of building a vessel may be too high to ensure a reasonable profit. In most cases specifications are altered without first examining the probability of the mishap occurring again and considering the cost of the added components. To prevent a vessel from becoming uneconomic a trade-off study should always be undertaken whenever a new component is added to a specification.

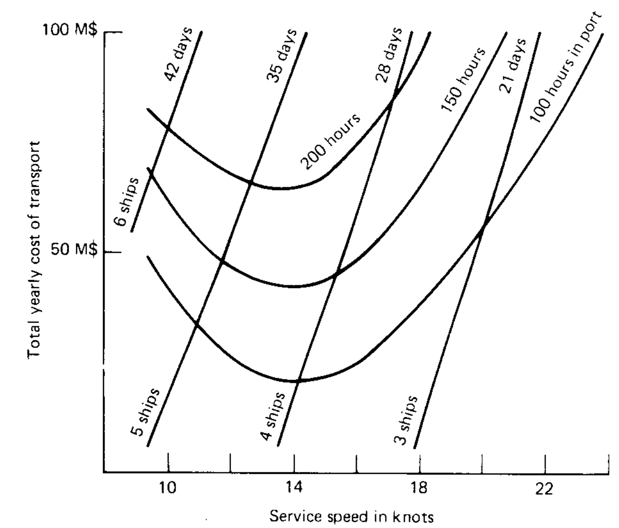


Figure 13.2 Example of a graph based on a sensitivity analysis. Interdependencies between number of ships, their speed and the time spent in port per roundtrip. (From Getz et al, 1968)

13.3 PROBABILITY DISTRIBUTIONS AND SENSITIVITY ANALYSIS

A sensitivity analysis determines the limits beyond which variables and assumptions cannot change without making a project uneconomic. In addition it is necessary to find out whether variables and assumptions will actually exceed these limits. In many cases it is not possible to come up with a definite answer because there may be uncertainty about how the assumptions and variables may develop. Often it is only possible to come up with an estimate of the most likely values and of the limits within which variables may vary. These estimates may then be used as the basis for developing probability distributions. For example, a distribution can be constructed as described in Section 12.3.1.

It may also be possible to construct a histogram based on previous observations and to use the histogram to establish a cumulative distribution as shown in Figure 12.8. Figure 13.3 illustrates a cumulative distribution of cruise rates over a period of five years. If Figure 13.3 is taken as a basis, there is a 50% probability that cruises will be offered at less than \$600/week, whereas the probability that cruises will be offered at less than \$500/week is rather low. If an investor accepts no more than a 5% probability of not obtaining his break-even rate, the project would have to balance on a rate of no more than \$450/week. Otherwise, it should be rejected.

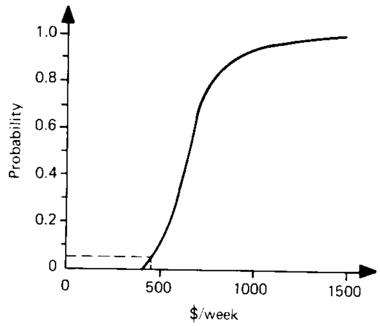


Figure 13.3 Cumulative distribution of the experienced average rate for a one week cruise in a special trade over the last five years. For 50 percent of the time the offer has been below 600 \$/week. The lowest offer has been 350 \$/week, the highest 1500 \$/week

Provided that the variables are independent of each other and the probability of outcomes which are inferior to the break-even rate is low, the probability that all variables will end up with adverse values at the same time is low. For example, when there is a 5% probability that the rate will fall below the break-even point and there is also a 5% probability that the costs will be above the break-even point. The probability that both these events will occur at the same time is:

$0.05 \times 0.05 = 0.0025$

or 25 times in 10 000

The critical assumption is that the variables are *independent* of each other. However, in marine industries this is often not the case. A slump may affect all parts of the industry. When the demand for transport decreases so does the demand for raw material and the demand for recreation and so on. In some cases the interdependence of the variables favours the investor because when income goes down, so does the cost. However, this is not always the case. For example, the value of the contract currency may change in a way that emphasizes the negative effect of the other changes. When variables are dependent on each other they have more or less the same probability of change. For example, if there is a 5% probability of a reduction in the demand for oil and the demand for recreation is dependent on the demand for oil, there will also be a 5% probability of a reduction in the demand for recreation. Thus there will be a 5% probability of a simultaneous reduction in demand for oil and recreation.

When dealing with uncertainties and variables which are interdependent the calculations illustrated in Table 13.1 should be used. In Table 13.1 the initial assumption is that the freight rates are reduced by 1% and that the costs will generally vary with the rates. The degree of dependency between the changes can be estimated by sound judgement. Because the profit is only a small part of the gross income a small change in the rates will have a great impact on the profit.

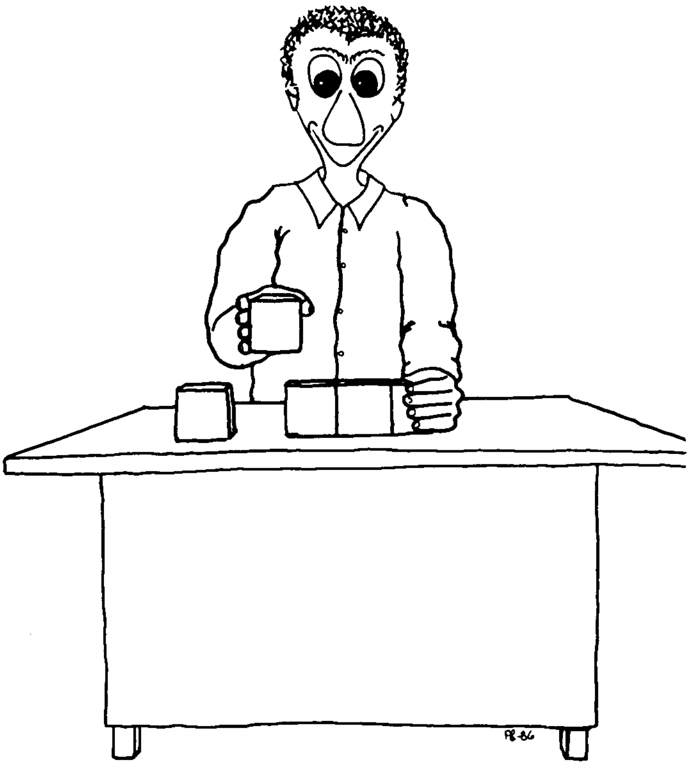
TABLE 13.1 The effect of a 1% reduction of freight rates

Item	*Share of economy, in per cent*	*Change in relation to change of freight rates*	*Weighted impact on the economy in per cent*	
			Negative	*Positive*
Income	100	1:1	100	
Costs				
Capital, loan, insurance, administration	50	1:10		5
Manning	25	1:5		5
Food and similar	10	2:1		20
Fuel	10	1:1		10
Port dues and similar	5	1:2		2.5
Aggregated effect on profit, %			– 100	+ 42.5

The net reduction of income is 57.5% of the rate reduction. A 1% reduction of rates gives an 0.575 net reduction of income. The profit is 5% of the gross income. A 1% reduction of income gives a profit reduction of 11.5%.

14

DESIGN OF INTEGRATED SYSTEMS



14.1 INTRODUCTION

An integrated system may be defined as a system where the components are designed to fit together so that the demands for performance and economy of the system as a whole will have preference over the performance and economy of the individual components. Typical examples of integrated marine systems include:

Transport chains: For example, a system of door-to-door transport comprising overland vehicles, ports, storage, loading/unloading facilities and vessels in which the various components are integrated to provide the most efficient, rational and economic overall transport.

Offshore oil and gas exploration systems: For example, a conglomerate of sub-sea wells, processing platforms, supply, security and maintenance vessels, loading buoys and transport vessels or pipelines with booster stations, as well as shore bases, ports and terminals. The system is integrated so that each component is adjusted in relation to the others in order to deliver oil and gas ashore in the most efficient and economic way.

In principle, as much of the integrated system as possible should be included in the design because this will result in the best overall economy. In practice, the design of very large systems requires so much work to bring the different clients together, establish a joint basis for design and coordinate the design work, that designs of systems larger than the examples given above are rarely undertaken.

14.2 PREREQUISITES FOR THE DESIGN OF INTEGRATED SYSTEMS

There are five main prerequisites:

1. The parties involved must agree to pursue an overall solution. System performance must be measured by a cost index such as cost per tonne carried, cost per container, cost per year, cost per tonne produced or, simply, total costs. This implies that there must be agreement on how the responsibility will be shared between the parties and how the costs will be divided and the income shared.
2. The design team must be organized so that there is good contact will all the involved parties. As the design progresses, suggestions and solutions should be discussed with all those involved.
3. The leader of the design team must have sufficient authority to ensure that the design work is well coordinated.
4. There must be sufficient *time* and *resources* to carry through a design for the complete system.
5. There must be a plan to secure the resources needed to implement a complete system.

If these five prerequisites cannot be satisfied, there is little reason to try to design the complete system.

14.3 MODELLING AN INTEGRATED SYSTEM

Use as few variables as possible for each component of the system. For example:

- For a ship, use d.w. or cubic capacity and speed.

- For a semi-submersible, use payload.
- For a port or shore base, use storage capacity, loading/unloading capacity, number and size of vessels that can be served at the same time.
- For an oil field, use the number, capacity and location of wells and platforms, pipelines and booster stations.

Construct your own model based on overall functions and use this model to design the initial overall solution. Examples of overall functions include:

- Ship costs as a function of d.w. and speed.
- Semi-submersible costs as a function of payload and given environmental conditions.
- Reliability of supply service as a function of size (d.w.) and engine power (speed) of supply vessels.
- Port costs as a function of ship size (d.w.), number of ships to be served simultaneously, unloading/loading capacity and storage capacity.
- Storage costs as a function of storage capacity.
- Land transport costs by tariff.

After an overall solution has been developed, refine the design of the components one at a time by using a wider range of variables and more precise cost functions for each component. Check the overall economy by entering the refined component designs into the overall solution. Carry out a sensitivity analysis by a systematic variation of the component capacities. Use the more precise cost functions for this analysis.

14.4 ESTABLISHING A PLATFORM FOR SYSTEM DESIGN

As a rule it is the need to replace the *major components* of a large system which gives rise to a system design. There is seldom an opportunity to create a total system design right from the beginning. Therefore you should first create the design requested. Afterwards, if the principals are interested, try to expand the frames of reference for the design. As a first step towards an overall design review the points listed in Section 14.2 and see if these can be satisfied.

If the clients agree with you on these points establish a basis for designing the total system:

- Do a good job on the design which was originally requested.
- Carry out a sensitivity analysis to see how the economy of the system component you are designing varies with the constraints or boundaries imposed by other components of the system.
- If a total system design would be to your advantage, investigate how the economy of the other system components would be influenced by an overall design. Keep in mind that satisfied customers are advantageous for everyone involved in the system. Take the steady development in technology and business into account and do not let immediate gains prevent the possibility of establishing long lasting integrated solutions which will provide an improved income.
- Make a preliminary design for the total system. Prepare an estimate of the required investment, operating costs, income and profit for all parties involved. Your preliminary design and calculations are the means of establishing the confidence with your principals which is necessary to do good work.
- Find out which parties are really necessary to maintain an integrated system. Approach them one by one, present your design and calculations and try to establish interest in a joint solution.

- If the response is positive call a meeting of those involved. Be sure not to neglect anyone who may have a decisive influence. Present plans for organizing the design work and try to ensure that the people at the meeting make decisions in accordance with the points listed in Section 14.2.

14.5 THE ECONOMICS OF LOGISTICS

14.5.1 Introduction

The improved economics of the logistics are often the reason behind the designing of an integrated system. In military terminology logistics is the science or art of moving and providing for troops. In industrial terminology logistics is the art of supplying the producer with the raw materials or consumables and of transporting the finished product to the customers.

14.5.2 Economics

The items listed below are the minimum that should be included in any calculation of the cost of logistics. The view is taken that the task is to supply somebody with something as is the purpose of transport.

Points that should be included in a calculation of the cost of logistics include:

- Production or exploitation costs, C_p
- The cost of moving goods into storage, C_{m1}
- The cost of the inital storage, C_{s1}
- Loss of interest on goods in the initial storage, C_{i1}
- The cost of packing, C_{pa}
- The cost of moving the goods from storage to the first carrier, C_{m2}
- The cost of loading the first carrier, C_{H1}
- The cost of forgone interest during the initial transport, C_{i2}
- The cost of transport using the first carrier, C_{T1}
- The cost of unloading the first carrier, C_{H2}
- The cost of moving the goods to storage, C_{m3}
- The cost of forgone interest during the second storage C_{i3}
- The cost of unpacking.

The loss of interest on goods in the first storage, the cost of foregone interest during first transport and the cost of interest during the second storage are calculated below.

$$C_{i1} = C_{a1} \times \frac{d}{360} \times i \times \frac{1}{1-t}$$

where:

$C_{a1} = C_p + C_{m1} + C_{s1}$ (accumulated cost)
d = days in storage
i = rate of interest on ongoing business
t = taxation rate

The cost of forgone interest during the initial transport is:

$$C_{i2} = C_{a2} \times \frac{d}{360} \times i \times \frac{1}{1-t}$$

$$C_{a2} = C_{a1} + C_{i1} + C_{pa} + C_{m2} + C_{H1}$$

where:

d = days under transport

The costs of forgone interest during the second storage (inventory costs) are:

$$C_z = C_a \times \frac{d}{360} \times i \times \frac{1}{1-t}$$

$$C_{a3} = C_{a2} + C_{i2} + C_{T1} + C_{H2} + C_{m3}$$

The production or exploitation cost is the cost of the goods *as produced*, for example, the cost of oil and gas from the processing plant or the cost of cars from the production line. The cost of moving goods includes the cost of moving and handling goods from a carrier to storage or vice versa. The cost of storage is the cost of renting or providing storage space. Examples of storage space include offshore loading buoys with storage tanks, pipe racks on an offshore platform, parking areas for new cars, container yards, either inland or in ports, warehouses and stacking areas.

Packing is the preparation of the goods for transport. Examples of packing include putting wares in cartons and boxes, loading and securing goods to pallets, filling containers, bundling pipes and bales, liquefying gas, filling drums with liquids. Unpacking is the opposite of packing. A carrier is a transport facility. Examples of carriers include, pipelines with booster stations, vessels, railways, trucks and aircraft.

The cost of forgone interest must be multiplied by a factor that takes taxation into account. This is because this loss is not exempt from taxation. This loss must be covered by earnings after tax as shown below:

$$f'(1-t) = C_i$$

$$f' = C_i \frac{1}{1-t}$$

f' = That part of earnings which covers the loss of interest, C_i

The cost of all of the items mentioned above, and perhaps many others as well, should be calculated and presented to all the parties involved in the project along with a review of all the gains which could be obtained by an integrated design. This can form the basis for a discussion of the possibility of designing a complete integrated system from the start.

15

QUALITY ASSURANCE

15.1 INTRODUCTION

Quality is defined as compliance with specified requirements. A quality assurance (QA) system comprises all documented procedures, routines and instructions which ensure that a product is delivered in accordance with specified requirements. Although they make no direct reference to QA, Chapters 2 and 13 were both prepared partly on the basis of QA principles. In this chapter some of the rules of design work will also be derived on the basis of QA considerations.

General information on QA systems is included in Norwegian Standard NS 5801 (15 pages of English and Norwegian text) and NS 5802 (12 pages of English and Norwegian text). NS 5801 deals with QA systems. NS 5802 discusses inspection systems. Ellefsen (1984, 1985) supplies a good deal of useful information about QA systems in relation to the building of a semi-submersible. He also discusses the use of QA systems in relation to shipping companies, marine contractors and subcontractors.

A QA system includes:

Quality review (QR): which is a systematic review of documentation and suggested solutions. For example, QR might include a review of the design documentation and the design solution.

Quality audit (QAu): which is a planned and systematic review of a company's quality assurance system for verifying conformance with requirements or a corresponding review of a product's conformance with requirements. There are several different types of audits including *system audits, process audits* and *product audits*.

15.2 QA AND THE PURCHASER–CONTRACTOR RELATIONSHIP

If a purchaser finds it necessary for the development and production of the systems or objects he orders to be in accordance with QA principles, his first serious approach towards a potential contractor should be to check whether the contractor has sufficient capacity and organization to maintain a QA system. The contractor should be able to supply a general description of his QA system and provide documentation about his procedures, instructions and routines, including QR and QAu. The QA, QR and QAu procedures should include ordering, checking and accepting deliveries of subcontractors. There should also be established procedures for verifying the QA systems of subcontractors.

A QA manual should specify the organization of the QA system and refer to the detailed procedures for ensuring quality. Only when it can be verified that the potential contractor has a satisfactory QA system should he be invited to submit a bid.

A detailed *quality assurance plan* should be prepared for each specific contract. This plan should cover all the activities related to the contract and to the relevant parts of the contractor's organization. The main elements which should be covered are planning, organization, performance, verification and documentation. It is important for a quality assurance plan to specify schedules and identify the milestones leading to the contracted delivery. The quality assurance plan should also specify how the purchaser and the contractor will cooperate in the QA scheme. This includes the rules governing the purchaser's right to carry out controls, checks and quality audits on the contractor's premises and the contractor's obligation to provide assistance in these checks. The rules for taking corrective action, specifications of approval procedures and rules for informing the other party when something does not conform to the specified requirements should also be documented. This means that the contractor must have a documented system of non-conformance procedures and corrective actions.

Internal control is a part of a QA system. Internal control is the contractors own system for ensuring that the deliveries are in compliance with the requirements stipulated in the contract. The requirements for internal control systems have been issued by the Norwegian Maritime Directorate and by the Norwegian Petroleum Directorate. The contractor's internal control system must comply with these requirements.

QA principles should also be applied to both the design work itself and to the specification, which is a result of the design work.

15.3 QA APPLIED TO THE DESIGN WORK

A system and a product are of good quality when they are in accordance with specified requirements. A design study or design work has quality when it is carried out in accordance with specified requirements. Specifications for design work are given in Chapter 2. The main items of this specification are discussed in relation to QA below.

The *objective* of the design should be clearly specified. It should be possible to check the degree to which the objective has been fulfilled at QA reviews. QA reviews are extremely useful for monitoring progress and the spending of time, labour and money on design work.

The *restrictions* on the design solutions and the *conditions* of the design work should be clearly specified. They should be checked during QA reviews in order to determine the economic consequences of adhering to them.

The *reponsibility* of making decisions and the *authority* to do so, as well as the *reponsibility* for gathering the design information, such as market reviews, port restrictions, and rules and regulations from authorities, as well as the *responsibility* for carrying out the remaining tasks related to the design work should be given to named persons.

The *information* needed for the design should be clearly specified by type and degree of detail. Examples include, market information such as rates and cargo flow, customer satisfaction as measured by the amount of claims and the regularity of the existing service; port information such as the depth, length of quays, width of locks, working time, charges and dues. Each piece of information should be clearly documented by source and date. The person who gathered or received the information may include an evaluation of its completeness or accuracy to be included in the documentation.

A design budget should be prepared at the outset stating the available time, man power in terms of people and hours needed and other resources. The budget should also specify the amount of resources which should be used for the different design activities.

A QA *review group* should be appointed. The members of this group should not be engaged in the design work but should represent all parties which are potential users of the design.

QA reviews should be scheduled at the beginning of the design work. The reviews should cover:

- The relevance of the design objective and the restrictions in view of the results obtained to date.
- The progress and relevance of the design work in relation to the aim of the work.
- The spending of resources.
- The time allocated to the design task by key personnel.
- Deviations from the original plans.
- Whether the design work is organized and carried out in accordance with sound practice. The suggestions in this book may form a basis for this discussion.

As a result of the QA review, decisions should be made concerning the continuation and organization of the design work; changes in design objectives, budgets or schedules;

changes in responsibility and job allocations; other corrective actions to be taken and the timing of the next QA review.

A *design journal* should be maintained. It should include a description of the design situation when the work commenced and the reasons behind the design objectives. It should also include restrictions, limitations, allocation of personnel, information about the budget and about future plans. Minutes of all important meetings and any major decisions and their background should be entered into the journal along with the outcome of the QA reviews. The journal should also contain a complete documentation of the design work. The state of the design work should be apparent from the journal at all times. If the design work is discontinued or terminated, the background and reasons for this decision should be noted in the journal. It is a good idea to keep the design journal in a database system where it is possible for anyone to read it at any time but where only one person has the authority to add to it.

When completed the design work should result in a specification of the design solution. The specification is discussed below.

15.4 QA APPLIED TO SPECIFICATIONS

15.4.1 Introduction

Designs may be carried out by either the purchaser or a contractor. The specification prepared by the purchaser is used as a reference when he makes enquiries about prices and delivery times and asks for bids. The specification made by a contractor may be included in a *contract* and thus become a basis for *production*.

15.4.2 Common practice

The purchaser's specification may, and in many cases, should, contain only *functional* requirements. The purchaser should carry out a QA review of the specifications prepared by contractors based on his own functional requirements. After some negotiation a final specification can be prepared and used as a basis for a contract. This is the common practice in the development of building specifications for the contracting of ships and semi-submersibles.

15.4.3 QA review of building specifications

QA imposes the requirement for a specification to be termed in such a way that the performance of a product can be measured against the terms of the specification. Quality is assured when the performance corresponds to the specification or is better than the specification.

A QA system requires quality to be documented. This means that a system for reviewing and documenting the quality of materials, the quality and performance of the work and the deliveries of subcontractors must be set up.

The QA review of a building specification should aim to ensure that:

1. The requirements of the purchaser's original specification have been met and that all items mentioned in the specification have been included.
2. The building specification lays down requirements which can be checked via a quality audit of the product.
3. The establishment of a QA plan is included in the contract.
4. Sufficient time and resources are allocated to carry out the quality audits, quality control and quality reviews.

15.4.4 Functional requirements versus specified solutions

It is better to specify a performance requirement rather than a concrete solution because performance requirements secure a specific performance whereas a specified solution only secures the provision of certain items or services. Performance requirements should only be abolished in cases where they cannot be specified accurately enough to be checked by QA reviews.

Some examples of *good* performance specifications are given below:

Specification: To obtain a speed of 14 knots through water at a draught of 10 metres, a head wind of up to 4 m/s and a significant wave height of up to 0.5 m at a power of 80% of the maximum continuous rating of the propulsion machinery.

Specification: To have sufficient stability to satisfy the rules of the Norwegian Maritime Directorate (Norwegian Maritime Directorate, 1982).

The first specification is exact in itself. The second specification refers to a precise set of rules and requirements. The compliance of either specification can be checked by surveys, trials and tests.

Some examples of bad performance specifications are:

Specification: The outfit of the cabins is to be in accordance with the general standard of the trade.

Specification: The workmanship is to reflect good shipbuilding practice.

These specifications are poor because their basis is obscure and the requirements cannot be quantified.

15.4.5 Quality through reference to authorities, classification societies and established rules and regulations

For more than 100 years the shipping industry has had a QA and QR system of its own. Requirements for vessels have been laid down by international and national authorities and classification societies. Inspectors employed by these authorities are responsible for surveying the building of vessels and certificates are issued when the deliveries are in accordance with the rules and regulations. This method of defining and securing quality should be included as part of a modern QA system. However, present QA systems require more extensive documentation and a more detailed follow up than was foreseen in the past.

When reference is made to classification societies and national or international authorities this reference is part of the specification of the product. Therefore all the relevant elements of QA must be applied to this part of the specification. Survey reports, certificates and documentation of prescribed tests and experiments should be considered to be a part of the QA documentation. They should correspond to QA standards and should be evaluated and treated as any other QA documentation.

15.5 QA DOCUMENTATION

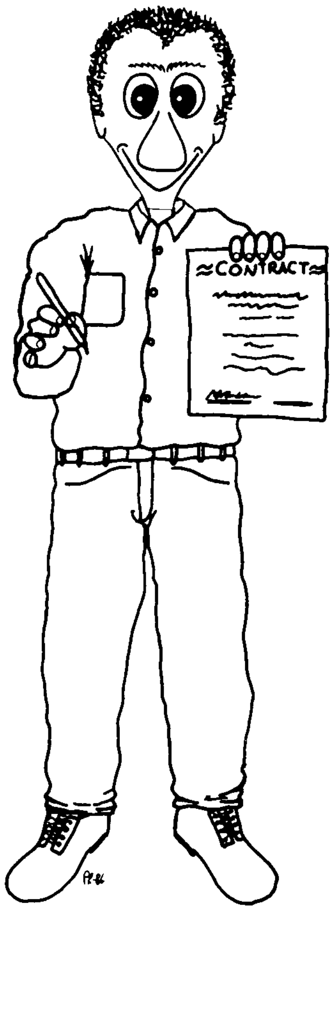
A modern QA system should anticipate the documentation of all decisions and activities throughout the lifetime of a project. Ellefsen (1984, 1985) mentions the principal activities listed below:

- Concept development studies.
- Selection of main contractor.
- Establishing contracts.

- Selection of subcontractors.
- Design
- Construction.
- Controls and checks.
- Corrective steps in the case of deviations from the specification or due to a reformulation of the aims and specifications.
- Final documentation.

The first three items in this list are dealt with in this book. It is always important to document the reasoning behind decisions and to record the information available when the decisions were made. It is also important for this documentation to be prepared in a format which is convenient to include in the total documentation package of a project.

CONTRACTS AND SPECIFICATIONS



16.1 THE STRUCTURE OF CONTRACTS

The main part of a contract should include the *terms* of the contract. There should also be a set of enclosures. Person (1985) suggests that the enclosures should include information about compensation, milestones, the subdivision of work and the delivery date, drawings and specification. The contract should state that if there is any discrepancy between the contract, specification and the drawings, the contract shall have precedence over the specification and the specification shall have precedence over the drawings.

16.1.1 Terms of contract

As a minimum requirement, the terms of contract should include the following:

- A statement identifying the *contract partners*, including information about their domicile, their mailing address, telex, telephone and fax numbers.
- Explanations and definitions of the *terms* and *expressions* used in the contract and in the enclosures.
- A statement about the *laws* which apply in the interpretation of the contract.
- A description of the objects or systems which are the subjects of the contract. This should include the main specifications and include references to drawings and specifications.
- The conditions for *validation* of the contract, for example details of the licences which must be obtained, who will obtain the licences and the consequences of not obtaining the licences.
- National and international *rules* and *regulations* to be applied and of the *flag of registration*.
- Information about the relevant *classification society*.
- Terms for the settlement of *disputes*.
- Specification of accidents which will be considered as *force majeure* and information about who will carry the losses and the consequences if the contract is not fulfilled.
- A statement of the consequences if the contract is not *fulfilled*, due, for example, to default or delayed deliveries or reduced performance.
- *Amendments* and *additions* to the contract, including the purchaser's right to order changes and the contractor's right to make reservations as to the time and extent of delivery. This should also include the procedure for confirmation of admendments.
- The *place* and *time* of delivery including reservations in the event of *force majeure*.
- Details of the *materials* and the purchaser's deliveries.
- The purchaser's reservations or approval procedures with regard to *subcontractors*.
- Details of the *property* of objects under construction and terms for the *insurance* of material, equipment, stocks and partly completed objects.
- *Inspection* and *approval* procedures, including trial trips and shop tests as well as statements about who will carry the cost of the trials and who has the responsibility of supplying fuel for the trials. Procedures for accepting or rejecting any component should also be defined: A QA system will help to ensure that these matters are properly dealt with.
- The terms of the *guarantee*, including the period of the guarantee, the rules for repairing damages and the contractor's obligations during the period of guarantee.
- Information about *patents*, including the ownership of inventions, the responsibilities with respect to existing patents and the copyrights for the specifications and drawings.
- The conditions for *assigning* the contract to a third party by any of the contract partners.

16.1.2 Contract enclosures

The contract enclosures should include information about the following:

- *Compensation* including:

The form, schedule and currency of payment; fixed prices or unit prices for labour, material and other deliveries; the estimated volume of deliveries.

Specification of purchaser's deliveries including the time of delivery, installation procedures and payment for installations, and information about how such deliveries will be reckoned in relation to the deadweight or payload.

Terms of financing, loans, rate of interest and down payments.

Taxes and duties, and who is responsible for paying them.

The consequences of *defaulting* payment.

- *Milestones*, including:

The completion schedule for major items including the schedules for purchase of materials, prefabrication, erection and delivery for each major component.

- A complete *specification* of the components to be delivered.
- A complete set of the drawings used as a basis for the contract.

16.2 STANDARD CONTRACTS

Standard contract forms are issued by different associations and corporations. Some examples are listed below.

Standard Form of 7 October 1981 for Contract for the Building of Ships at Norwegian Shipbuilding Yards prepared by the Norwegian Shipowners' Association and the Norwegian Shipbuilders' Association, 15 pages (see NSA 81, Norwegian Standard NS 2780, 1985)

Standard Shipbuilding Contract issued by the Association of Western European Shipbuilders, 1972, 30 pages (see Association of Western European Shipbuilders, 1972)

British Shipbuilders Shipbuilding Contract, 1983, 50 pages. There is one version for UK owners and one version of foreign owners. (See British Shipbuilders Shipbuilding Contract, 1983).

North Sea Offshore Lump Sum Construction Contract, 1981, prepared by the Federation of Norwegian Engineering Industries (Mekaniske Verksteders Landsforening (MVL)) and the Norwegian Industry Association for Oil Companies (Norsk Industriforening for Oljeselskaper (NIFO)), 40 pages. (See NIFO and MVL, 1983).

Standard contracts issued by the MVL, Statoil and Norsk Hydro (see Statoil, 1983 and MVL and Norsk Hydro, no date)

It is a good idea to study the relevant standard contract forms before making a contract of your own. In many cases a standard contract may be used without alteration. However, even in circumstances where a standard form cannot be used a review of the standard form will serve as a reminder of all the details which must be included. If you are drafting your own contract the more lengthy standard contracts will be of the most help.

Some of the standard forms have been prepared jointly by associations which represent both parties for whom the form is intended. Others have been prepared by only one party. It is important to keep this in mind when considering the use of a standard form as the basis for your own contract.

16.3 THE PARTY IN CHARGE

When the task is to design a very large and complicated system, for example, a complete chain of transport or a supply system for offshore activities, there must be one party who coordinates the contract negotiations and the signing of contracts. This responsibility may well fall to a marine company. If this is the case the company will be required to oversee the contracts for the building of ships, the rent of offshore bases or quay and storage areas in ports, the loading and unloading of supplies or other cargo and the auxiliary services at bases and in port.

Frequently contracts will also cover other aspects of transport and supplies. A QA system may be required to make sure that quality is maintained with regard to these additional services. In some cases you will have to deal with companies which are understaffed or are otherwise unable to maintain a complete QA system. In these cases the contracts may be adapted to conform to the terms and style of contracts generally used in the marine industry. However, if this is done, it is very important to know the background of the contractor and to determine whether he has experience in serving marine units. You should also check whether the contractor's business is sound and that there are no conditions which could cause him to misinterpret a contract.

Where you are forced to deal with completely unknown conditions, you should try to sign preliminary contracts for a limited period while you collect further information about the contractor from his other customers. You can also try to seek the cooperation of other people with similar interests and allow them to devise a 'letter of intent' or a contract.

16.4 PERFORMANCE REQUIREMENTS VERSUS PRESCRIBED SOLUTIONS

It is an advantage for the purchaser to specify the required *performance* rather than how the performance shall be achieved. In any case, it is important that *only one* of the parties has the complete responsiblity of ensuring that the object which is delivered performs in accordance with the requirements laid down by the contract and specification irrespective of which of them has described how the required performance standard is to be obtained. The party which carries this responsibility is bound to warn the others if, for any reason, the planned solution will not produce the required performance standard. He is also responsible for finding a better solution.

This responsibility usually rests with the builder or contractor. However, the purchaser may have the right to recommend or demand certain solutions without becoming responsible for the performance if the contractor does not object in writing.

The purchaser may wish to recommend certain solutions because of his experience with certain types and makes of equipment, company standardization, customers' preferences, special agreements with subcontractors, credit terms and inexperienced contractors.

The important elements of performance requirements include payload, cubic capacity, position keeping ability, stability, speed, endurance and fuel consumption. Each of these requirements should be exactly quantified and referred to specified conditions. If possible these should be conditions which can be verified.

16.5 EXPERIENCE AS A BASIS FOR SPECIFICATIONS

Computer-based systems for collecting, sorting, storing and retrieving information are useful tools for storing information derived from experience and transforming it into a basis for future specifications. The list below summarizes activities that may generate useful experience and indicates how that experience may be used.

- *Building of vessels*: generates experience in style and form of contracts, contract fulfillment, ability to cooperate, engineering and labour skills, quality of workmanship, meeting deadlines and handling the costs of extras.

- *Operation of vessels*: generates experience related to fulfilling the requirements of a contract; the working and living conditions of officers and crew; wear and tear and damage of vessels; maintenance of machinery and hull; speed and fuel consumption; manoeuvrability; seaworthiness; preservation of cargo; mooring operations; loading and unloading operations; cleaning of cargo compartments; catering and upkeep of accommodation.

- *Earning potential of a ship*: generates experience related to the appraisal of charterer; reports from supercargoes and inspectors; reports from agents; round trip times and transport capacity.

16.6 PAYLOAD

The payload should be referred to:

- A specified draught and corresponding specific gravity of water.
- Longitudinal and vertical location of the centres of gravity of the cargo, fuel and other supplies. This should also be specified when homogeneous loading is assumed.
- No heel.
- Trim within limits set by the maximum allowable draught.
- No ballast.
- Fuel and other supplies as per end of voyage.
- Specific stability requirements.

It should be specified whether the payload is to be verified at the maximum allowable draught. If the maximum allowable draught is different from the payload draught, both should be specified. The maximum allowable draught is a global limit of the draught at any point of the vessel, forward, midships, aft, port and starboard. It is not sufficient if the draught is within limits at midship but larger than the limit at another point due to trim or heel.

Payload should be *verified* by measuring draught, trim, heel and specific gravity of water for the vessel in light, or almost light, condition. Corrections should be made for missing parts of the light ship, extra weights on board and the increase in displacement when the vessel is loaded down to payload draught.

The location of the centre of gravity of the payload in the fully laden condition should be specified also when it is assumed that the centre of gravity lies in the geometric centre of the cargo compartments.

16.6.1 Payload margins

The relative importance of the light ship weight varies quite a bit between one type of vessel and another. For a VLCC, the light ship weight is only 15–20% of the displacement. Semi-submersibles and combined car ferries and passenger vessels, on the other hand, have a light ship weight up to 90% of the displacement. Correspondingly, a five per cent error in estimating the light ship weight of a VLCC will influence the deadweight by only about one percent. However, an error of five per cent in estimating the light ship weight of a semi-submersible or a car ferry and passenger vessel will influence the deadweight by fifty per cent. Thus, semi-sumbersibles and car ferry and passenger vessels require much more accurate weight and stability calculations and control than do VLCCs and similar vessels. However, irrespective of how strictly the calculations and controls are carried out, there will be a degree of uncertainty in the estimates. This is due to such things as tolerances of material dimensions and unforeseen changes in subcontractor's deliveries. Recommended uncertainty allowances for various types of vessels are shown in the table below.

Type of vessel	*Uncertainty allowance for deadweight (%)*
Large tankers (VLCCs and ULCCs),	1.00
Oil/bulk/ore and oil and ore vessels above 80,000 t d.w.	1.00
Product tankers	1.25
Parcel tankers	1.50
Bulk ships 50–100,000 t d.w.	1.25
Dry cargo vessels below 50,000 t d.w.	1.50
Container vessels	1.50
Coasters	2.00
Supply vessels	3.00
Car carriers	3.00
Semi-submersibles	4.00
Combined passenger vessels/car carriers	4.00

16.6.2 Loading conditions

Most vessels are intended for use with different types of cargoes and on different types of engagements. This flexibility may be crucial to the earning potential of the vessel. A contract should refer to the *types* and *quantities* of cargo which must be carried in order for the vessel to fulfil its purpose. The contract should explicitly mention the conditions of draught, trim, heel and quantity of fuel and ballast under which the various types of cargoes must be carried. The examples below illustrate the different loading conditions under which various types of ships and semi-submersibles may be at the limit of their performance.

16.6.2.1 Example: Dry cargo ships

Loading condition: Loaded to summer draught with a homogeneous cargo to a certain height above deck (for example, four containers high) and with only 10% of the fuel and bunker capacity utilized.
Critical characteristics: Stability, trim and heel.

Loading condition: Loaded to summer draught with heavy cargo in every second hold.

Critical characteristics: Strength, deflections, trim, freeboard in damaged condition.

Loading condition: Loaded with a specified quantity of cargo and full supplies.
Critical characteristics: Draught, trim, heel, stability.

Loading condition: Loaded to summer draught and in a transient condition with respect to quantity of fuel and ballast causing (wide) tanks to have free surfaces.
Crucial characteristics: Stability, rolling period.

16.6.2.2 Example: Ro/Ro vessels

Loading condition: At quay with open side doors and heavy rolling equipment being used on deck or heavy loads being lifted on by using your own gear.
Crucial characteristics: Stability, angle of heel and the risk of water entering through a submerged side door opening.

Loading condition: Loaded with a homogeneous cargo.
Crucial characteristics: Draught, trim and heel.

16.6.2.3 Example: Tankers

Loading condition: Loaded with homogeneous cargo to summer draught.
Crucial characteristics: Trim, heel, steering, pollution risk.

16.6.2.4 Example: Passenger vessels

Loading condition: Loaded to summer draught.
Crucial characteristics: Stability when damaged.

16.6.2.5 Example: Semi-submersibles

Loading condition: Loaded with full payload and in a condition of changing from operation or transit draught to survival draught.
Crucial characteristics: Stability.

Loading condition: Loaded with full payload and in damaged condition.
Crucial characteristics: Stability, inclination in damaged condition.

16.6.3 The no heel and no trim condition

In practice it is impossible to design a vessel so that it will float in a condition of no heel and no trim with any type of cargo or for any loading. On the other hand, for any vessel there will be at least one combination of loading conditions and restrictions on draught, trim or heel where its performance must be 100% utilized. These critical combinations should be stated in the contract with a precise description of:

- The kind of cargo, its stowage factor, location and centre of gravity.
- The location of fuel and other consumables, their specific gravity, degree of compartment utilization (tank filling) and centres of gravity.
- The quantity and location of ballast, if any, including centres of gravity and degree of tank filling.

- The maximum allowable draught, forward and aft, port and starboard. The draught limitation may also set limits for trim and heel.
- The maximum allowable trim, if any.
- The maximum allowable heel, if any.

The majority of naval architects assume the *no heel condition* as a matter of course. In spite of this, many vessels will not float in an upright position without an asymmetrical distribution of fuel, fresh water or ballast. There is therefore good reason to specify a no heel condition in the contract. A heel may increase the draught of the vessel beyond what is specified. For example, a beam of 20 metres and a heel of only one degree will increase the draught by 17.5 cm.

The *trim* should not increase the draught beyond the maximum allowable. This means that there should be no state of trim which would allow the forward or aft draught to exceed the maximum allowable draught under normal operating conditions.

If consumed supplies must be replaced by *ballast* to keep the trim or heel within given limits the specification should state to what extent the ballast should be reckoned to reduce the deadweight. The contract should provide that this practice must be approved by the relevant national authority, who may deny approval for the homogeneously loaded condition.

Normal quantities of fuel and other supplies may be carried in the compartments which provide the most favourable conditions of trim and heel. The quantities of these supplies should be specified.

16.6.4 Weight of the light ship

A a basic rule, anything needed to make a vessel 'immediately ready for service' is part of the light ship. This includes water in the boilers, if any, and a certain amount of lube oil and fuel, although this is often questioned. For the sake of clarity it should be made explicity clear whether the following items are included as part of the light ship:

- All owners' deliveries.
- Lube oil in the machinery.
- Systems liquids according to specified tank levels. This includes hydraulic oil, cooling liquids in refrigeration systems, fuel for emergency diesels, water in the firefighting system and cooling water.
- Liquid remaining in sumps, pipes, pumps and tanks which cannot be discharged by the installed pumps.
- Fuel remaining in tanks and pipes after the prescribed trials and tests.
- Spare parts as required by class or as specified in addition to class requirements.
- Outfit and equipment for passengers.
- Moveable equipment such as fork-lift trucks.
- Equipment for handling, securing and loading cargo.

16.7 CUBIC CAPACITY

Cubic capacity may be specified by volume for liquids (98% filling), grain, bales, containers and cars and other units on wheels. It should be clearly stated which compartments are to provide the specified cubic capacity and how the capacity is to be measured.

16.7.1 Liquids

The extent to which the volume of hatchways, trunks, slop tanks, settling tanks and pipelines should be included in cubic capacity and whether the rated volume should be reduced to allow for thermal expansion should be specified. The volume should be checked by measuring devices on the contractor's premises or, preferably, when the compartments are filled for the first time with the specified liquid.

16.7.2 Grain cargo

Whether the volume of hatchways, trunks, feeders and discharging installations are to be included in volume for grain should be specified. As a rule, volume is measured to the inside of the side plating, to the top of the double bottom or its ceiling and to the underside of the decks. However, a percentage should be deducted for frames and frame battens, stiffeners, girders, deck beams, hatch covers and webs. It is preferable to check the volume when the first full cargo of grain is loaded.

16.7.3 Bale cargo

The minimum horizontal and vertical cross-section of a compartment, recess or niche to be included in the bale cubic capacity must be stated.

The bale cubic capacity is measured to the inside of frames, or frame battens if fitted, to the underside of deckbeams and to the outer edge of stiffeners. Deductions for inclined sides, webs, hatch covers, air ducts, ladders, sounding pipes, stanchions and doors should take into account that these items take up much more of the bale cubic capacity than does the space they occupy. The space created by the inclination of the sides should preferably be included in the deductions. It is preferable to check the bale capacity when the vessel is filled with cargo for the first time.

16.7.4 Containers

The units by which capacity is to be measured should be stated. Units may consist of twenty foot equivalent units (TEU), forty foot equivalent units (FEU) or units based on another specified container. The dimensions of the unit should be given. For example, a TEU has a length (l) x beam (b) x height (h) = 20 x 8 x 8.5 ft.

The under deck container capacity for *lift on /lift off* (Lo/Lo) vessels is the number of containers that can be carried directly under the hatch openings. The container capacity for a *bulk carrier equipped for containers* is taken from drawings which show fixed positions of the containers and specified maximum stowage heights. On *roll on/roll off* (Ro/Ro) vessels the under deck capacity is the number of containers that can be stowed under deck with the aid of fork-lifts and can be safely secured for an ocean voyage. The extent to which ramps between the decks and the parking areas for the container handling equipment are included in calculation of the container capacity should be stated.

On deck container capacity is the number of containers that can be placed on deck by a given loading method and safely secured for an ocean voyage. The containers must be carried within the stability requirements for the specific loading condition.

In theory the location of containers may be shown on drawings and the capacity calculated from the drawings. However, this theoretical capacity should be checked during the first full loading of the vessel.

16.7.5 Cars, trailers and other units on wheels

The type of cars or vehicles to be used as measuring units and their stowage area, including clearances, should be made clear. The gross capacity is given by the area of the inner bottom and permanent and portable decks. Deductions must be made for recesses and niches that cannot be easily occupied and for all areas which have difficult access due to obstacles such as pillars, air ducts, webs, bins, doors and other installations and equipment.

Only one unit should be used to calculate the capacity on each deck. The possibility that a mixture of different car sizes could be used to obtain a good utilization of capacity should not be considered. The extent to which ramp and turning areas are to be included in the capacity should be stated. Capacity should be verified during the first filling of the decks.

16.8 POSITION KEEPING ABILITY

Semi-submersibles, drilling ships and support vessels must comply with position keeping specifications under different weather conditions. Position keeping requirements should be quantified by specifying the *thrust* required in different directions or 'equivalent current' that will impose the the same loads on the position keeping system as the anticipated combined actions of current, wind and waves. The position keeping ability should be verified by measuring bollard push or pull or by moving the vessel through water at a speed corresponding to the equivalent current.

16.9 STABILITY

The minimum stability required should be ascertained by reference to the national authority which is to approve the vessel or to the rules and regulations of an authority of another country.

The extent to which ballast, fuel, fresh water and non-homogeneous loading of the vessel may be used as a means of obtaining the required stability and trim should be stated. It should also be specified that the vessel is to float with no heel (zero degree inclination) when symmetrically loaded with cargo, fuel, fresh water, other supplies, and, if foreseen, ballast. If any asymmetrical loading is acceptable to obtain the no heel condition, this loading should be clearly specified. This is especially important in the case of vessels which may have an asymmetrical layout or after part, such as ferries and other Ro/Ro vessels.

Maximum acceptable figures for initial metacentric heights should be specifed for various cargo conditions in order to maintain ship movements and inertia forces within acceptable limits. This is especially important for all types of vessels with deck cargo stacked high, such as container ships, and for vessels in which gentle movement is desired to provide greater comfort for passengers or crew.

16.10 SPEED

A specified speed is an element in most contracts. For the majority of vessels, which have fixed pitch propellers, verification of speed is a problem. Speed trials for many types of vessels must be carried out with the vessel in a lighter condition than specified in the contract. In addition, the weather conditions are usually much better than the vessel will meet in service. Under conditions of lighter load and better weather the propeller will not be able to absorb the full power of the propulsion machinery if the propeller is designed for a heavier condition. In order to be able to verify whether the specified speed will be reached in a heavier condition, it is first necessary to determine how the propeller will function under lighter conditions. A formula for converting the trial test results to laden speed should be agreed. A verification at first full load is preferable but it may be difficult to get into the contract.

16.10.1 Designing a fixed propeller

The first step is to determine the service condition for which the propeller is to be designed. The propeller will have a 100% fit to this condition only. The following considerations may be useful:

The propeller will never have a heavier load than when the weather conditions are so bad that the captain reduces the propulsion power voluntarily. The load which will occur under these conditions should be the upper limit when selecting the design load.

On many routes the weather conditions are rarely so bad that power is voluntarily reduced and much lighter loads are more characteristic of the service conditions. The loads of the service condition may be the correct design load to use.

Some types of vessels, such as tankers, spend almost half of their time at sea in ballast. This condition may result in a ligher propeller load than normal service conditions. In these types of vessels it may be more economical to use a design load which is between the loaded service and ballast condition load.

Weather conditions may markedly influence the propeller load. It is a good idea to base the selection of design load on knowledge of the frequency of different weather conditions.

The condition of the surface of the hull will deteriorate as the vessel ages. Modern paint and anti-fouling systems may greatly reduce deterioration but there will be some increase in propulsion resistance with age. Townsin, Medhurst, Hamlin and Sedat (1984) and Townsin, Byrne, Svensen and Milne (1986) have published data on ship hull roughness.

Great care should be taken to ensure that the main engine does not become overloaded in adverse weather conditions. The interpretation of the engine manufacturer's propeller curve should be discussed with the manufacturer.

Harvald (1983) lists the following figures for *average resistance increase* in relation to trial conditions of ships:

North Atlantic, westward	25–35%
North Atlantic, eastward	20–25%
Europe–Australia	20–25%
Europe–Eastern Asia	20–25%
Pacific	20–30%

For design purposes Harvald recommends assuming an average resistance increase over the estimates for resistance during fully loaded trial trips in calm weather of 25% for ships on the North Atlantic and 20% for ships in other areas. This may be a little high for vessels with modern paint systems. However, Harvald's figures could be used as a guide if sufficient information about the loading condition and expected weather is lacking. Otherwise, an economic analysis of speed and power relationships should be carried out. An example of this type of analysis is given in Section 16.10.4.

Once the service condition has been determined the next step is to design the propeller for this condition. The service condition should be specified in terms of the mean indicated pressure of the main engine, propeller revolutions per minute, power delivered to the propeller, the propeller's speed through water and the resistance of the ship.

The third step is to calculate how much power will be absorbed in the trial condition and what speed this amount of power should produce. The propeller K_T and K_Q-J diagram (see Section 16.10.2) and the resistance curve for the ship in the trial condition are necessary for this purpose. An example of this type of calculation is given in Section 16.10.2. The expected (i.e. calculated) trial trip speed should be specified in the contract.

Finally, the fourth step is to measure speed on the trial run to see if it corresponds with the expected speed.

16.10.2 Calculation of obtainable trial trip speed

The basis of the calculation is a propeller K_T and $K_Q - J$ open water diagram as shown in Figure 16.1. The formulas used to plot the diagram are given below.

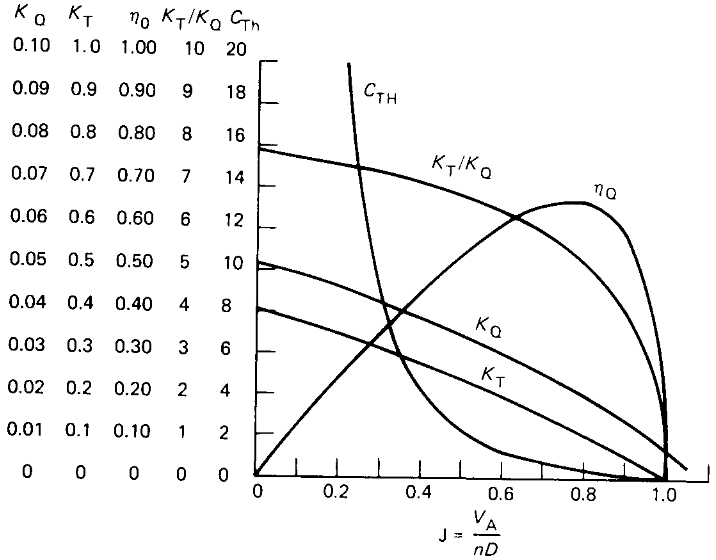


Figure 16.1 Propeller K_T, $K_Q - J$ open water diagram

$$K_T = \frac{T}{\rho n^2 D^4},\ K_Q = \frac{Q}{\rho n^2 D^5},\ J = \frac{V_A}{nD},\ \eta_0 = \frac{K_T}{K_Q} \cdot \frac{J}{2\pi},\ C_{TH} = \frac{8}{\pi} \cdot \frac{K_T}{J^2}$$

where:

T = propeller thrust (N)
ρ = Mass density of the water (kg/m³)
N = Propeller revolutions per second (1/s)
D = Propeller diameter (m)
Q = Propeller torque (Nm)
v_A = Speed of advance of propeller (speed through the water immediately surrounding the propeller, (m/s))

$$v_A = v(1-w)\ \text{(m/s)}$$

where:

v = speed of vessel (m/s)
w = wake fraction

The wake fraction, w, in the trial condition should be known. For a vessel which trims by the stem in the trial (ballast) condition, the trial condition wake will not differ much from the service condition wake in many cases.

The thrust and power delivered to the vessel at different speeds can be found using the K_T curve and compared with the resistance curve of the trial condition. This procedure is illustrated by the example below.

16.10.2.1 Example: Calculation of trial run speed

The basic parameters are:

- Propeller diameter $D = 4.1$ m
- Propeller rev. per second in service condition, $n = 2.00$
- Service speed = 6 m/sec
- Mass density of water = 1025 kg m^{-3}
- The wake fraction is assumed to be the same for service and trial condition, 0.25
- The resistance in the trial trip condition is 80% of the resistance in the service condition at same speed.

Propeller at Design Point (Service)

$$J = 6\,\frac{(1-025)}{2 \times 4.1} = 0.549$$

K_Q = 0.032 (from Figure 16.1)

P_D = $2\pi\, n\, K_Q\, \rho n^2 D^5 = 2\pi \times 2 \times 0.032 \times 1.025 \times 2^2 \times 4.1^5$
= 1910kW (Power delivered to the propeller)

η_P = 0.7 (Propulsive coefficient)

P_B = 0.7 x 1910 = 1337 kW (Power available for propulsion)

Calculation: The propeller revolutions per second are assumed to be the same in the trial condition as in the service condition. The power delivered by the propeller at different speeds of advance is calculated and compared with the trial run resistance curve. The calculations are based on the diagram in Figure 16.1. Table 16.1 shows the power delivered by the propeller for various speeds. The curve of this power is shown in Figure 16.2. The intersection of the trial run resistance curve with the curve of the power delivered by the propeller gives the speed and power of the trial. The intersection of this curve with the trial run resistance curve gives the trial trip speed and power.

Table 16.1 Calculation of power delivered to the propeller

v m/s	v_A m/s	n 1/s	J -	K_Q -	P_D kW	0.7 P_D kW
6	4.5	2	0.549	0.032	1910	1337
7	5.25	2	0.640	0.028	1671	1170
8	6	2	0.732	0.0234	1397	978

Service

v = 6 m/s
P_B = 1337 kW
P_D = 1910 "
n = 2 r.p.s.

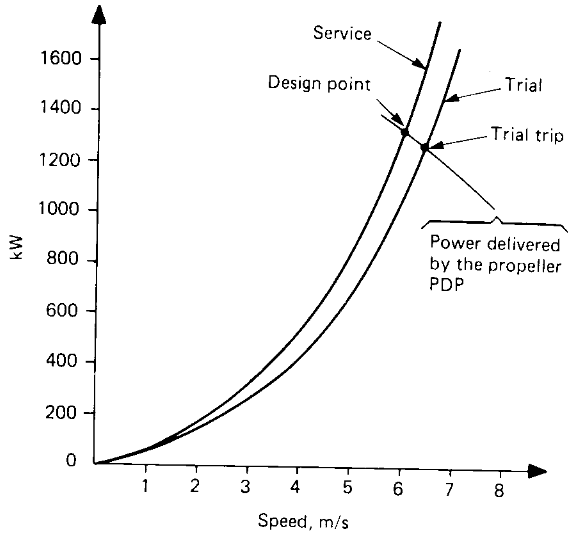


Figure 16.2 Graphs of propulsion power delivered by the propeller, PDP, and of effective resistance, P_B, in the service and trial trip conditions. The intersections of the PDP curve with the P_B curves give the power and speed of the service and trial trip conditions.

Trial

$v = 6.45$ m/s
$P_B = 1255$ kW
$P_D = 1255/0.7 = 1793$ kW
$n = 2$ r.p.s.

Harvald and Hee (1983), present diagrams which illustrate their investigations into how power, revolutions and speed vary between service, ballast and trial conditions. Their diagrams are difficult to interpret but they appear to show that the trial speed may be between 0.3 and 0.5 m/s higher than the service speed and that the trial power may be between 3 and 20% less than the service power.

16.10.3 The influence of engine type

16.10.3.1 The diesel engine

The power delivered by a diesel engine is limited by the mean pressure in its cylinders and the number of revolutions per minute. When the pressure is at its maximum the power is proportional to the number of revolutions per unit of time. In order to maintain speed an increase in resistance must be met by a corresponding increase in cylinder pressure. This is possible if the propeller is designed for heavy conditions and does not absorb the full engine power in light conditions. If there is no increase in cylinder pressure the speed will drop until the resistance corresponds with the power that can be delivered by the diesel engine. This is illustrated in Figure 16.3.

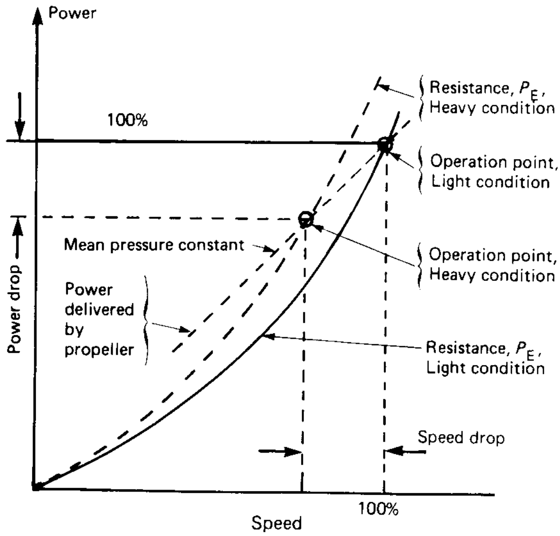


Figure 16.3 Effect of resistance increase beyond the power limit of a diesel engine. If 100% of the power is taken out of the engine for the light condition, only a reduced power can be utilized in the heavy condition. Correspondingly, there will be a greater drop of speed than would have been the case if 100% of the power could have been used in the heavy condition.

16.10.3.2 The steam turbine

The power delivered by steam turbines may increase within certain limits if the revolutions are forced down due to increased resistance and a corresponding drop in ship speed. Thus, a propeller driven by a steam turbine may be designed for a higher torque than a propeller designed for use with a diesel engine.

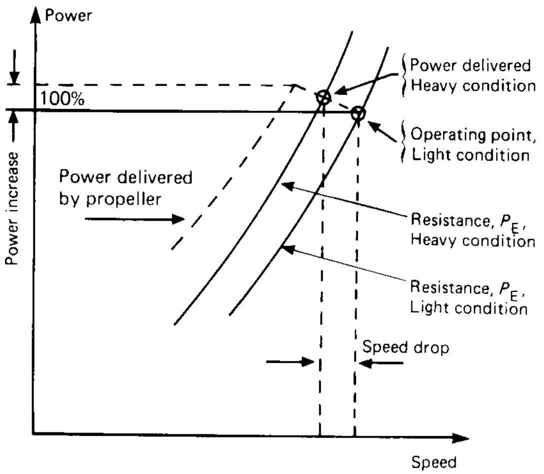


Figure 16.4 Relation between speed and power of a steam turbine propelled vessel when operating conditions change from 'light' to 'heavy.'

16.10.4 Determining the design condition of the propulsion system

Average figures for estimating the increase in resistance under service conditions as opposed to trial conditions were given in Section 16.10.1. The reason for assuming a conditon of increased resistance for design purpose is twofold:

- To ensure that the propulsion system can maintain the design speed even if there is some deterioration of the hull surface and a certain degree of bad weather.
- To have enough power to produce a higher speed than the design speed in good weather conditions. This will make it possible to regain time lost during bad weather.

For a fixed propeller the best design condition is one that ensures an acceptable compromise between these two goals. To arrive at this compromise you must have reliable data on the expected weather and the loading conditions of the vessel and information on how the vessel performs under different combinations of these conditions. If these data cannot be obtained, the average figures given in Section 16.10.1 should be used. Another way of determining design conditions for a propulsion system is illustrated in the example below.

16.10.4.1 Example: The relationship between the propeller and the average speed

Purpose of the investigation: To find the average speed for two different propellers and to compare their ability to maintain a fixed schedule.

Propeller design load: Propeller A = trial condition + 5%; Propeller B = trial condition + 20%.

The speed obtained by the two propellers is shown in Figure 16.5. Table 16.2 summarizes the average speed during the summer.

Table 16.2 Average speed during the summer

Weather, Bf	0–2	2–4	4–5	5–6	6–7	7–8	8–10	
Fraction, %	10	26	22	17	10	8	7	
Speed								
Propeller A	16	15.5	14	12	10	7	3	
Propeller B	14	14	14	14	13	11	6	
Expected fraction of average speed:								Expected average speed:
Propeller A	1.6	4.03	3.08	2.04	1.0	0.56	0.21	12.52
Propeller B	1.4	3.64	3.08	2.38	1.3	0.88	0.42	13.10
Average Speed, Summer:								
Propeller A:	12.52 knots							
Propeller B:	13.10 knots							

Conclusion: Under summer conditions the heavy propeller (B) provides a higher average speed than the light propeller. Because winter conditions are heavier than summer conditions, propeller B will be superior all year round.

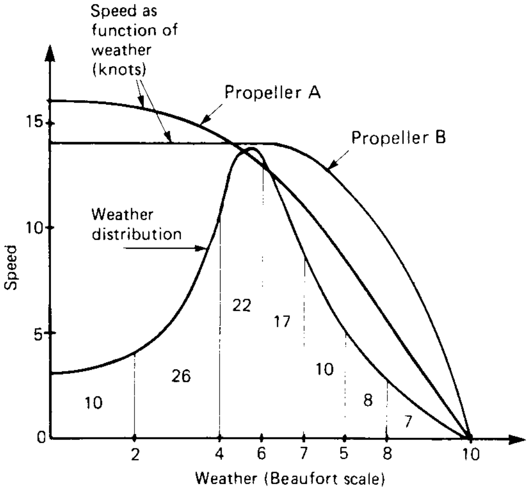


Figure 16.5 Relation between weather conditions and speed obtained by two different propellers. (Numbers in columns indicate percentwise frequency of the weather condition) the average speed during the summer.

Probability of maintaining a schedule: For long sea crossings the probability of encountering average weather conditions is higher than for short crossings. For short crossing of, say, 1–2 days the weather may be more more or less the same for the whole crossing. In that case the weather conditions may be described by the probability of not exceeding a certain weather limit. If the diagram shown in Figure 16.5 is interpreted in this way, there is a probability of 0.07 of the wind exceeding Force 8 and a probability of 0.07 + 0.08 =0.15 of the wind exceeding Force 7 and so on. Correspondingly, if a service speed of 11 knots

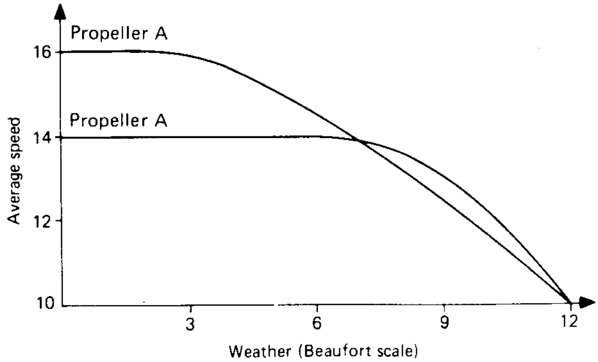


Figure 16.6 Expected average speed for propeller A and B for different upper limits on weather conditions. Weather below the limit is distributed as per Figure 16.5.
Expected average speed for a given worst condition and weather distribution otherwise as given by diagram of Figure 16.5,horizontal axis shows weather for worst condition.

Table 16.3 Calculation of expected average speed

Propeller A:							
Upper weather limit, Bf:	2	4	5	6	7	8	10
Sum of speed fractions	1.6	5.63	8.71	10.75	11.75	12.31	12.52
Sum of weather fractions	0.1	0.36	0.58	0.75	0.85	0.93	1.0
Expected average speed, when the weather does not exceed the given limit:	16.0	15.6	15.0	14.3	13.8	13.2	12.52
Propeller B:							
Upper weather limit, Bf:	2	4	5	6	7	8	10
Sum of speed fractions	1.4	5.04	8.12	10.5	11.8	12.68	13.1
Sum of weather fractions	0.1	0.36	0.58	0.75	0.85	0.93	1.0
Expected average speed for given worst cond.	14.0	14.0	14.0	14.0	13.9	13.6	13.1

is required to maintain schedule, the probability of propeller B meeting this demand would be $1 - 0.07 = 0.93$. The probability that propeller A would meet this demand is $1 - (0.1 + 0.08 + 0.07) = 0.75$.

For crossings where the weather does not exceed a certain limit the expected average speed can be calculated by assuming that the relative distribution of weather below the upper limit is as shown in Figure 16.5. It follows from the calculations and curves shown in Figure 16.6 that under these conditions propeller A will provide a higher average speed than propeller B for all cases where the upper weather limit is 7 Bf or less, or for 85 out of 100 crossings.

16.11 STEERING AND MANOEUVRING ABILITY

As of 1989 there are no established rules governing the steering and manoeuvring ability of vessels. Both the United States and Germany have made proposals to the IMO but their proposals have been either withdrawn or not adopted. However, rules may come into force in the near future. Therefore it is a good idea to check with the relevant national authority or the IMO before beginning work on a new design.

Vessels with a comparatively slender body, where the block coefficent $C_B \leq 0.75$, or with adequate bow and stern thrusters, will, as a rule, have no manoeuvring or steering problems. However, in the face of economic pressure, many new hull forms are being tried and the behaviour of these new forms may be unknown. It is therefore recommended that a model test be carried out to check the steering and manoeuvrability even if the block coefficients are as low as 0.7. This should also be done for vessels which frequently operate in harbours, close to offshore installations, in congested waters or in canals. Philip Mandel (1967) provides a thorough discussion of model testing.

The IMO requires that diagrams based on full scale stopping and turning manoeuvres be posted in the wheel house. Directions for carrying out full scale stopping and turning as well as spiral and zig-zag manoeuvres are given in Section 16.12.2.

A summary of the German proposal to the IMO (1982) is reproduced in Table 16.4 in order to provide a guide to the level of performance which could be required for these manoeuvres. Many large full-bodied ships and ULCCs have a manoeuvrability which is far below these proposals. The German proposals were not adapted because it was felt that it was too early to quantify manoeuvrability requirements (Berg, 1984).

Table 16.4 Requirements to manoeuvring and steering ability as contained in the German proposal before IMO (IMO82).

Criterion:	*Rudder angle*	*Type of vessel* Cargo	Bulk	Container	*Dimension* Special	
Distance travelled for 10° change of course	= 10°	1.75	1.75	1.75	1.75	Ship's length
	= 20°	1.25	1.25	1.25	1.25	
Turning radius	= 10°	5	4	5	3.6	Ship's length
	= 20°	3.3	2.9	3.3	2.6	
Over-shoot angle (zig-zag)	= 10°/10°	10	8	8	10	Degree
	= 20°/20°	15	12	12	15	Degree
Distance travelled until rate of change of yaw angle is reversed (zig-zag)	= 10°	1.3	1.5	1.5	1.8	Ship's length
	= 20°	1.3	1.5	1.5	1.8	

Clarke *et al.* (1983) provide an analytic treatment of manoeuvring and steering criteria. They define turning ability as the change of heading angle from an initial strait course per unit rudder angle after the vessel has travelled one ship length. They recommend a turning ability of 0.3, which is equivalent to a 10 degree change of heading over one ship length when the rudder is placed hard over in excess of 30 degrees. Norrbin and Nomoto (1969) have suggested that the turning ability of large tankers may be only 0.2.

In order for a ship to be course stable, the centre of pressure of the hull in pure yaw should be ahead of the centre of pressure in pure sway. For unstable ships the rudder control must react to the rate of turn of the ship so that any unwanted change of heading can be counteracted by a quick reaction of the rudder. Clarke *et al.* (1983) present a set of design charts which make it possible to select a rudder area that will secure course stability and satisfy the turning index.

Less than adequate steering performance may be improved by attaching fins to the after body to improve the flow of water to the rudder. Tatano (1977) recommends the following modification of the stern to imporove the course keeping ability: shallow overhang, well rounded horizontal and buttock lines, good clearance between the stern and the top of the rudder and a well immersed propeller.

16.12 TRIAL TRIPS

16.12.1 Speed trials

It is advisable to use standard codes for trials. Standard codes have been published by the British Ship Research Association (1977), Thomson (1978), SNAME (1974) and the Norwegian Standard Association (1985). References may also be made to trials and tests required by national and international authorities such as the IMO (1982) and by classification societies. Classification societies have also developed rules for testing equipment such as anchor windlasses, steering engines and other machinery and automation systems. In the offshore oil industry the codes laid down by oil companies (see NIFO and MVL, 1983; Den Norske Stats Oljeselskap AS, 1983 and MVL and Norsk Hydro, undated) and the American Petroleum Institute (API) set the standard.

Standard codes and practices should be judged on the background of what are sound requirements to the vessel in question, and modified to fit particular cases as necessary. The following discussion is limited to speed and manoeuvring trials, assuming rules and regulations of authorities and classification societies, and codes of practice etc. to give a sufficient background to specify other trials (see also Chapter 15 on quality assurance).

The contract or specification should contain a clause which states that speed trials should include a *sufficient* number of runs in opposite directions over a known distance. This distance should be measured in the same direction as the vessel is heading during the trials and *not* in the direction that the vessel moves over the ground which may be influenced by currents which are not parallel to the vessel's heading. In addition, the weather conditions under which the trial should be held should be specified and the procedures for correcting for the influence of weather should be clearly defined.

Vessels which have unusual shapes or low propulsion power in relation to their displacement, such as VLCCs, OBOs (oil, bulk, ore carriers) and semi-submersibles must travel a comparatively long distance in order to obtain their full speed. The speed should be monitored continuously before the trial for these types of vessels and the trial run measurements made when the speed through the water no longer increases.

One run in each direction is sufficient only when the current does not change between one run and the next. If the current changes over time this may be expressed by

$$V_c = a_0 + a_1 t + a_2 t^2 + a_3 t^3 \text{ etc.}$$

If the first run is made at $t = 0$, a second at $t = 1t$ and a third at $t = 2t$, the measured speed over the ground will be

$$\begin{aligned}
V_1 &= V_m + a_0 \\
V_2 &= V_m - (a_0 + a_1 t + a_2 t^2 + a_3 t^3 \ldots) \\
V_3 &= V_m + (a_0 + 2a_1 t + 4a_2 t^2 + 8a_3 t^3 \ldots) \\
V_4 &= V_m - (a_0 + 3a_1 t + 9a_2 t^2 + 27a_3 t^3 \ldots)
\end{aligned}$$

where:

V_m = true speed through the water

If the speed of the current, V_c, varies proportionally with time,

$$V_c = a_0 + a_1 t$$

then

$$V_m = \frac{V_1 + 2V_2 + V_3}{4}$$

$$= \frac{(V_m + a_0) + 2(V_m - a_0 - a_1 t) + (V_m + a_0 + 2a_1 t)}{4}$$

If the speed of the current varies with the second power of t,

$$V_c = a_0 + a_1 t + a_1 t + a_2 t^2$$

then

$$V_m = \frac{V_1 + 3V_2 + 3V_3 + V_1}{8}$$

The current is, as a rule, caused by the tide. The way the tide varies with time will change from place to place. Assuming that the tide varies as a sine function of time, the following may be taken as a rule:

1. When the current speed is low it varies, at least, with second power of t.
2. When the speed of the current is at its maximum it is either constant or varies proportionally with time.

Table 16.5 Tide variation as a sine function of time

Variable	*Value*		
Tide $= \sin 2\pi \frac{t}{23}$	Max	0	Min
*Current $= \cos 2\pi \frac{t}{23}$	0	Max/Min	0
**Acceleration $= -\sin 2\pi \frac{t}{23}$	Min	0	Max

*The current minimum is the maximum speed in the negative direction.
**The minimum acceleration is the maximum acceleration in the negative direction.

A comparison of two trial runs in opposite directions and a check of tide tables will reveal the true condition. Table 16.5 illustrates what happens if the tide varies with time as a sine function of time. The trials should be carried out in an area where the *water depth* is more than 20 times the draught of the vessel. This should be included in the specifications.

The procedures for carrying out trial runs and analysing the results are described by Harvald (1983) and Todd (1967) and will not be discussed here.

16.12.2 Steering and mavoeuvrability trials

Four different tests are used to determine the steering and manoeuvrability of vessels:

- The spiral manoeuvre, used to test course stability
- The zig-zag or overshoot manoeuvre, used to test the response on the rudder.
- The turning circle manoeuvre.
- The stopping manoeuvre.

Norwegian Directorate and IMO regulations (1971) require diagrams based on the results of the turning circle manoeuvre and the stopping manoeuvre to be posted in the wheel house in a place where they can be easily seen by the officer on watch and the pilots. An example of stopping distance information is shown in Figure 16.11.

Mandel (1967) provides a thorough discussion of these manoeuvres, how they can be used to determine the characteristics of a vessel and how the vessel characteristics may be derived from model tests and theory.

16.12.2.1 The spiral manoeuvre

The spiral manoeuvre begins with the vessel on a straight course and travelling at constant speed. The propulsion power is kept constant during the manoeuvre. The rudder is set at an angle of 15–20 degrees to one side and kept at this angle until the vessel has a steady rate of turn. When the steady rate of turn has been reached, the rudder angle is decreased by about five degrees and held until the vessel again reaches a steady rate of turn. The rudder angle is then decreased by a further five degrees and held at that angle until the vessel once again reaches a steady turn rate.

This stepwise change of rudder angle is continued from the maximum angle to one side to the maximum angle to the other side and back again. If the vessel is *course stable* the rate of turn is the same for the same rudder angle whether the rudder position is varied from zero to maximum or from maximum to zero. Figure 16.7 illustrates the relationship between rudder angle and rate of turn for course stable and unstable vessels.

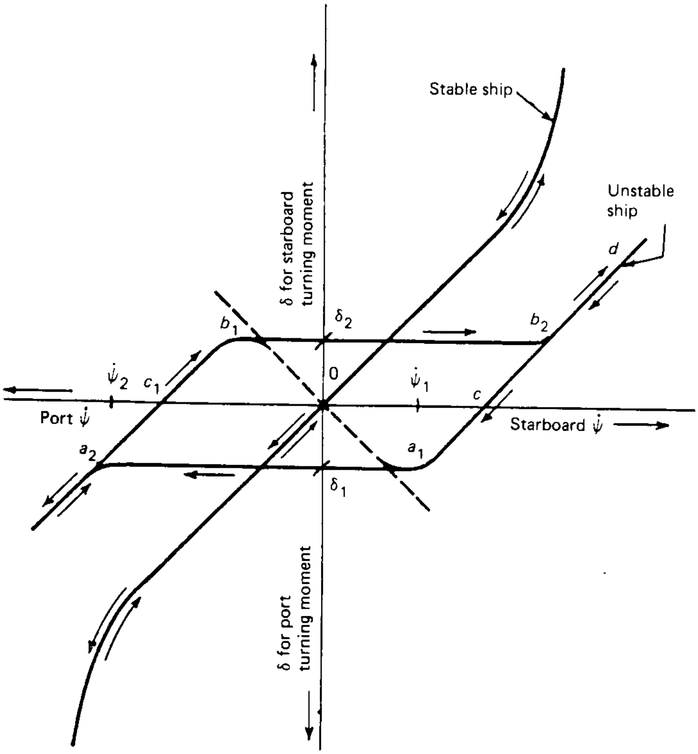


Figure 16.7 The rudder angle, δ, plotted against the rate of turn $\dot{\psi}$. For stable vessels there is one and only one rate of turn that corresponds to a certain rudder angle; for unstable vessels the rate of turn may vary within wide limits and with opposite directions, for one and the same rudder angle. The horizontal parts of the graph of the unstable vessel (point a_1 to a_2 and b_1 to b_2) indicate that the rate of turn suddenly will change from $\dot{\psi}_1$ to $\dot{\psi}_2$ when the rudder angle has been reduced from a starboard deflection throught zero to the angle δ_1 to the port. Correspondingly, there will be a sudden change of rate of turn when the rudder angle has been reduced from a port deflection through zero to the angle δ_2 to starboard (Mandel, 1967)

16.12.2.2 The overshoot and zig-zag manoeuvre

The overshoot manoeuvre starts with the vessel on a straight course at constant speed. The propulsion is kept constant during the manoeuvre. The rudder is moved at its maximum rate of turning to a given angle and is held steady until the vessel has made a predetermined change in course. Often the number of degrees of course change is set equal to the rudder angle, as in Figure 16.8.

As soon as the vessel has reached the chosen course, the rudder is laid hard over to the same angle on the opposite side. The rudder is kept in this new position until the vessel has moved a given number of degrees to the opposite side. Generally, the degrees of course change are equal to the course change in the first part of the manoeuvre.

The zig-zag manoeuvre consists of one or more repetitions of the overshoot manoeuvre. The results of the overshoot and zig-zag manoeuvre give an indication of rudder control. The overshoot angle and the overshoot width are characteristic features of a vessel (see Figure 16.8). Section 16.11 provides guidance for setting performance requirements.

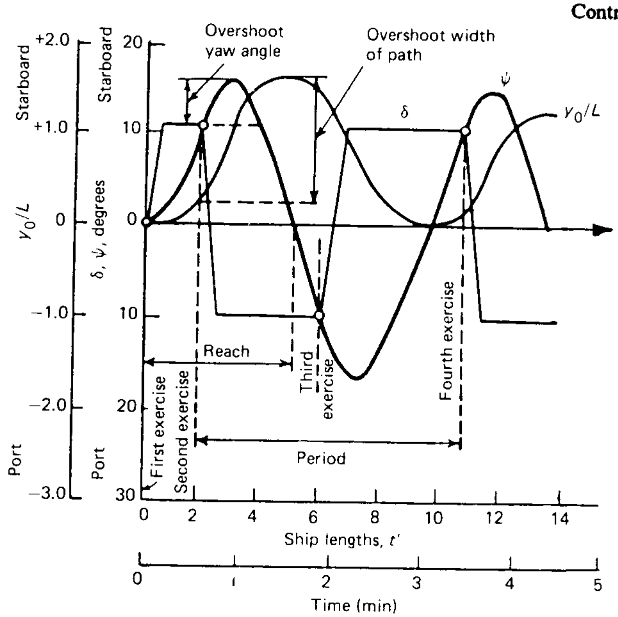


Figure 16.8 Results of an overshoot and zig-zag manoeuvre. Rudder angle, δ, yaw, ψ, angle and the dimensionless width of path of the vessel, yo/L, as function of vessel's travel in the direction of the original course. (Mandel, 1967)

16.12.2.3 The turning path manoeuvre

By IMO regulations require this manoeuvre to be carried out for both port and starboard turns at full power, the power corresponding to a slow speed and at no power. The vessel must be moving at full speed when the manoeuvre is begun.

The manoeuvre begins with the vessel running ahead at constant speed on a straight course. The rudder is set at the maximum rate of turn to a preselected angle. It is held at this angle throughout the manoeuvre. After a while this will make the vessel turn at a constant radius.

This manoeuvre makes it possible to determine the advance, or the distance travelled from the time the rudder is moved until the vessel has made a 90 degree change of course. It also makes it possible to determine the tactical diameter of the turning operation (see Figure 16.9). These features give an indication of the manoeuvrability of the vessel. The turning path manoeuvre is illustrated in Figure 16.9.

16.12.2.4 The stopping manoeuvre

The manoeuvre is begun with the vessel running at constant speed and course. The propulsion power is either cut off or reversed to a given level and the vessel's movement and the speed (r.p.m.) of the propellers are monitored until the vessel has come to a complete stop. The IMO requirements state that the manoeuvre must be carried out under slow, half and full speed reverse power. The stopping manoeuvre allows the characteristics of the head reach or advance, the track reach and the lateral reach to be determined. This is illustrated in Figure 16.10.

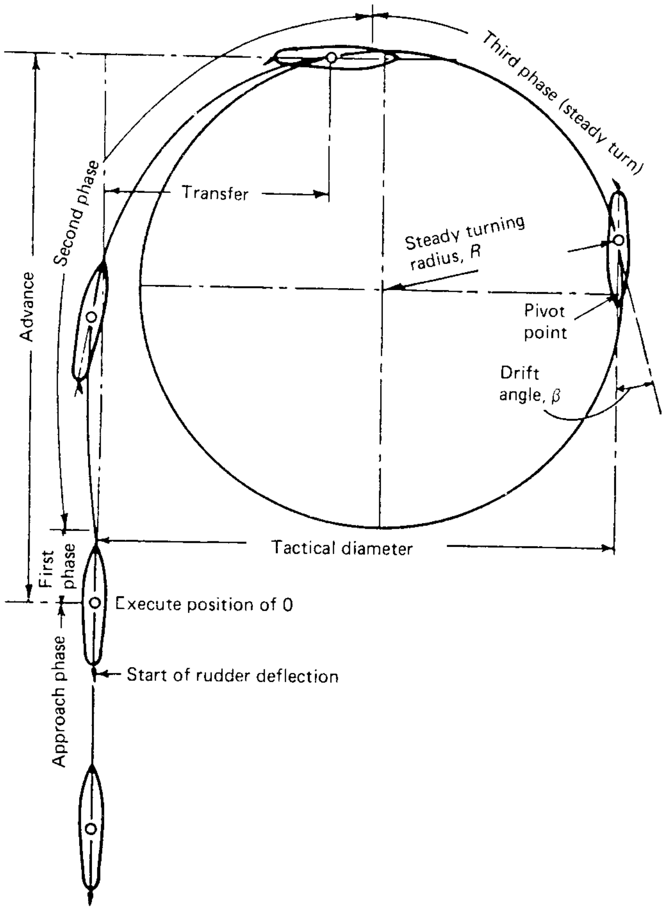


Figure 16.9 A ship turning path with characteristic features (Mandel, 1967)

16.13 ENDURANCE

Endurance is a measure of how long a vessel can remain at sea or how far it can travel without taking on additional supplies. In order to specify endurance the time at sea, the average power delivered by the propulsion machinery, the average power delivered by the auxiliary machinery, the fuel consumption of the propulsion and auxiliary machinery and the daily consumption of supplies such as fresh water, food, mud, pipes and cement should be specified.

The specification of endurance should clearly state that the endurance is a basis for calculating the required storage capacity for fuel and other supplies, *not* an indication of how much of these items should be included for the calculation of deadweight. These items are always included in the deadweight. The question is to what extent.

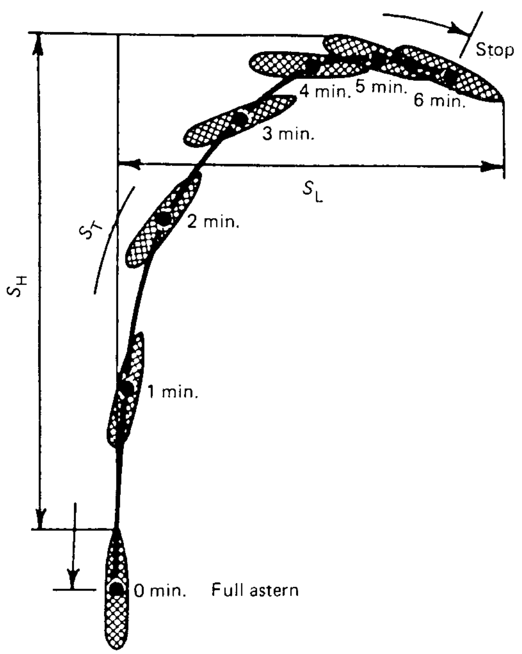


Figure 16.10 Stopping manoeuvre. Typical track and change of heading of a ship with a single screw that turns left when being reversed (Harvald, 1983). S_H is the head reach, S_L is the lateral reach, and S_T the track reach

16.14 FUEL CONSUMPTION

The fuel consumption specification should include:

- The specific fuel consumption (sfc) for all major engines.
- The type of fuels for which the sfc is valid.
- The specific calorific value of the fuels.
- The range of engine performance within which the sfc is valid.
- Environmental conditions (air temperature, pressure and humidity and water temperature) for which the sfc is valid.
- An indication of how deviations from the specified environmental conditions will influence the sfc and the performance of the major engines.
- Under what conditions checks of the sfc and other performance characteristics will be made.

16.15 CERTIFICATES

All contracts and specifications contain a clause which states that the vessel is to be built according to the specifications of a particular, or in some cases, more than one classification society and according to the rules and regulations of one or more international or national authorities.

All fees and charges incidental to classification and compliance with specified rules and regulations are generally paid by the builder or contractor.

The requirements of the *classification* society depend on the class of the vessel. There is one main class which determines the general design of the vessel. A vessel may also be

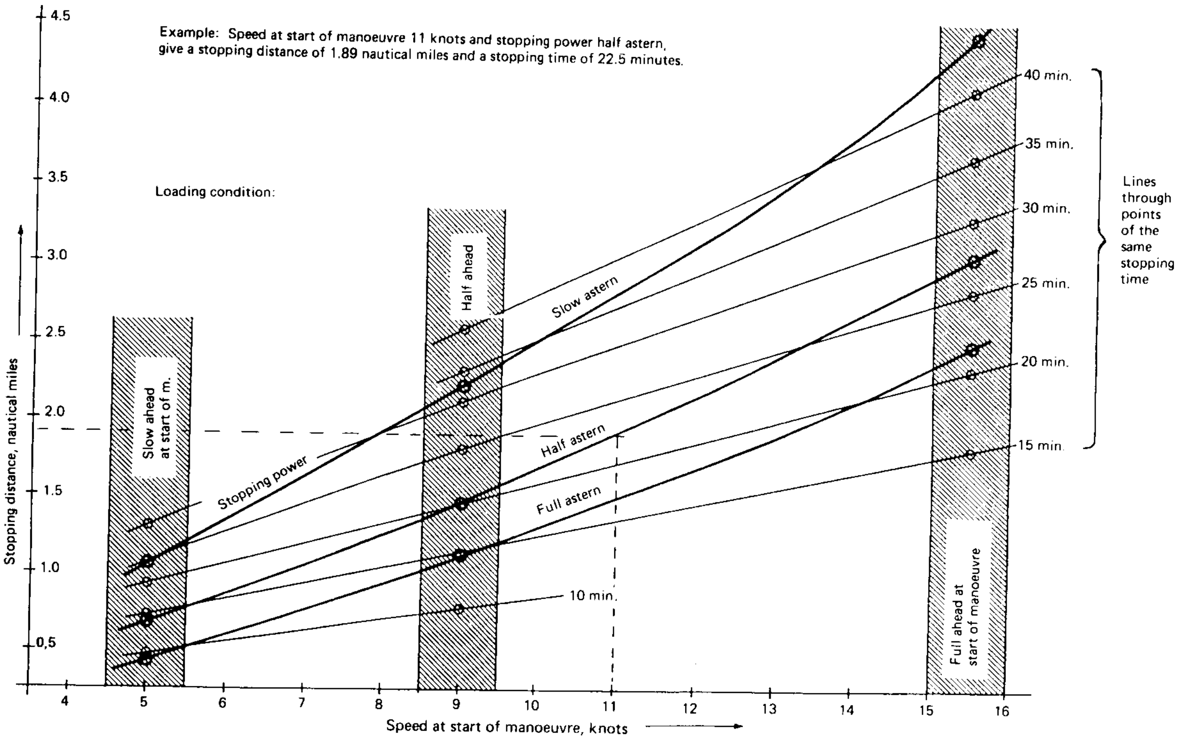


Figure 16.11 Information on stopping distance (advance) and time, as required by IMO to be posted in the wheelhouse when the stopping manoeuvre has been carried out at different original speeds and different reversing powers. The diagram is based on manoeuvring tests carried out with a clean underwater surface in calm weather with no wind, waves or current and in deep water

of an additional class, for example for navigation in ice, unmanned machinery systems (EO) or fire protection.

The national *authority* of the vessel is the authority of the vessel's country of registration. If the vessel will be calling at foreign ports where special rules and regulations are enforced, it is necessary to specify that the vessel must satisfy the regulations of other national authorities. A typical example of this situation is when ships are to call at ports in the United States where the US Coast Guard enforces pollution control regulations and rules concerning the safety of tankers and the handling of chemical fluids. Another example is the Australian and New Zealand Safety Working and Harbour Regulations issued by the Waterside Workers Federation. These require all vessels calling at Australian or New Zealand ports to satisfy certain rules concerning their cargo loading and unloading equipment and access to cargo compartments.

Classification societies and authorities issue certificates and class notation to confirm that a vessel has been built in accordance with their rules and regulations. A list of some of the international and national conventions which may be referred to in a contract as well as a list of certificates which may be required for vessels built to the rules and regulations of the Norwegian Maritime Directorate (Sjøfartsdirektoratet) and some examples of class notations used by Det norske Veritas are given in the next two sections.

16.15.1 National and International Conventions

Examples of international conventions that may be referred to in a contract are listed below

1. The International Convention for Safety of Life at Sea, 1974.
2. International Convention on Load Lines, 1966.
3. International Labour Convention Code of Practice, Safety and Health in Shipbuilding and Shiprepairing (Gothenburg, Sweden 1972).
4. The Governmental Marine Agency's Regulations related to tonnage measurements of ships.
5. The rules and regulations governing Navigation of the Panama Canal and Adjacent Waters (including tonnage measurement).
6. The Suez Maritime Universal Company's Rules of Navigation (including tonnage measurement).
7. Any national legislation related to design construction and operation of ships and semi-submersibles.
8. International Tele-communication and Radio Regulations (Montreux 1965) and Annexes and Revisions (Geneva 1976).
9. International Convention for the Prevention of Pollution from Ships, 1973, including provisions for sewage disposal plants.
10. Regulations of the U.S. Coast Guard, Pollution Prevention for Vessels and Oil Transfer Facilities and Marine Sanitation Device.
11. Waterside Workers Federation's Regulation of Australia.
12. IMO Resolutions

16.15.2 Certificates, documents and records required for Norwegian ships

Documents that may be required for Norwegian ships are listed below. The list is based on a list in Norwegian provided by the Norwegian Maritime Directorate and published with their kind permission.

1. *Certificate of Nationality*
Issued to all registered vessels having an overall length of 15 metres or greater and all vessels in foreign trade.

2. *Certificate of Name*

Issued to all registered vessels having an overall length of 15 metres or greater.

3. *Certificate of Identity for Vessels*

This certificate is issued on application to vessels having an overall length less than 15 metres.

4. *Builder's Certificate*

This certificate is prepared by the builder and becomes an official document when it is registered. The builder's certificate is the *title* deed to the vessel.

Where a vessel is purchased abroad, the *bill* of sale certified by a Notary Public, and registered, serves the same purpose as the builder's certificate.

5. *Certificate of Delivery*

This document is issued when a ship is purchased abroad. The document is notarized by a Norwegian consulate or other Norwegian agent abroad.

6. *Trading Certificate*

This certificate is issued to cargo ships, fishing vessels, barges and pleasure crafts of a tonnage of 50 and above. It is also available for cargo ships of a tonnage of less than 50, but which require an international load line certificate. Tugs of 25 metres and above may obtain a trading certificate if desired. A trading certificate may be valid for up to five years.

7. *Cargo Ship Safety Construction Certificate*

This certificate is issued in accordance with The International Convention of Safety of Life at Sea, 1974 (SOLAS 1974). The certificate may be valid for up to five years. The certificate is provided for cargo ships of a *tonnage* of 500 and above when engaged in trading abroad.

8. *Cargo Ship Safety Equipment Certificate*

The certificate is issued for cargo ships as specified in point 7. The certificate is valid for up to two years.

9. *Passenger Certificate for an International Voyage*

This certificate is issued to passenger vessels trading abroad. The certificate is valid for up to one year.

10. *Passenger Certificate for a Short International Voyage*

This certificate is issued to passenger vessels trading abroad. The certificate is valid for up to one year.

11. *Passenger Certificate*

There are two categories of passenger certificates, one for ordinary passenger ships and one for car ferries. The certificate is issued to ships regardless of their size, and is valid for up to five years.

12. *Passenger Ship Safety Certificate*

This certificate is issued to passenger ships trading abroad as specified in point 9 and 10. The certificate may be valid for up to one year and is issued in accordance with SOLAS 1974. The certificate also covers the vessel's radio station.

13. *Certificate for Space Requirements for Passenger Ships in Special Trades*

This certificate is issued to ships — not necessarily passenger vessels — which, for example, carry pilgrims. The certificate is issued in accordance with requirements laid down in the Protocol on Space Requirement for Passenger Vessels in Special Trades, 1973.

14. *Cargo Ship Safety Radio Telegraphy Certificate*

The certificate is issued to cargo vessels of 1600 gross registered tons and above. It is issued in accordance with SOLAS 1974, and is valid for up to one year.

15. *Cargo Ship Safety Radio Telephony Certificate*

The certificate is issued to cargo ships of a tonnage of 300 and above, but less than 1600 GRT. It is issued in accordance with SOLAS 1974, and is valid for one year.

16. *Safety Radio Telegraphy Certificate*

This certificate is issued to passenger vessels in domestic trade, and is valid for one year.

17. *Safety Certificate of Radio Telephony*

This certificate is issued to cargo ships and passenger vessels in domestic trade and also to fishing vessels. The certificate is valid for one year.

18. *Safety Certificate of Radio Telephony*

This certificate is issued to passenger vessels in domestic trades where open sea passages of more than 5 nautical miles are not undertaken. The certificate is valid for three years.

19. *International Tonnage Certificate (1969)*

This certificate is issued to vessels that are required to be measured and whose freeboard length is 24 metres and above.

20. *International Tonnage Certificate (1947)*

This certificate is issued in accordance with the 1947 tonnage convention for existing vessels when a vessel is changed or altered in such a way that in the opinion of the Norwegian Maritime Directorate, there is no substantial change of the tonnage.

21. *Norwegian National Tonnage Certificate (1982)*

This certificate is issued to vessels which are required to be measured and having a freeboard length less than 24 metres and an overall length of at least 15 metres.

22. *Tonnage Certificate (1982)*

This certificate is issued to vessels that are required to be measured where the freeboad length is 24 metres and above, and the gross tonnage according to the 1969 convention, is less than 4000.

22a. *Suez Canal Special Tonnage Certificate*

This certificate is issued in case a ship trades through the Suez Canal.

22b. *Panama Canal Tonnage Certificate*

This certificate is issued in case a ship trades through the Panama Canal.

23. *International Load Line Certificate (1966)*

This certificate is issued to ships of 50 Units of Tonnage and above, or with a length of 24 metres and above, and which are engaged in international trade.

24. *Load Line Certificate for Cargo Vessels in Domestic Trade*

This certificate is issued to cargo vessels of 50 Units of Tonnage and above, or with a length of 24 metres and above.

25. *Load Line Certificate for Passenger Vessels in Domestic Trade*

This certificate is issued to passenger vessels of 15 Units of Tonnage and above, or with a length of 24 metres and above.

26. *Certificate of Marking of Vessels with no Load Line Certificate*

The certificate is for a load line mark.

27. *Load Line Certificate for Fishing and Catching Vessels*

The certificate is issued for fishing and similar vessels of 15 Units of Tonnage and above, or with a length of 24 metres and above.

28. *Certificate of Equipment for Fishing Vessels*

The certificate is issued for fishing and similar vessels with a length of 10.67 metres and above, and with a tonnage less than 50. The certificate is valid up to two years.

29. *Mobile Drilling Platform Certificate of Fitness*

The certificate is valid up to five years.

30. *Mobile Drilling Platform Safety Equipment Certificate*

The certificate is valid up to five years.

31. *Mobile Drilling Platform Safety Construction Certificate*

The certificate is valid up to five years.

32. *Mobile Drilling Platform Safety Radio Installation Certificate*

The certificate is valid up to one year.

33. *Mobile Drilling Platform Load Line Certificate*

The certificate is valid up to five years.

34. *Letter of Compliance*

This certificate is issued to foreign mobile drilling units intended for operation on the Norwegian continental shelf. The certificate is valid up to five years.

35. *International Oil Pollution Prevention Certificate (IOPP certificate)*
The certificate is issued to oil tankers of a tonnage of 150 and above, and for any other ship of a tonnage of 400 and above, and also to mobile platforms.

36. *Certificate Concerning the Carriage in Bulk of Dangerous Chemicals*
This certificate is issued in accordance with the rules and regulations laid down in IMO's international code of construction and equipment for vessels which are to carry dangerous chemicals in bulk. The certificate is valid up to five years.

37. *Document of compliance with the special requirements for ships carrying dangerous goods*
This certificate concerns the carriage of packed dangerous goods and dangerous dry cargo and bulk, issued in accordance with SOLAS 74.

38. *Certificate Concerning the Carriage of Liquefied Gases in Bulk*
This certificate is issued in accordance with the IMO's international code for the construction and equipment of ships carrying liquefied gases in bulk. It is valid for 5 years.

39. *Certificate of Installation of Welding System*
The certificate is issued by the firm installing the plant and endorsed by a Ship Control surveyor. It is valid up to 4 years.

40. *Certificate of Installation of Gas Fired Installations*
The certificate is issued by the firm installing the plant.

41. *Certificate of Installation of Electrical Plant of 42 V and Less*
The certificate is issued by the firm installing the plant.

42. *Certificate for Personnel and Cargo Lift*
The certificate is valid for up to 5 years.

43. *Certificate of Seaworthiness*
The certificate is issued to vessels after survey of repairs or alleged deficiency made good.

44. *Removal Certificate*
Permit to move an unseaworthy ship to a port of repair.

45. *Specification of Crew*
This certificate is issued to vessels of a gross tonnage of 50 and above, except for fishing vessels.

46. *Licence for Establishment and Operation of a Radio Station*
This is a mandatory document issued by the Telecommunication Authority.

47. *Certificate of Prototype Approval of Ship's Equipment*

48. *International Load Line Exemption Certificate*
This certificate may be issued for an occasional international voyage of a vessel which does not fully comply with the requirements of the International Convention of Load Lines (1966).

49. *Exemption Certificate*
This certificate is issued in accordance with the International Convention of Safety of Life at Sea 1974 (SOLAS 1974).

50. *Tow Permit*
This certificate is issued to a vessel which is to carry out a voyage in tow.

51. *Towage Permit*
This certificate is issued to vessel undertaking a towing mission.

52. *Certificate on Civil Liability for Oil Pollution Damage, 1969*
This is mandatory for all ships carrying a cargo of more than 2000 tons of oil in bulk.

53. *Grain Loading Stability Booklet*
This certificate is issued by the builder and approved by the Norwegian Maritime Directorate.

54. *Cargo Gear Certificate*
This certificate is issued by the builder (contractor).

A condition for obtaining many of the certificates mentioned above, is that the performance and quality of all important components and systems must be documented by certificates issued for each of them. These include among others, certificates for navigation lights, anchors and chains, stern tube, rudder stock with accessories, hatch covers, pilot ladders, life saving equipment, water tight doors, windlasses, main engine and auxiliaries, propeller shaft, air compressors, pumps and valves, boilers, emergency machinery, steering gear, electrical generators and switchboards.

16.15.3 Service and equipment and system notations used by Det norske Veritas

16.15.3.1 Vessels

Examples of terms used include:
ICE C, 1A* , 1A etc.
Ice Breaker
Floating Hotel
General Cargo Carrier
Ore Carrier
Tanker for Oil
Trawler
Tug
Fire Fighter (I,II or III)
Crane Vessel
Column Stabilized Unit
Self-Elevating Unit
Drilling Vessel
Pipe Laying Vessel
Dredger

16.15.3.2 Equipment and system

Abbreviations used include:
HELDK — helicopter deck
CRANE — shipboard crane
DSV — diving system
DYNPOS — dynamic positioning
KMC — cargo refrigerating plant
EO — periodically unattended machinery space
F — fire protection
F–A — fire protection for accommodation
F–M — fire protection for machinery space
F–C — fire protection for cargo space

16.16 NON-FULFILMENT OF CONTRACTS

All contracts contain a clause which states that if the contract specifications are not fulfilled within given margins the builder is liable to compensate for this by reducing the price of the vessel. The items which are usually mentioned in this clause include the deadweight capacity or payload, the cubic capacity and cargo areas, the loading and unloading capacity, speed, fuel consumption, endurance, vibration and noise and delayed delivery.
There are three degrees of deviation from contract specifications:

1. Deviation within the given margins of uncertainty. There is no penalty for this.

2. Deviation up to a specified limit. The penalty is in proportion to the deviation from specifications.

3. Deviation beyond a specified limit. In this case the customer has the right to cancel the contract.

16.16.1 Cancellation of the contract

The contract should be written so that a purchaser may refuse to take delivery of the vessel if its performance differs so much from the specification that it is unsuitable for the planned service. The conditions for cancellation of the contract should be based on:

- The minimum *cargo capacity* required to handle the contracted or expected cargo inflow.
- The minimum *loading and unloading capacity* required to prevent exceeding the planned time in ports.
- The minimum speed required to maintain a schedule or to carry out a specified number of voyages per year.
- The *steering and manoeuvring performance* required for safe and economic operation of the vessel.
- The *fuel consumption* required to maintain the specified endurance. The fuel consumption should not be more than 3% higher than specified.
- The minimum *endurance* required to maintain service; for example to maintain a continuous drilling operation in accordance with the planned supply service, to complete a voyage or to sail to a fixed schedule without more bunkering than foreseen.
- The ability to *maintain position* within specified margins.
- The maximum acceptable noise or vibration for passengers and crew.
- The *deadline* for completion of the contracted work and any other time limits which must be met in order to establish the planned engagement.

16.16.2 Penalties for contract non-fulfilment

Compensation for non-fulfilment of a contract should reflect the losses caused by the deviation from the specified capacity. The losses generally take the form of reduction of gross annual income. Annual losses in income may be transformed to an equivalent capital outlay by *dividing* the sum of the losses by a *capital recovery factor* corresponding to the foreseen lifetime of the vessel and the rate of return obtained on ongoing activities of the purchaser. If the rate of return on ongoing business is unrealistic in relation to the expected rate of return on the ordered vessel, the company's rate of discount should be used. The capital recovery factors for lifetimes of 12 and 20 years are shown below.

Rate of return, %:	8	10	12	16	20
Lifetime;					
12 years:	0.1327	0.1468	0.1614	0.1924	0.2253
20 years:	0.1019	0.1175	0.1339	0.1687	0.2054

Assuming that deviations within the given margins of uncertainty do not entitle the purchaser to any compensation, the losses should be calculated as shown below.

16.16.2.1 Cargo capacity (d.w., Cubic, Area)

Deficit = $\mathrm{d}C$ beyond margin of uncertainty

Annual loss $= F \dfrac{\mathrm{d}C}{C}$

$$\text{Compensation} = \frac{F}{CR(i\%,N)} \; \frac{dC}{C}$$

$$\text{Compensation per unit deficit} = \frac{F}{CR(i\%,N)} \; \frac{1}{C}$$

where:
F = gross annual income
C = specified cargo capacity
$CR\ (i\ \%, N\ )$ = capital recovery factor at rate of interest = i;
lifetime = N years

16.16.2.2 Loading/unloading capacity

Deficit = dL, beyond margin of uncertainty

$$\text{Relative deficit} = \frac{dL}{L}$$

$$\text{Compensation} = \frac{F}{CR(N,i)} \times \frac{T_p}{360} \times \frac{dL}{L}$$

$$\text{Compensation per unit deficit} = \frac{F}{CR(i\%,N)} \times \frac{T_p}{360} \times \frac{1}{L}$$

where:
L = specified loading or unloading capacity
T_p = time spent during loading and/or unloading per year in days
360 = number of days on hire per year (could be 350)
F = gross annual income

16.16.2.3 Speed

Deficit = dV, beyond margin of uncertainty

$$\text{Compensation} = \frac{F}{CR(i\%,N)} \times \frac{T_s}{360} \times \frac{dV}{V}$$

$$\text{Compensation per unit deficit} = F \; \frac{T_s}{360} \; \frac{1}{L}$$

where:
F = gross annual income
V = specified service speed
T_s = time spent at sea (steaming) per year, in days

16.16.2.4 Steering and manoeuvring

Inadequate steering and manoeuvring performance will cause excessive use of rudder and thereby loss of propulsion power and increased demand for steering power and increased dependency on tugs when manoeuvring in ports, on rivers and in canals.

$$\text{Compensation} = \frac{C}{CR(i\%,N)}$$

where:
C = annual costs due to inadequate steering and manoeuvring
CR ($i\ \%, N$) = capital recovery factor at rate of interest = i ;
lifetime = N years

16.16.2.5 Fuel consumption

Excess consumption = dK, beyond margin of uncertainty

$$\text{Relative excess} = \frac{dK}{K}$$

$$\text{Compensation} = \frac{C_F}{CR(i\%,N)} \times \frac{dK}{K}$$

$$\text{Compensation per unit of excess} = \frac{C_F}{CR(i\%,N)} \times \frac{1}{K} \times \frac{T_s}{360}$$

where:
K = specific fuel consumption according to contract
C_F = annual cost of fuel

16.16.2.6 Endurance

Contracts should specify the compensation due as a result of the extra costs or reduced income resulting from refuelling and deviations from schedule due to the need to refuel more frequently than originally planned. Contracts for stationary service platforms such as drilling platforms, offshore hotel and maintenance platforms and platforms for subsea support should specify the compensation due to offset the extra costs or reduced income incurred by the need for more frequent replenishment of supplies such as pipes, cement, gas, mud and provisions.

16.16.2.7 Position keeping

The compensation should cover the cost of altering the vessel to allow it to maintain position within specified margins as well as the loss of income suffered while the vessel is being altered.

16.16.2.8 Noise

IMO regulations state that the maximum allowable noise level on board *cargo ships* is 60 DbA in cabins and mess for vessels of 3000 tonnes and above and 65 DbA for vessels below 3000 tonnes. Vessels which have a higher noise level should not be accepted.

The specified noise limit for *passenger vessels*, such as cruise ships, is between 45 and 55 DbA for cabins. On more luxurious vessls the limit is lower. If the noise is not kept below the specified level it may be difficult to attract the category of passengers originally planned for. This may justify compensation which reflects the loss in earning capacity.

The noise level is generally required to be below 45 DbA for cabins on moveable and permanent offshore installations (Brubakk, 1987).

16.16.2.9 Delayed delivery

The compensation due for income lost due to delayed delivery can be calculated as shown below.

$$\text{Compensation} = F\,\frac{dT}{360}$$

where:
F = gross annual income
Deficit = dT, time elapsed beyond contracted time of delivery

16.16.3 Premium for excess capacity

Some contracts contain a clause by which the builder is entitled to an increased payment for the vessel if excess capacity is provided. Before accepting this clause you should ensure that the excess capacity can be used to generate income. The excess capacity must exceed the limit set by the safety margins in order to justify increased payment. Conditions for granting a premium for excess capacity are discussed below.

16.16.3.1 Cargo capacity

The predicted inflow of cargo must be great enough to secure full utilization of the excess capacity. The total capacity of the vessel must be such that the excess capacity can be used. This means that the premium should only be allowed for excess deadweight capacity if the vessel has sufficient cubic capacity and deck area to make use of the extra deadweight capacity and vice versa. It should also be possible to use the excess capacity within the planned schedule and trading pattern.

Use of the excess capacity should not lead to difficulties in the operation of the vessel. It should not lead to increased time in port, reduced speed or a larger draught than specified.

The compensation for excess capacity beyond the margin of uncertainty can be calculated as shown below.

$$\text{Compensation} = \frac{dC}{C} \times D_u \times P$$

where:
C = specified capacity
D_u = estimated degree of utilization
P = purchase price of the vessel
dC = excess capacity

16.16.3.2 Loading and unloading capacity

There should be sufficient capacity in port to handle the excess capacity of the vessel. It should be possible to move cargo and from the vessel at the same rate as originally planned. The capacity for handling ballast should also be great enough to match the increased loading and unloading capacity. It should also be possible to use the increased capacity within the planned schedule and trading pattern.

It should be possible to use the excess capacity within the existing rules and regulations in port, including anti-pollution regulations and regulations concerning the use of the vessel's own gear and working time.

Compensation for excess capacity, dL, beyond the margin of uncertainty can be calculated as shown below.

$$\text{Compensation} = \frac{dL}{L} \; \frac{T_s}{360} \times D_u \times P$$

The degree of utilization is dependent on the number of ports where the vessel's equipment may be used and on limits that may be created by the items mentioned in this section.

16.16.3.3 Speed

It must be possible to utilize the excess speed within the planned schedule and trading pattern. The specified daily fuel consumption should not be exceeded.

Compensation for excess speed over specification can be calculated as shown below.

$$\text{Compensation} = \frac{dV}{V} \times \frac{T_s}{360} \times D_u \times P$$

where
V = specified speed

T_s = time spent at sea per year
D_u = estimated degree of utilization
P = purchase price of the vessel
dV = increase of speed

16.16.3.4 Fuel consumption

Claims of reduced specific fuel consumption in relation to contract should be documented through controlled tests where the calorific value of the fuel, the fuel consumption per unit time and the power delivered by the engine are monitored. The results of the controlled tests should then be compared with the specified values.

The premium due to the builder as a result of reduced fuel consumption can be calculated as shown below.

$$\text{Compensation} = \frac{C_F}{CR(i\%,N)} \times \frac{dK}{K} \frac{T_s}{360}$$

where:
K = specific fuel consumption according to contract
C_F = foreseen, annual cost of fuel
T_s = time at sea per year
$C_R\,(i\ \%, N)$ = Capital recovery factor at N years and a rate of interest of $i\%$.
dK = reduced fuel consumption

16.16.3.5 Endurance

A premium for endurance beyond specification should be given only if the increased endurance can be used to increase income. In most cases the specified endurance is in accordance with a planned operation which cannot be modified to take advantage of increased endurance. Therefore, in most cases a premium is not justified.

16.16.3.6 Position keeping

A premium for position keeping ability better than that specified should only be paid if the improvement is of benefit to the owner. If the specification ensures a safe and reliable operation, an improvement beyond the specification is of little use.

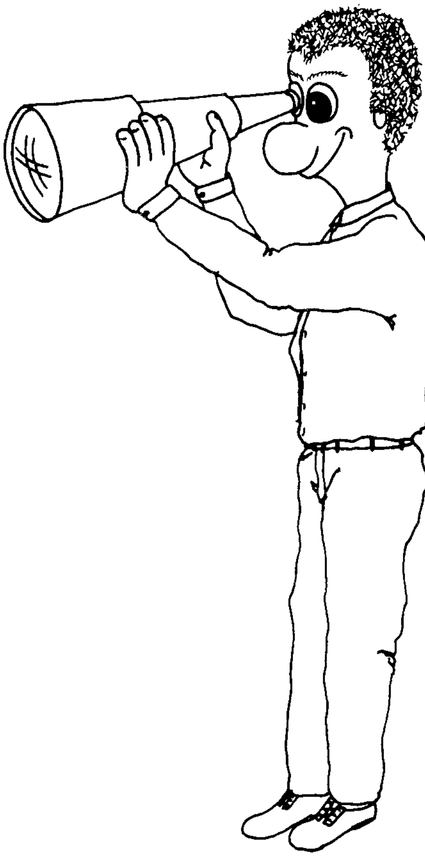
16.16.3.7 Early delivery

In some cases early delivery will make it possible to begin generating income sooner than anticipated. If this is the case, the contractor should receive a premium which reflects a resonable share of the *net profit* gained.

However, early delivery can sometimes cause problems for the owner because the vessel cannot begin its intended use until a scheduled date. If this is the case the owner may refuse to take delivery until the contracted delivery date.

17

MARKET RESEARCH



17.1 INTRODUCTION

The purpose of market research is to reveal the demand for a service. Demand may be dependent on general market conditions or be linked to specific customers or groups of customers.

Specific goups of customers may require shipping service even when the market is generally negative. Therefore, when conducting market research it is important to investigate the possibility of finding customers of this kind. Surveys based on statistics and general information about developments in commerce, industry and transport may draw attention to promising groups of customers.

Extra effort is often required on the part of both the shipping company and the customer to develop a market. Cooperation must be based on mutual trust. The shipping company must establish itself as a trustworthy transport specialist in the minds of its customers.

Both general and specialist markets have their own characteristics. The general characteristics of the shipping market are usually known. Under normal conditions there is usually a good balance between supply and demand. Demand for specialist markets is usually unknown. The challenge for the shipping company is to reveal the demand and adapt the supply to it. Some sources of market information are reviewed in this chapter and the information which characterizes a market is discussed.

17.2 SOURCES OF MARKET INFORMATION

Market information may be divided into two categories, factual market data and market development prognoses.

Factual or real market data about imports and exports may be obtained from official reports such as the OECD (Organization for Economic Cooperation and Development) statistics, through overviews from *national statistics bureaux* and from import/export lists from individual ports. Information about ocean-borne cargo may also be found in specialized publications such as *Maritime Statistics*, which is a pilot project undertaken by the UN statistical office and financed by the Norwegian government, *Transport Statistics* published by the EEC and *European Transport Statistics* published by the UN Economic Commission for Europe

Information about tonnage and tonnage supply may be found in private publications such as *Fearnleys Review* (annual publication), *Platou Reports* (annual publication) and in *Drewry Reports* (1980). Reports from the Institute of Shipping Economy, Bremen, FGR and the statistical publication of the Netherlands Maritime Institute (1975) are also good sources of information.

Raw data about contracted new ships and existing ships may be obtained from Lloyd's in London and from the weekly magazine *Fairplay*. Both institutions maintain computer data bases and can produce statistical printouts for a fee.

The OECD produces statistics about transport and commerce. Statistics from the various national bureaux of statistics may be obtained through the central bureau of statistics in your own country. Import/export lists for individual ports may generally be obtained from the relevant port authorities who usually store this information on computers and will provide printouts for a fee.

Private companies have also established international data banks. Some examples include the MARINTEK/NHH Shipping Data base at the Norwegian School for Business Administration in Bergen, and the data bases maintained by US companies such as the General Electric Company (Schenectady, NY), I. P. Sharp Associates (Washington DC), Chase Econometrics/Interactive Data Corporation (a subsidiary of the Chase Manhatten Bank, New York) and the Wharton Econometric Forecasting Associates in Philadelphia.

It is time consuming to collect and process raw data. Therefore it is not usually possible for market statistics to be completely up to date. The OECD statistics on trade are about two years old when they are published. Other statistical publications may contain more recent data. However, all statistical publications provide information about the past.

Many reviews and studies based on generally available market statistics are published but because it takes time to prepare these publications they are even more out of date than the statistics themselves. However, reviews can still be valuable because of the insight and knowledge of the people who prepare them. In any case, any user of statistics must keep in mind that nobody can reliably predict the future. Nevertheless, statistics that describe the past development can still be of great use. This is discussed below.

17.3 USING MARKET INFORMATION

17.3.1 Monitoring your own performance

Trade and transport statistics may be used to estimate how large your own share of different markets has been. By comparing the general development with the development of your own service you can get an idea of how your past efforts may have influenced demand. For example, it may be possible to determine whether the introduction of new and modern ships, the reduction of round trip sailing time or other changes have had any influence on your market share. Thus information about past development may indicate which actions may have a positive effect in the future. This information can be used to improve your company's performance.

17.3.2 Forecasts

Statistics can also be used as the basis for making prognoses. For example, if the demand for holiday cruises has been increasing by an average of 10% per year over a period of five years, you can assume that this trend will continue for some years. However, this would be a very crude way of using statistics because the reasons for the past increase in demand were not examined and it was simply assumed that demand would continue because it was there in the past.

If we examine cruise traffic, as an example, a better use of statistics would be to examine such things as what share of the holiday market is taken up by cruises, how the total holiday market has developed, whether vacation time has increased, whether legislation or trade union agreements are likely to influence the amount of vacation time, whether the level of income of cruise passengers and income fluctuations will influence the demand for cruise holidays and so on. These examples illustrate that forecasts need not, and in most cases, should not, be based on direct analysis of the statistics. Instead you should try to reveal the underlying causes for a particular development and try to determine how these may change in the future.

The gross national product (GNP) is often taken as a good indicator of economic activity in general. A correlation can be demonstrated between fluctuations in the GNP of a country, export and import activity and other activities which influence the demand for marine transportation. Other useful economic indicators include the steel production index, the rate of unemployment and population development. Information about the development of the GNP and other market indicators may be obtain through national bureaux of statistics.

Some industries have special indicators. For example, the accumulated temperature indicator is useful for the prediction of the energy demand for heating purposes in central and northern Europe. The accumulated temperature indicator (*DAC*) is the accumulated sum of temperature in degrees after a certain date. It has the form shown below:

$DAC = S\ \Sigma t_i$

where:

t_i = temperature margin at day i; $t_i = T - t_{ri}$

T = the highest temperature that has any influence on the demand for heating

t_{ri} = recorded temperature at day i

$i > I$, I is the date when the recordings start.

The value of T and I may be based on experience. For example, if $T = 10°C$ it is assumed that temperatures above this limit have no influence on the demand for heating. If I = October 15, it is assumed that temperature fluctuations before that date will have no significant influence on demand. As time progresses temperatures continue to be recorded and the development of the DAC can be compared with that of previous years. Differences are interpreted as indicators of changes in the the demand for heating.

Forecasting methods are discussed in Section 17.5.

17.4 THE NATURE OF MARKET DEVELOPMENT

Any transport demand arises out of some need, whether it be for food and clothing or for recovery or entertainment. It is the responsibility of the design team to explore the origins and backgrounds of the demands and provide an estimate of the development for the planning period. To do this it is necessary to reveal and examine the underlying causes or trends.

A variable cannot continue to increase indefinitely and will reach its limit sooner or later. For example, vacation time cannot exceed 365 days in one year and the demand for vacation time will cease to increase long before that limit is reached. There are similar examples of limitations in other areas. For example, the demand for cars will probably not exceed one per person and the consumption of grain and cereals will eventually be limited by human consumption. Therefore, when planning a service, it is necessary to define the basic needs that the service is designed to satisfy and to determine how far the need is from satisfaction.

Demand may arise out of the need for new developments or the need to maintain and replace existing developments. New development will eventually reach a limit. Thereafter

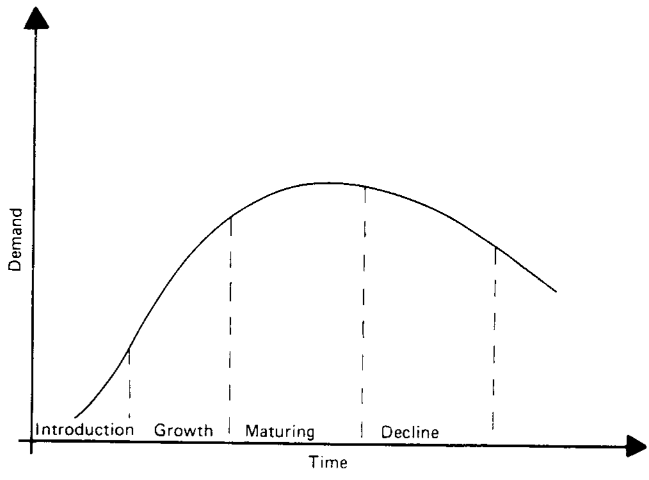


Figure 17.1 A typical development of demand over time

only a replacement and maintenance market will remain. Depending on how well the new development is established, the replacement and maintenance market will continue for some time. However, even replacement and maintenance activities eventually end. For example, when there is no more oil in an offshore field, the demand for maintenance and replacement of equipment on the field vanishes. Thus the majority of demand developments follow the S-shaped curve illustrated in Figure 17.1 when plotted against time.

The problem is to relate the development to the S-shaped curve to any given time. It is sometimes useful to transform statistics into actual examples. For instance, a 10% annual increase means a doubling of demand over the course of seven years. When applied to the holiday cruise market this increase may be expected to occur when holiday cruises constitute only 2% of the total holiday market but it will not be expected to occur when cruises constitute 50% of the market. This also illustrates how the market share also gives an indication of the stage of a development. If, for example, there is a potential demand linked to one million individuals, and the present supply corresponds to only 50 000, an annual increase of 10% would develop as shown in Table 17.1.

Table 17.1

Year	*Market share (%)*	*Annual increase*		*Time until market is satisfied, (years)*
		in number of customers	*in per cent of total market*	
0	5	5 000	0.5	31
5	8	8 000	0.8	26
10	13	13 000	1.3	21
15	21	21 000	2.1	16
20	34	34 000	3.4	11
25	54	54 000	5.4	6
30	87	87 000	8.7	1

Table 17.1 illustrates how close demand may be to disappearing when the market share is of any magnitude. For example, the table shows that when the market share reaches 21% there is only half the time remaining until the market is satisfied compared to when the market share was only 5%. When the share is approximately 50%, there is only a quarter

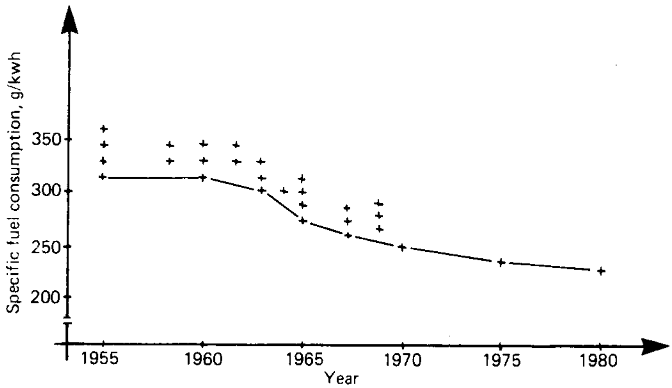


Figure 17.2 Development of specific fuel consumption of steam turbine plant. Published by kind permission of RINA, London

of the time remaining until the market is satisfied. These conclusions are based on the assumption that the 10% annual growth will continue until the demand is satisfied. In fact, there will be a diminishing growth of demand long before a market is 100% satisfied. In any case, it is important to find out the degree of demand satisfaction that exists in a growing market. In general, the growth potential will not be large if the demand satisfaction is more than 50%.

An S-shaped curve may also be used to illustrate the progress of technical developments and improvements. For example, Figure 17.2 illustrates how specific fuel oil consumption for steam turbine plants has developed from the 1950s to the 1980s. The specific consumption remained relatively stable up to about 1960, then there was a steady trend towards reduced consumption for about 10 years followed by a further stable period. Technical improvements often follow a discovery or invention which is gradually developed to a higher degree. However, eventually its use can no longer be improved upon and the development ends.

The complete cycle of development of market growth and technical developments from initial growth through stagnation to termination may last only a few years. This is sometimes not observed when a market is considered in general because one part of the market may replace another in such a way that the development of these individual parts combine in such a way that the demand appears to be steady. The apparently steady market may collapse abruptly if new sub-markets are not created. This is illustrated in Figure 17.3.

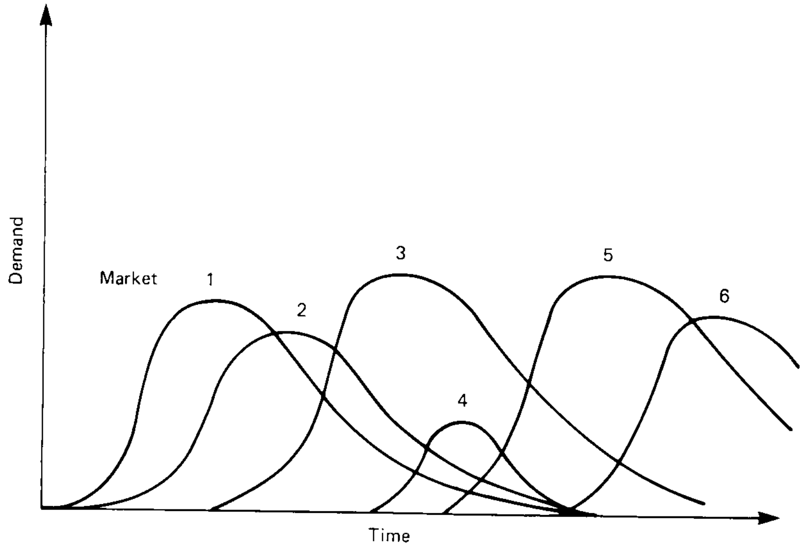


Figure 17.3 Example of how demands of submarkets may add to produce a general, steady demand

17.5 SPECIAL FORECASTING METHODS

One method of forecasting is based on *monitoring* the development of certain indicators. The accumulated temperature indicator discussed in Section 17.3.2 is a good example of this type of indicator. Other examples of this type of indicator include the weather, which can serve as an indicator of the outlook for crop harvests in different areas; the sales of automobiles, which can serve as an indicator of steel consumption and of variations in distribution of consumer income; political polls, which give indications of political developments and government activity, and the trends in exchange rates, which give an indication of future import and export activity.

Before selecting an indicator, you must study the conditions most relevant to the market in question and determine which indicator is most representative. The chosen indicator should not be too difficult to investigate. Because the indicator will be evaluated at regular intervals, the data necessary to produce it must be available at least as frequently as there is need for the indicator.

Another method of forecasting is to work out several *scenarios* and evaluate their consequences. Try to imagine two or three different developments and, on the basis of past experience, work out preliminary plans for meeting these developments. An example of this is shown in Figure 13.1. This figure illustrates how the deadweight capacity of a ship can be adjusted to satisfy a set of different scenarios. When studying the impact of different scenarios it is advisable to avoid details and keep planning and design on a high level.

When used on a general level the scenario technique may provide quick results. For example, in order to investigate possible fluctuation in the demand for tankers you could assume that the Suez Canal will be closed again. A simple calculation of the corresponding increase in demand for tankers will reveal that the unused capacity of laid up and slow moving vessels is more than sufficient to satisfy the increased demand. Because the closing of the Suez Canal is the action that would have the greatest impact on the demand for tankers, this simple scenario excercise in fact reveals that there will be enough existing tanker capacity to meet the demand in almost any case. This means that any tankers a designer designs must be more efficient and economical than laid up ships whose capital charges are based on their scrap value.

Input/output analysis may be used to calculate the *average* or *terminal* stages of dynamic occurrences based on past development. The essence of this method is to use data from past developments to establish coefficients of likelihood for the change of a system from one stage to another. As a simple example, take the employment of combination ships. If there are only two categories of employment for these ships, the oil trade and the dry bulk market, the probabilities that a ship will stay in the trade in which it is currently employed, be switched to the other trade or be laid up can be calculated. These probabilities are called transition probabilities.

As an example, assume that the probability of switching from a dry bulk voyage to an oil voyage is 0.1; the probability of being laid up after the dry bulk voyage is 0.4; the probability of switching from an oil voyage to a dry bulk voyage is 0.2 and the probability of being laid up after an oil voyage is 0.3. Because the sum of the probability coefficients is 1, the probability of following a dry bulk voyage with another dry bulk voyage is 0.5, and the probability of following an oil voyage with another oil voyage is also 0.5. To make it easier to obtain an overview, the probability figures may be presented in a transition matrix as shown below.

From		*To*	
	Dry Bulk	Laid up	Oil
Dry Bulk	0.5	0.4	0.1
Laid up	0.25	0.5	0.25
Oil	0.2	0.3	0.5

Assuming that the same transition matrix is valid whenever a combination ship terminates a voyage and provided that the matrix satisfies certain conditions, the average distribution of voyages will reach a steady state which is independent of the actual distribution when the matrix comes into effect. For the matrix shown above the steady state will be expressed by the following coefficients:

Dry bulk voyages, 35/111
Laid up 'voyages', 46/111
Oil voyages, 30/111

The general equation for the steady state coefficients are:

$$
\begin{aligned}
\pi_0 &= \pi_0 p_{00} + \pi_1 p_{10} + \pi_2 p_{20} \\
\pi_1 &= \pi_0 p_{01} + \pi_1 p_{11} + \pi_2 p_{21} \\
\pi_2 &= \pi_0 \pi_{02} + \pi_1 \pi_{12} + \pi_2 \pi_{22} \\
1 &= \pi_0 + \pi_1 + \pi_2
\end{aligned}
$$

where:

π_i = steady state coefficients; $i = 1,n$
p_{ij} = transition probabilities, $i = 1, n$; $j = 1,m$

Correspondingly, the general form of the transition matrix for three possible states is as shown below.

From		*To*	
	A	B	C
A	p_{00}	p_{01}	p_{02}
B	p_{10}	p_{11}	p_{12}
C	p_{20}	p_{21}	p_{22}

The input/output method should be used with caution. In marine industries conditions change continuously. Thus the coefficients of the transition matrix are also changing continuously. In unstable periods there may not be so many transitions that the steady state will be reached before the transition matrix is altered. On the other hand, steady state coefficients give an indication of the conditions that current conditions may lead to. Therefore they form some basis for deciding what action to take ahead of developments.

In general, the shipping industry has not been able to make good use of forecasts. Forecasting methods have been well known for many years but in spite of this the industry has experienced a deeper recession in the past few years than it has ever known. This recession is caused, to a large extent, by overactivity in ship building and the construction of new ship yards. This expansion continued long after any market study would have shown that the market would collapse.

17.6 MARKET CHARACTERISTICS

17.6.1 Introduction

It is important to obtain a good insight into the needs that a project is planned to satisfy whether the task is to develop a service for a particular customer or to look into the possibility of generating a new market. Only by taking careful account of market characteristics can a competitive lead be gained.

In order to gain insight into the demands of a market it is necessary to undertake a systematic review of its characteristics. The example below illustrates an internal company memo which discusses the possibility of a shipping company finding work for certain types of ships by becoming a member of a conference.

17.6.1.1 Example: evaluation of conference membership

Access to West Southbound Conference — Reemployment for our Z-Ships

Recommendation:

1. To file a formal application for conference membership (which will probably not be granted).
2. To enter the market with our five Z ships as soon as they are returned from the charterer (at end of year), offering freight rates 30% below the present if we have to go in as an outsider.
3. Start to build up our agency services *now*, we have 6 months to go.

Conclusion

The Z-ships will need 5–7% of the cargo volume of the conference lines at 70% of the present average freight rate to cover operating costs.

To reach our target internal rate of return of 15%, we would need 12–15% of the market at the same freight rate. This is based on a value of the ships equal to 50% of the price as new, which is high on the present market.

If we are able to attract only high-paying cargo we could do with smaller market shares, but it is likely that we will get mainly low paying cargo in the opening phases. A share of 15% of the market and awkward cargo would mean a 90% utilization of ship's capacity, which is high. The conference has two weak members which may give up after 3–6 months of hard, rate cutting competition. The Z-ships will be returned from charter at year's end. We have no further employment for them. Their loans have been paid down and we will have no cash outlays on the ships provided we get operation expenses with overhead covered.

We need to establish a net of agents in the southern region with good relations with the governments.

Summary of Investigations

1. Access to Conference

Informal contacts have revealed that conference partners are unwilling to take up new members. National Governments in southern regions want more shipping lines to join the service, but are *at present* not strong enough to influence conference decisions.

2. Present Service

Present conference service offers two departures per week from any major port, one departure per week for any outport. The quality of the service is as usual in the liner trade including door to door transport based on carriers containers. The Bill of Ladings (receipt to consignor for cargo received for shipment) states where and when the cargo is taken over by the carrier. Agents make only small efforts to attract cargo as the conference has a well established monopoly. The conference members offer a total transport capacity that exceeds demand with an ample margin.

The service is similar to our own WSI line, and operationally, it would cause us no problem to take up competition.

3. Limitations on Competition

Conference members have shared the market between them. There are limitations on how many calls per year each member can have for all major ports and for some ports also on how much cargo that may be accepted per year by each member. In addition, each member has to make a minimum number of calls per year in some of the outports in order that the weekly service shall be maintained.

4. Competitition from Non-conference Members

There is no regular 'outsider' service in the trade, only more random calls by a company that underbids conference rates considerably in order to fill up ships that take the major part of the cargo elsewhere.

5. Strength of Conference Members

There is no indication of how long the conference would tolerate a regular outsider. Five of the present seven companies are strong and could sail with a loss for perhaps a year or two. The other two have no resources. In spite of the two weak members, the conference may lower rates considerably in order to press out an outsider.

The two weak members of the conference have in total a market share of about 15%.

6. Required Own Share of Market

It is felt that to get into the conference it would be necessary to undercut present rates by 20–30% and to build up a service that would provide at least one call every second week in all major ports. Such a service could be maintained by our Z-ships which would need 5–7% of the total market revenue to cover operating costs, and 12–15% to also reach our target internal rate of return of 15%. The latter is based on ships value at 50% of price as new, which is high in the present market.

7. Market Duration and Development

The southern region consists of small, developing countries that have steadily increased their trade during the last 15 years. There is no indication that this development will not continue, the area is rich in minerals, agricultural products and partly also in oil.

Some countries are more developed than the others, with considerably higher standards of living. One may expect that the people of the less developed countries, will demand to come on the same level as in their neighbouring countries and that this will lead to increased import of fabricated goods. The area has been politically stable since the nations became independent. There is no sign of coming political unrest.

8. Ships' Capacity Utilization

An average cargo composition would mean about 75% capacity utilization for the ships to carry a market revenue share of 15%. In an opening phase we would probably get awkward cargo requiring 90% capacity utilization to get 15% of the market revenue.

9. Customers and Rebate

Governments in the southern region may give preference to an outsider, but the governments do not control the high paying cargo. A change of buying terms from cif (cost, insurance and freight covered by the vendor, i.e. the vendor selects ships for his cargo) to fob (free on board deliverance by the vendor. The buyer decides to which ships or service the cargo should be delivered) may change this.

Customers in the northern region are dependent on regular shipments in order to sell products at small intervals and not put them on stock. Compared with two sailings per week a shipper changing to a service with sailings only every second week would get his storage costs increased to 16 times of what he previously had. Assuming twice per week sailings to incur storage costs equal to 1% of the freight rate (which is high), a change to a bi-weekly service would mean a loss corresponding to an increase of the freight rate by 16%. To counteract this an outsider would need an introductory discount of about the double, say 30%.

10. Employment for the Z-Ship

It may be difficult to find re-engagement for our Z-ships when they go out of charter at years end, at least for the next 12–18 months. There are no remaining loans on the Z-ships and we could operate them with no direct outlays, provided that we get operating expenses included in our standard overhead, covered.

11. Buying up Competitors

It is likely that the two weak members of the conference will have to give up after 3–6 months of hard competition. Their ships are old and not worth much. Their share of the service is, however, as mentioned 15%, sufficient to make it an attractive alternative for the Z-ships. Provided that the freight rates are restored after the fight, we could pay $10 million for the bigger and $5 million for the smaller of the two companies.

12. Agencies

Our set up of agents in the southern region is based on occasional calls by our bulk ships and not sufficient for a liner service. It will take up to six months to get a sufficient net of agents to cover the area. Expenses related to agents will be commissions and some minor fees. Both have been included in our calculations. It is important to find agents with good relations with the governments.

13. Possibilities for an Outsider

All taken into consideration, an outsider should have reasonable chances of getting into the market.

The present service is technically and organizationally good, but no efforts are made to open new markets for the trade. The conference act as a monopoly with little initiative towards customers.

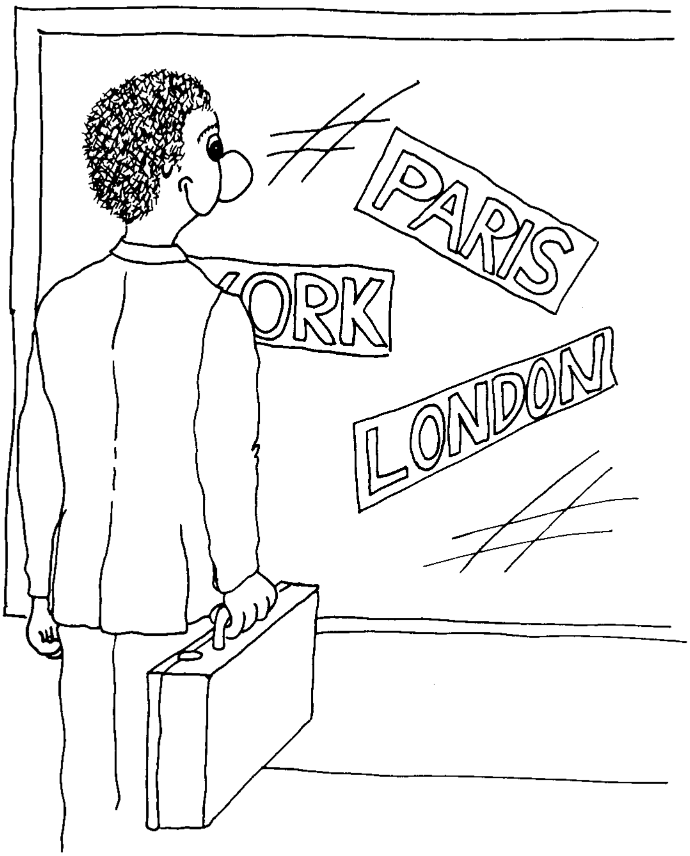
The conference is in opposition to governments in the southern region.

An active marketing and product development joint with the producers, which have been extremely successful for our WSI service, would undoubtedly pay off also in this trade.

Marketing PQ/AS 6.5–81

18

SELECTING A MARKET



18.1 INTRODUCTION

The fundamental requirement when choosing a market is to find projects that will generate sufficient profits to secure the continued existence of the company, and preferably allow the company to expand. In order to satisfy these requirements it is necessary to find areas where the risk of getting the business spoiled by competition is as small as possible. In order to compete effectively it is necessary to use the company's advantages to the greatest possible effect. The requirements and demands of the market should be matched with the company resources in a way that will provide better results than those of competitors.

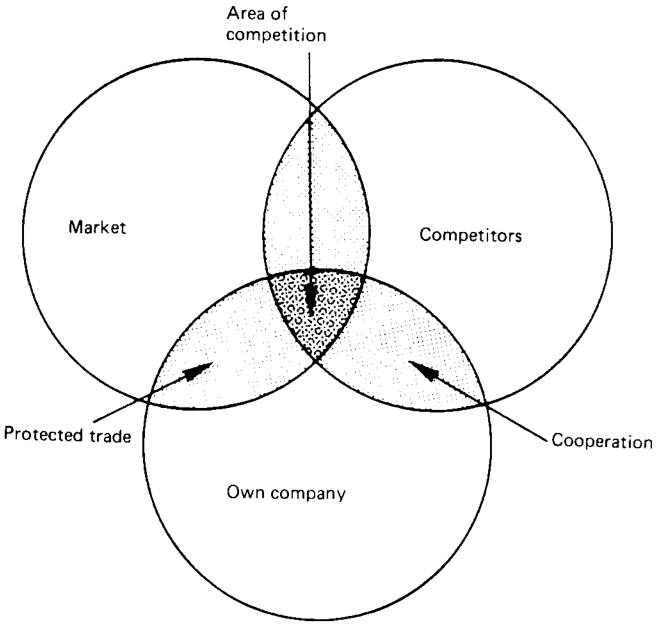


Figure 18.1 An illustration of relations to market and competitors

The aim should be to find a market where your resources can give the best results, rather than seeking a market which matches your resources exactly. It is not sufficient to know only your own resources and what you can achieve. You must also have an idea of what your competitors can do and adjust your strategy in light of this.

A common mistake is to put the main emphasis on good utilization of your own resources instead of emphasizing the possibility of obtaining a good market position. This is what happened when some owners continued to buy and operate large sailing ships long after the steam engine had been introduced. The owners knew how to operate and run sailing ships and there was a market for shipping. However, they forgot to evaluate sailing in terms of the customer's evaluation of the service. When the steam engine came into use, the sail was out.

There are many other examples. What they illustrate is that wishful thinking is a great hindrance in the development of good projects. It is desirable but *not sufficient* and *not always possible* to obtain a good match between your own resources and the demands of the market.

18.2 MARKET REVIEWS

The number of possible ways to match the demands and requirements of the markets on one hand, and the resources of the company, on the other, is very great. In order to find a good match it is necessary to process great quantities of information. A lot of data about markets must be reviewed and compared with information about your own resources. Some simplified examples of market reviews are shown in Table 18.1. Table 18.2 illustrates a comparison between the resources of a company and the requirements and opportunities in some markets.

Table 18.1 Markets; Quarterly Review per October 1, 1982

Market name *Characteristics*	* COAL FROM NORTHERN MINES	OCEAN MINING *SUPPLY* SERVICE	NORTH SEA TRAMP TRADE	NEW PROPOSALS (write down and hand over to the secretary of the marketing group)
Development	200,000 Kt/year increasing at 10–15% per	Start 1988–90 in the Pacific. Bases in USA	Growing in connection with the oil activities	
Duration	More than 20 years	More than 20 years	More than 20 years	
Saturated/not saturated	Tonnage always available	Special ships not existing. Supply vessels from the North Sea may be converted	The present service is maintained partly by very old ships	
Quality of present services	Conventional transportation. Polluting		The majority of the ships are badly adjusted to modern methods of transportation	
Resources of competitors	Have capital, lack cargo handling knowledge	Have capital. Know-how as one's own. Any one may join a mining company	The majority of owners have only one or two ships. Lack capital for fleet renewal	
Level of income	As the freight market	Good in the beginning	Low in the general trade, high for special risks	
Customers' degree of satisfaction	Satisfied, but authorities threat to introduce anti-dust pollution regulations		Have adjusted themselves to present situation. Room for improvements	

Market name / *Characteristics*	* COAL FROM NORTHERN MINES	OCEAN MINING *SUPPLY* SERVICE	NORTH SEA TRAMP TRADE	NEW PROPOSALS (write down and hand over to the secretary of the marketing group)
Demand for Know-how	Development of non-polluting loading/unl. eqpm. Nav. in ice	As for the supply service in the North Sea	Transportation of big objects. Logistics	
Required magnitude of investment	1–2 modern ships, 6–12 M$ Shore storage to be adjusted to non polluting loading/discharging methods, 2M$	A reliable supply service for a longer period	10 to 20 M$ for special ships, 20 to 40 M$ to build up transportation service for a chain of grocery stores	
Conditions of competition	Present shipping companies have interests in mines	The customers' demand is for quality of service and reliability and not so much for low costs. Long term contracts possible for owners with a good international reputation	Some owners have modern ships, but the majority of market demand is covered by old vessels. A minority of owners engage themselves also as consultants in transportation and have obtained good, long-term contracts	

* Included in the last survey

Table 18.2 Comparison Sheet: Own Resources and Possible Markets

Evaluation of: Engagement in ocean mining supply and transport service Date: 15/3–1982

Sign: SE + STh

Status of own resources		*Comparison with engagement under review*
Investment capacity:	Up to 40 M$ per year 1984–86	Sufficient to build up a fleet of supply vessels
Fleet:	Six supply vessels engaged in the North Sea Two barges Two laid-up tankers	The services in the North Sea and for ocean mining are of the same nature. The existing supply vessels could be used in the Pacific in a start-up phase. Tankers could be converted for carrying of manganese nodules.

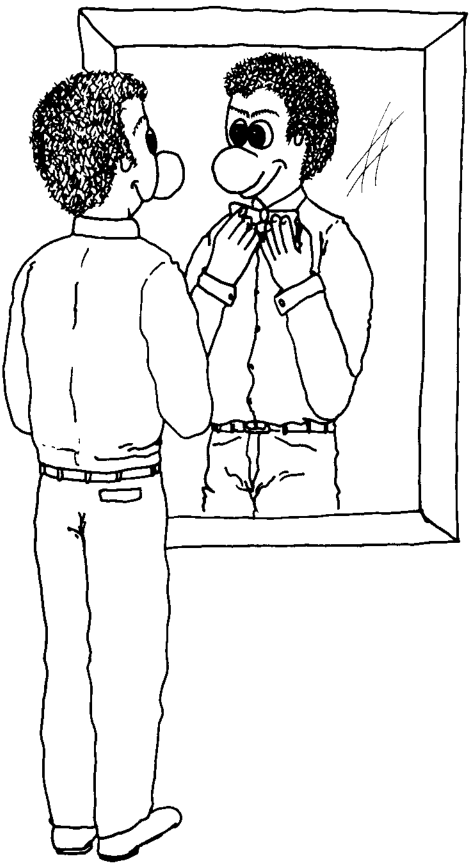
Status of own resources		*Comparison with engagement under review*
Organization:	Well developed department for supply service. Maintains a general cargo line between U.S. West Coast and the Far East with chartered ships. Skeleton organization for tanker trade	The department for supply service may be expanded to cover ocean mining. Cargo lines and tanker department may be discontinued without great damage.
Personnel:	Stable crew and officers and a good staff in the department for supply vessels. The line department has overcapacity. The network of port captains and agents in the United States is intact. Consultants are used for design.	The men onboard prefer to work in the North Sea because it is close to home. It may be difficult to obtain stable crews in the Pacific. Crews could be hired in East Asia. Port captains and agents in the United States may be of use. The staff lacks special knowledge about the services required by ocean mining companies. Will be dependent on external (foreign) know-how during the introductory phase.
Relations to customers:	The cooperation in the North Sea is based on mutual confidence. Many complaints because of damage to the cargo carried by the line. The cooperation with financial institutions, yards, consultants and government authorities is good.	Present customers in the North Sea may be used as references when and if approaching ocean mining companies. Mining companies have no experience in maintaining and operating ships.
Economic positions:	Good return on the supply service. The line renders a small surplus. Debt on tankers has been paid and expenses related to tankers are limited to lay-up costs. Debt on supply vessels is in total 35M$. The cash-flow is satisfactory for the present engagements. For new investment borrowed money should by policy decision not exceed 70%. New engagements should be self-supporting cash-wise.	The ones who establish themselves early in the market will probably get a reasonable return on investments. The usual building credits for new ships will be offered by any yard. It may be difficult to obtain credit for converting the tankers. The demand for investment in ocean mining itself is very high. Mining companies will probably wish to avoid to invest in a supply service.
Risk:	By policy decision risk should be kept small through long time contracts.	Ocean mining is different from oil exploitation. Minerals will be more subject to market fluctuation than oil, and more dependent on the level of the general industrial activity. Political changes may make raw materials on ocean beds very attractive. Supply vessels converted for ocean mining could be reconverted to North Sea service without great outlays. The laid up tankers have a total market value of 6 M$. If converted to carry ocean modules, they can not be employed in other transport. Conversion will cost 2 M$ each.

Status of own resources	*Comparison with engagement under review*
Competition:	Nobody has up to now engaged themselves in supply service for ocean mining. Other owners who work in the supply service in the North Sea may be interested. It will be necessary to build up technical know-how in order to get a foot-hold in the market.

Conclusion: We should try to establish contact with companies who plan to engage themselves in ocean mining in order to investigate the possible terms of establishing an arrangement of cooperation. Plans to convert the supply vessels and the tankers should be worked out in sufficient detail to show prospective customers that we are prepared to take up a supply and transport service. A cooperation with technical consultants should be established for preparing plans for conversion.

19

DESIGN FOR A MARKET



19.1 INTRODUCTION

Once a market has been selected, the next step is to design the physical system or organization which will be successful in the market. To do this you need to have a concrete set of information as a basis for the work. The market selection process should generate numerical specification of demands and constraints. Some of the market information may be too uncertain to produce exact figures but upper and lower limits should be defined numerically and these figures used as a basis for a sensitivity analysis.

The major types of information needed to design sea transport systems are discussed below. The discussion does not cover all types of information required but it is intended to serve an example to stimulate thinking when you are attempting to gather information for an actual design project. Generally, market information for a design should include specifications for:

- Required transport capacity.
- Transport distance.
- Frequency of call.
- Type of commodity.
- Cargo treatment requirements.
- Limitations set by physical, commercial and political constraints.
- The capacity of, and constraints imposed by, existing plant which will eventually be included in the new system.
- Costs, delivery dates and/or earliest start-up time for the elements of the new system.

19.2 REQUIRED TRANSPORT CAPACITY

The mass and cubic capacity, and eventually the number of units, of the cargo should be determined as inflow or volume per unit of time.

The cargo inflow may be subject to seasonal fluctuations. This may be compensated for by maintaining a capacity which corresponds to the peak demand and making only partial use of it during periods of low demand, or by maintaining a lower capacity and taking additional ships on charter when demand is higher than capacity. In addition, your own surplus capacity may be offered to other companies during periods of low cargo inflow. The optimum strategy can be determined as shown in the following example.

Example: Transport capacity

An analysis of the best strategy for coping with varying transport demands is outlined below.

Demand: 30 000 tonnes transport capacity in the months of December, January and February; 50 000 tonnes of capacity in June, July and August. There is a linear increase in capacity demand from February to June and a linear decrease in demand from August to December.

Capacity and costs: Own fleet X tons per month at f \$/ton for 12 months. Chartered fleet $(50\,000 - X)$ tons per month at c \$/ton for y months.

The number of months, y, for which additional capacity has to be hired, may be expressed in terms of own fleet's capacity, X, by the following relations:

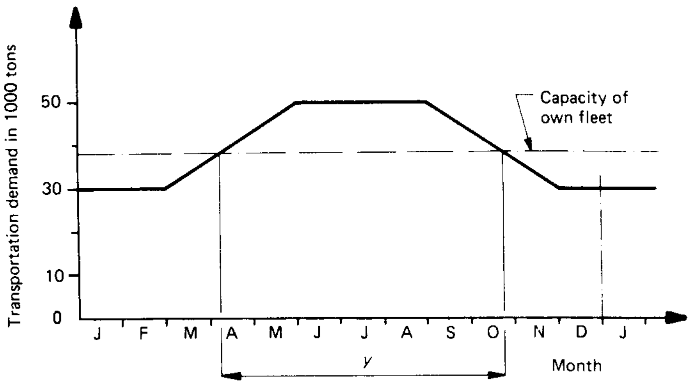


Figure 19.1 Example of seasonal fluctuations of cargo inflow

$$y = 3 + 6 \quad \frac{50\,000–X}{50\,000 - 30\,000} \qquad \text{for } 30\,000 \leq X < 50\,000$$

$$y = 0 \qquad \text{for } X = 50\,000$$

The case is of interest only when $30\,000 < X < 50\,000$

$$y = 3 + 6 \ \frac{50\,000–X}{20\,000}$$

The total cost of transportation per year is then

$$TCO = 12 \text{ x} f \text{ x } X + \left(3 + 6 \ \frac{50\,000–X}{20\,000}\right) (50\,000–X) \text{ x } c$$

The minimum cost is found by differentiating TCO with respect to X

$$\frac{\delta TCO}{\delta X} = 12f + \left(\frac{-6}{20\,000} (50\,000–X) + \left(3{+}6 \ \frac{50\,000–X}{20\,000}\right)(-1)\right) \text{x } c$$

$$0 = 12f - \left(15 - \frac{6X}{20\,000} + 18 - \frac{6X}{20\,000}\right) \text{x } c$$

$$0 = 12f - 33c + \frac{12X}{20\,000} \ c$$

$$12XC = 20\,000\ (33c–12f)$$

$$X = 20\,000 \ \ \frac{11c - 4f}{4c}$$

For all demand above 30 000 tons per month to be taken up by hired ships (X=30 000), we have

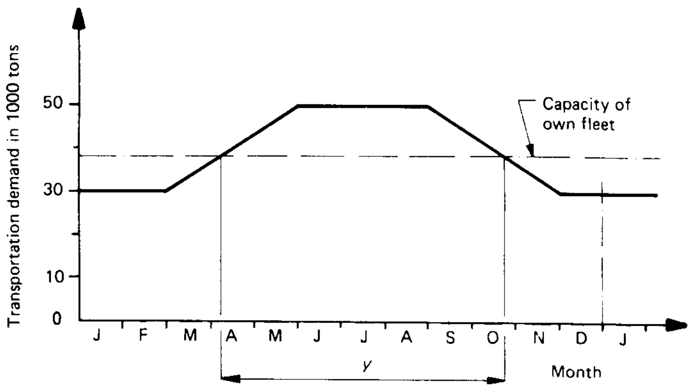


Figure 19.1 Example of seasonal fluctuations of cargo inflow

$$y = 3 + 6 \quad \frac{50\,000 - X}{50\,000 - 30\,000} \qquad \text{for } 30\,000 \leq X < 50\,000$$

$$y = 0 \qquad \text{for } X = 50\,000$$

The case is of interest only when $30\,000 < X < 50\,000$

$$y = 3 + 6 \ \frac{50\,000 - X}{20\,000}$$

The total cost of transportation per year is then

$$TCO = 12 \times f \times X + \left(3 + 6\ \frac{50\,000 - X}{20\,000}\right)(50\,000 - X) \times c$$

The minimum cost is found by differentiating TCO with respect to X

$$\frac{\delta TCO}{\delta X} = 12f + \left(\frac{-6}{20\,000}(50\,000 - X) + \left(3 + 6\ \frac{50\,000 - X}{20\,000}\right)(-1)\right) \times c$$

$$0 = 12f - \left(15 - \frac{6X}{20\,000} + 18 - \frac{6X}{20\,000}\right) \times c$$

$$0 = 12f - 33c + \frac{12X}{20\,000}\ c$$

$$12XC = 20\,000\,(33c - 12f)$$

$$X = 20\,000 \ \frac{11c - 4f}{4c}$$

For all demand above 30 000 tons per month to be taken up by hired ships (X=30 000), we have

$$30\,000 = 20\,000\ \frac{11c - 4f}{4c}$$

$c = 4/5f$

For all demand to be taken up by own vessels,

$$50\,000 = 20\,000\ \frac{11c - 4f}{4c}$$

$c = 4f$

In most cases seasonal variations can be approximated by linear relationships. In cases where the fluctuation of cargo inflow is difficult to integrate, the optimum solution can be found by calculating costs (or income) for a stepwise variation of the capacity. If we set $c = 1.5$ in the example above this would mean:

$X = 30\,000$, $TCO = 630 \times 10^3 f$
$X = 35\,000$, $TCO = 588 \times 75 \times 10^3 f$
$X = 40\,000$, $TCO = 570 \times 10^3 f$
$X = 45\,000$, $TCO = 573 \times 75 \times 10^3 f$
$X = 50\,000$, $TCO = 600 \times 10^3 f$

The optimum capacity of your own fleet would thus be between 40 000 and 50 000 tonnes per month.

Cargo inflow and capacity offered are often interrelated. It is necessary to have excess capacity in order to attract new customers. A capacity increase obtained through increased sailing frequency will, in many cases, have the most positive effect, especially in the liner trade where you are competing in a more or less open market with many different shippers. If you expect that cargo inflow will increase with the capacity offered, it is necessary to quantify the dependency so that it can form part of the basis of the design. This quantification is usually carried out by the company's marketing and traffic departments. Generally, it is more economical to design for a higher capacity than the actual demand if this will contribute to a higher cargo inflow than would otherwise be obtained.

Sometimes the cargo inflow is so large that it sets no limit for the size of the ships. This has sometimes occurred in the case of oil tankers. In these cases the limitations set by ports, channels or economy may determine the size of the ships.

19.3 REQUIRED FREQUENCY OF CALL

In some trades a certain frequency of call may be customary. This may be due to the periodic fluctuation in cargo inflow, commercial practices or other reasons. In some ports documents are not processed over the weekend and there is little cargo available for loading on Mondays or Tuesdays. In other ports auctions are arranged on certain dates and it may be necessary to deliver cargo just before an auction. Different operators place different levels of importance on these conditions. Some try to follow strict schedules which are closely adapted to the requirements in different ports. Others allow themselves to operate in a more flexible way. It costs less to operate a fleet that does not have to follow a schedule strictly, especially when fuel costs are high. When operating a multi-port service it is almost impossible to call at all ports on their best days.

It is important to know to which extent requirements regarding frequency of call must be satisfied because this will determine the necessary speed and number of ships. It is also important to understand the consequences if the requirements are only partially met. The inter-relationship between frequency of call, ship's speed and number is discussed in Section 8.2.7.

19.4 COMMODITIES AND TREATMENT OF CARGO

A cargo should be sufficiently well described to make its influence on the transport system clear. The type of information needed includes, stowage coefficients, temperature requirements, ventilation requirements, e.g. for fruit, cars and livestock cargoes, the consistency of the cargo (solid or loose), the slide angle for dry bulk cargoes and the compatibility with other cargoes when it is to make up a mixed load. Also, handleability is an important property of cargo.

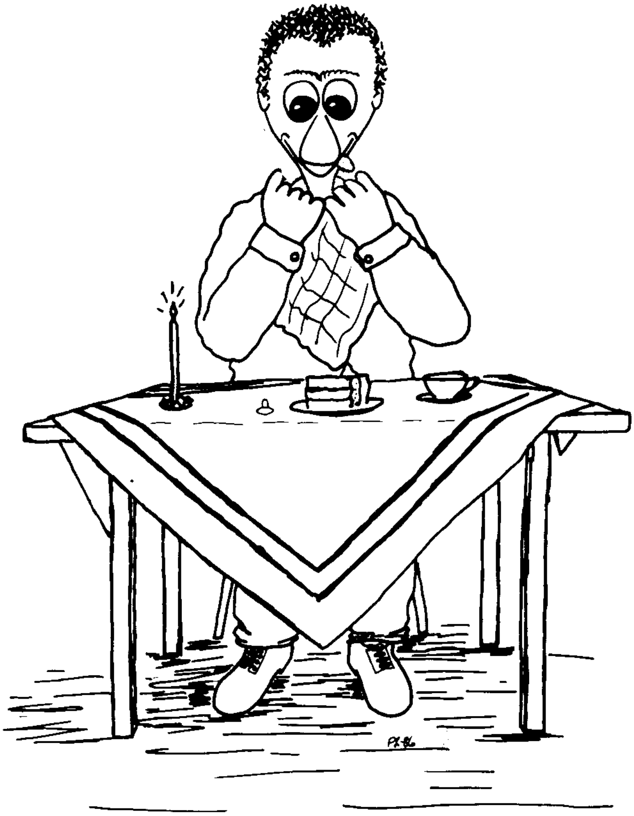
Generally the transport system must be adjusted to accommodate the physical properties of the cargo. However, you should first investigate how existing constraints may limit the design and what could be gained by avoiding them. Successful designs are produced by those who find ways to eliminate constraints or to satisfy them in new ways. Some examples of how cargo has been adjusted to new handling or transportation methods are listed below.

- Shipping wood in large preslung units rather than as loose timber and planks.
- Reducing the number of types of bags for artificial fertilizer from about 20 to 2 in order to simplify the mechanical handling. This sounds simple but it requires the fertilizer to be sold in different quantities than before. This influences the marketing of the product.
- Changing to containers and container ships for general cargo.
- Transporting sugar and other 'small' bulk commodities in bulk instead of in bags.
- Loading and discharging iron ore and other dry bulk commodities as slurry.
- Transporting oil from offshore wells by loading buoys and tankers instead of pipelines.

19.5 USE OF EXISTING PLANT

A transport system may have to be adjusted to accommodate such things as existing production plants, transfer stations and buffer storages. It is necessary to find out whether existing facilities set limits on the size of shipments, on the weight, volume or shape of the cargo and its packing or on the equipment which will interface with shore installations. The size of the shipments may be limited by such things as the available storage or production capacity, by deterioration in the quality of the cargo and by limited onward land transport capacity. The weight, volume and shape of individual pieces of cargo may be limited by production plants, cargo handling facilities anywhere in the transport chain, or by customers' preference. Shipboard equipment may have to be adapted to accommodate existing pipe connections, pumping stations, loading/unloading bridges, warehouses, barges and railcars. In any case, the requirements imposed by existing plant must be known in detail. If a change in the existing plant would mean an improvement in the total economy of the transport system, you must know how much the change will cost.

IMPLEMENTATION



20.1 INTRODUCTION

It should be kept in mind that a design may be discontinued at any stage if a change in conditions makes the intended enterprise unprofitable or unnecessary. However, any design which is carried through to completion should include a plan for its implementation. This plan should set deadlines for the steps which must be taken in connection with the implementation of the design. The plan should preferably cover the lifetime of the system. At the least it should cover all actions leading to full operation of the system.

Implementation is related to:

- The creation of the physical system. The physical system includes anything from an organization to actual objects, in most cases it includes both.
- The introduction of the physical system to the customers or the market. The customers are the prime users of the system.
- The introduction of the system to the personnel who will manage and operate it.

This chapter describes the sequence of actions related to the creation of a physical system and the introduction of the system. A large system, such as an origin to destination transport system or a supply system for offshore activities, is assumed. Many variables are involved, some of which may be irrelevant when dealing with smaller systems. However, this does not release the designer from examining all of the variables and making a professional selection of the variables relevant to his own project.

20.1.1 Plan for implementation

Each step in an implementation plan must have a deadline. A good way to establish deadlines is to take the date when the system is scheduled to be operable and work backwards in time. You should allocate a reasonable amount of time for the activities which lead to the start-up.

20.1.1.1 Example: Establishing a new ferry service

A suggested order of action is given below.

1. *Conclude preliminary talks* with the authorities involved by signing *letters of intent* related to the planned service. If necessary, establish permanent cooperation teams.
2. Begin *confidential surveys* of land or ports if required for the intended system or its spin-off activities. If relevant, begin preliminary negotiations with landowners.
3. Complete agreements on lease, purchase and development of land or port facilities.
4. Distribute *outline specifications* of items to be acquired or constructed to prospective contractors and brokers. Ask for bids to be tendered before a given deadline.
5. If publicity is required, *announce* the planned service. Complete specification and other documentation for the construction of berths ramps and parking areas. Distribute these to prospective contractors.
6. *Evaluate bids* for services, deliveries and construction.
7. Select a limited number of contractors for further negotiations.
8. *Complete* specifications and drawings of all major items. Begin final negotiations with contractors.
9. Sign a contract of delivery for all major items. Establish deadlines for all stages of the project.
10. Assign personnel to inspect and follow up the construction and deliveries. Allocate key personnel to operate the system. Make agreements concerning the starting dates and pay of personnel.

11. *Complete* the manning arrangements. Hire additional crew or allocate your own personnel for the service. Settle contracts and payments.
12. Begin *marketing* the service. If publicity is required invite key visitors to the building site and arrange sightseeing tours where appropriate. Prepare lists of officials and guests to be invited to the opening ceremony and possibly on introductory trips.
13. Complete the construction of ports and port facilities. Send out invitations to the opening ceremony.
14. Carry out a quality audit of port installations and facilities.
15. Carry out *trial trips* with the vessels to test machinery power and speed, manoeuvrablity, loading/unloading ramps, accommodation for passengers, officers and crew and life saving equipment and installations. (See Chapter 16).
16. Allocate cargo or supplies for use in commissioning of vessels and shipborne equipment.
17. Complete final trials and adjustments of vessls, ports, port equipment and facilities, mooring systems, radio communication, navigation equipment, storage space for cargo and supplies and any other items specified in the contract.
18. Commission vessels, ports and port installations.
19. Take over vessels and ports.
20. Bring the owner's deliveries and equipment on board.
21. Open the service.
22. Maintain extra personnel on board the vessels and in ports to monitor the performance of the service.
23. Make up a list of items that are unsatisfactory and which should be settled under the guarantee. This should be properly organized and continued throughout the guarantee period until the final settlement is completed.
24. Continue to follow up the service and instigate corrective action if necessary.
25. Evaluate the service and, if necessary alter the capacity or standard of service or otherwise revise the original plan.
26. Make provision for the replacement of vessels or other items. If necessary, make preparations to discontinue the service.
27. Make provisions to dispose of worn out components and for personnel changes.

These steps are summarized in the Gantt diagram shown in Figure 20.1. For an explanation of Gantt diagrams see Leech (1976).

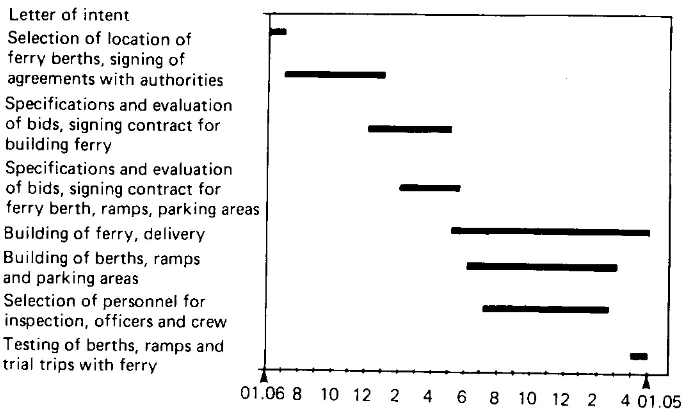


Figure 20.1 A Gantt representation of steps needed in the first phases of implementing a ferry service

20.2 INTRODUCING THE SYSTEM TO CUSTOMERS

The implementation plan should also cover the proposed plan for market development. In this sense, the implementation plan is also an outline of the strategy for market utilization. If it is not possible to make reasonably accurate estimates of future developments, implementation plans may be prepared based on both optimistic and pessimistic alternatives.

When preparing the marketing plans it may be necessary to find the answers to questions of a more fundamental nature than those concerned with the project itself. For example, it may be necessary to know whether you will sail under a national or a foreign flag, whether you will be competing with national companies or whether you will try to attract the attention of the general public. For an actual project it should be possible to find the answers to these types of questions by researching the company's policy and long-term strategy. Any elements of your plan that may contradict these policies will have to be put before the company's board.

The most important elements which should be addressed when preparing a marketing plan are mentioned below.

20.2.1 Selling transport capacity

Important issues include which type of agreement should be made with customers, other companies and, if advantageous, with competitors. Who should be the coordinating agent for a transport system and how should transport capacity be offered. Is it best to announce fixed departures for pre-determined destinations, to offer transport contracts, to make ships available for the charter market, or to offer ships on a bare boat basis? Is it possible to make special offers that would be particularly attractive to potential customers?

20.2.2 Acquisition of capacity

A major question is how capacity should be acquired. For sea transport should you own the ship or hire it? Should ships be bought second hand or be built? Would it be better to operate a combined fleet of owned and chartered vessels? What capacity should be offered in relation to the market demand? Where should any new ships be built?

20.2.3 Building up resources

The insight, knowledge and competence of the company for the planned engagement must be ascertained. Will it be necessary to re-train some of the employees? Is it necessary to hire additional personnel? Would it be advantageous to make an agreement with firms or individuals who have special skills?

In the case of transport by sea, what should be the schedule for entering ships into the market? Which flag should the ships carry? Should you charter, buy or build ships?

20.2.4 Marketing

How should the marketing be adjusted to the planned build-up of transport capacity? Who are the customers? Should the marketing be aimed at a small selection of individuals or companies, or would it be better to announce a general offer of transportation? Should important customers receive special attention and perhaps be invited to take part in the introduction of the new service?

In marine industries, where professionalism may be a selling point, it may be a good policy to engage your own personnel in marketing. However, you should also consider the advantages of engaging agents.

20.2.5 Duration of engagement

The lifetime of the market should be estimated and plans made for varying the engagement over time. How will hardware be disposed of? What will be the organization when market engagements are eventually discontinued? Should a plan be devised for maintaining contact with partners and customers after the market has declined?

20.3 INTRODUCING A SYSTEM TO ITS USERS

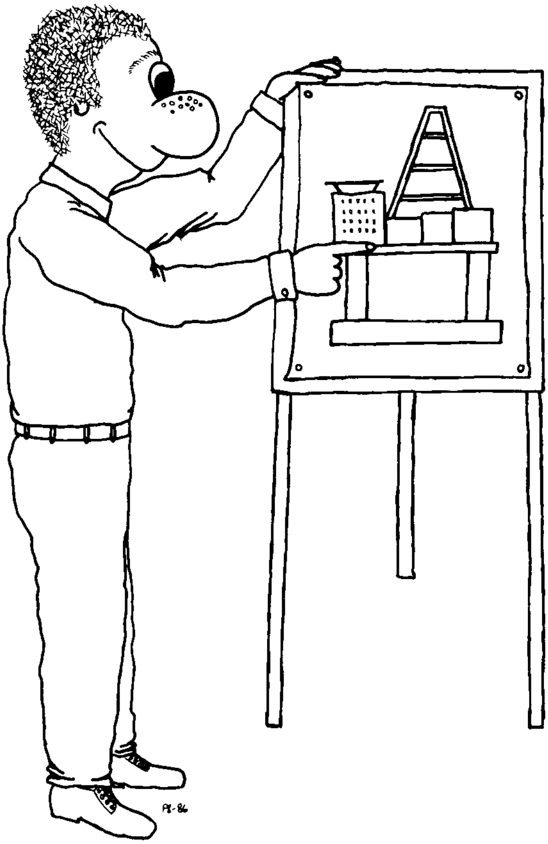
The users are the people who operate, market, maintain and manage a system.

People are conservative by nature. They dislike changes in working habits and attitudes. Therefore, it is necessary to introduce a new system to the people who are to use it well in advance. The best tactic is to invite the users to take part in the planning of the new system. This may encourage the personnel to feel responsibility for the new system and to try to get the best out of it. Some ideas about how to effectively introduce a new system to its users are listed below.

Inform all personnel who will be influenced by the new system of your intentions and ideas. Ask for comments. Try to establish an intra-company discussion of the advantages and disadvantages of the present service and the possibility of change. Emphasize that new systems must also be advantageous to customers.
Try to promote interest and participation in the new system by asking for suggestions about how it should be organized. Establish working groups to prepare proposals if necessary. Avoid unintentionally disrupting established work relationships and chains of authority. Allow ample time for the generation of suggestions.
Present and discuss the suggestions which emerge. Use scale models of important elements if any of the users find it difficult to comprehend drawings or verbal descriptions. Explain all the reasoning when the proposed solutions deviate from the suggestions and proposals received from the users.
Prepare mock-ups of parts that are crucial to an efficient operation and try them out with the users. These could include mock-ups of the bridge on a supply vessl, a crane driver's cabin, controls in manned submarines, diving bells and cruise ship cabins.
Invite the company's marketing personnel to develop schemes for presenting the new system to customers and prepare a schedule for the presentations.
Allow the users of the new system to make the scheduled presentations to customers.
Arrange follow-up meetings to discuss the customers' reactions to the new system, the users' experiences, corrective actions for improvement of the service and reworking of existing plans.

21

PRESENTING THE DESIGN SOLUTION



21.1 INTRODUCTION

The final design should always be presented in report form which is supplemented, in many cases, by drawings and scale models. A good technical report should offer the reader a sufficient overview of the problem, an explanation of how the problem has been dealt with and a presentation of the results. In addition, it should contain all relevant information generated in the course of the project. An overview should be presented very early in the report. Detailled information can be reported in appendices. The conclusions should be outlined in a separate chapter at the beginning of the report.

21.2 REPORT WRITING

A design report should include the topics listed below.

1. *Statement of the problem*: This should included the purpose of the work, an explanation of the problem to be solved and important conditions which were taken into account.
2. *Conclusion*: This should contain a condensed report of the findings and recommendations. Only information which can be found elsewhere in the report should be mentioned.
3. *Result*: This should outline possible solutions, recommendations, resources needed for implementation of the recommendations and the access to necessary resources.
4. *Assumptions*: This should include a discussion of the assumptions on which the results are based, assumptions to which the results are sensitive and the effect of uncertainty.
5. *Criteria*: This should include a description of the criteria used and why they have been used.
6. *Fulfilment of aims*: This should discuss the probability of fulfilling the stated aims in terms of revenue, increased competitive strength, compliance with rules and regulations and improved customer relations.
7. *Ranking of alternatives*: This should state whether all possible solutions were investigated, and if not, why not.
8. *Recommendations for further work*: This should include the reasons for recommending further work, the main aim of the work, the deadlines and starting times and a summary of the resources needed.
9. *Methods*: This should include a discussion of the tools and theories used and their relevance to the problem. Calculations should also be included.
10. A review of how the quality audits (QA) have been applied to the design, who has been engaged in quality reviews and how the results of the QAs have been documented.

When complete, the report should be subjected to a *quality audit* based on the points mentioned above.

21.2.1 Editorial checklist

Attention to the following list will help to ensure a successful presentation of the report.

- The presentation should be attractive.
- The contents list should include text, figures, tables and appendices.
- The body of the report should contain tables showing exact values, diagrams to provide an overview and to demonstrate trends, lists of symbols and abbreviations and numbered equations.
- The report should be subdivided to allow easy reference.
- A list of references should be provided.

21.3 DESIGN RESULTS

The design results should be presented in a factual way, preferably in conjunction with numerical data. There should be a clear ranking of the alternatives and a recommendation as to which is the best alternative. In addition the following points should be specified:

- The objective of the work or a description of the problem.
- The basic assumptions used.
- How decision variables have been varied.
- How the results vary with the decision variables.
- Which criteria have been used to select the alternatives.
- The extent to which the problem has been investigated. How and why any part of the problem has been excluded from the investigation.
- Possible uncertainties linked to basic assumptions, methods of calculation and methods for selecting solutions.
- How uncertainties influenced the result.
- Recommendations for further work.

The results of a design project should relate to the objectives. Thus, where the objective was to design a complete chain of transportation, the results should contain all the data necessary to implement the chain. Where the task was to design a single ship, the results should be limited to what concerns that ship.

The design results required depend on who the design is for. Managers will request very detailed results when the results concern their own operation. However, they will often accept more general figures for items where they are not directly involved. For example, a shipping company will give first priority to data about ships and parts of the service that are directly related to the ships. Any data about other parts of the service need not be detailed. However, a correct overview of the capacity and costs of other parts of the service should be provided.

21.3.1 End results

The examples below concern the elements of a chain of transportation and a supply service designed for a shipping company. They outline the data that would be produced as the *end result* of designing such a system. These data should not be mistaken for the types of output generated during intermediate stages of the design.

21.3.1.1 Example: The complete transportation chain.

The end results required include:

- Transport pattern over land and sea including port and places of cargo transfer.
- Transport capacity.
- Total cost of transport per unit of cargo, ie the total required freight rate.
- Total cost of transport for competing systems.
- Frequency of sailings and required storage capacities.
- Volume of cargo tied to the system of transport.
- Assumed economic lifetime, ie span of time the system is assumed to produce a net profit.
- Technical lifetime, ie span of time the system could perform a reliable service.
- Rate of interest and time of capital recovery used in economic calculations.
- Economic result for the different parties engaged in the transportation.
- Required share of the market and assumed efforts for market development.

- Organization of the transport, parties to be involved, required cooperation with others, contracts to be established.
- Technical solution in general, including information on necessity to use new technology.
- Risks in relation to recommended solutions, market development, cooperation with other parties, financing and political stability.

21.3.1.2 Example: A supply service

The end results required include:

- Which supply bases to use.
- Number and capacity of vessels.
- Frequency and availability of service.
- Weather conditions, assumed weather limits of the operation, if any.
- Total cost of the service.
- Storage capacity of base, item by item.
- Volume of supplies within the system.
- Assumed economic lifetime.
- Technical lifetime.
- Financing (rate of interest and time of capital recovery).
- Economic results for parties engaged.
- Assumed organizational set up.
- Technical solutions foreseen including information on eventual new technology.
- Risks in relation to the recommended solutions, operating conditions, obligation to maintain the service etc.

21.3.1.3 Example: A vessel

The end results required include:

- Cargo capacity, ie, deadweight, cubic capacity and deck areas.
- Economic criteria i.e. return on investment, time of capital recovery, internal rate of return, present worth, required time-charter hire, required freight rate, annual cash flow, and possibly others.
- Building costs (and prospective building yards).
- Earliest time of delivery.
- Running and maintenance costs.
- Economic lifetime.
- Technical lifetime.
- Calculated income and the assumptions on which these calculations are based.
- Main dimensions, fullness and draft.
- Restrictions imposed on main dimensions and their origin.
- Speed (and round trips per year).
- Engine power and type of main machinery.
- Fuel consumption.
- Bunker capacity and endurance.
- Type of cargo and special equipment for cargo stowage.
- Special features where the solution differs from known ships or type of ships.
- Special requirements of adjacent sub-systems such as quays, locks, canals, land transport systems, etc.
- Particulars of ship borne loading/unloading installations, see detailing for the port.

21.3.1.4 Example: A port or a supply base

The end results required include:

- Investments, if any.
- Annual cost of operation and maintenance.
- Economic lifetime.
- Technical lifetime.
- Calculated income and the assumptions on which these calculations are based.
- Economic criteria, ie return on capital, capital recovery time, internal rate of return, present worth, annual cash flow, cost per ton trans-shipped, and possibly others.
- Depth at quay and in approach channels.
- Length and width of dock basin.
- Required storage capacity.
- Required transport capacity to and from the storage.
- Required loading/unloading capacity as
  - — volume per unit of time
  - — mass and dimensions of the largest lift
  - — reach over the water and over the quay
  - — transport capacity from and to the quay front during loading/unloading operation
  - — hours of operation per day, days of operation per year
- Loads exerted on the quay by the ships via
  - — ramps
  - — mooring lines
- Limitations on loading/unloading equipment set by the ship.
- Frequency of call.
- Demand for tugs, lighters, bunkering services and similar.

21.3.1.5 Example: Land transport

The end results required include:

- Investments.
- Annual cost of operation and maintenance.
- Economic lifetime.
- Technical lifetime.
- Calculated income and the assumptions on which these calculations are based.
- Economic criteria i.e., return on investments, capital recovery time, internal rate of return, annual cash flow, cost per ton carried, and possibly others.
- Cargo type, handling methods, means of transport, and equipment for cargo storage.
- Rate of cargo flow to and from the port.
- Adaptation to the storage and loading/unloading equipment in port.
- Adaptation to producers' plants.
- Conditions related to topography, land or others which may influence design of the land transport.

21.3.1.6 Example: Results for the producers and the consumers

The end results required include:

- Total required freight rate.
- Operators of the different links in the chain of transportation.
- Shipping documentation.

- Form of shipment and requirement for packing.
- Dimensions and weight of eventual unit loads.
- Cargo handling systems.
- Frequency of shipping and shipping volumes.
- Storage capacity.
- Assumed rate of production or consumption.

21.3.2 Summary

These lists are not exhaustive, and are biased in the sense that they are prepared under the assumption that the design is being carried out for the shipowner. The lists would be different if a port authority or a land transport company were responsible for the design. In spite of this, the list contains a large enough selection of items to give a good idea of what type of information may be required for a final report on a design project. They also give ideas of the types of output that would be required for other types of clients.

21.4 THE CONCLUSIONS

The conclusions should be placed at the beginning of the report. They should contain all the important results. For example:

1. What will be obtained by implementing the solution?

- Degree of goal attainment.
- Economic results (strength, profit, costs).
- Change of sphere of business.
- Control of additional activities.
- Access to new markets.
- Changes in competitiveness.

2. What is required to implement the solution?

- Money.
- Knowledge.
- Manpower.
- Area (e.g. building site).
- Equipment (e.g. fabrication facilities).
- Time.

3. How obtain the required resources.

- Loan or credit (private and governmental).
- Investment of our own capital.
- Establishing a partnership with parties with the required resources.
- Hiring consultants.
- Engaging subcontractors.
- Through cooperation with customers.

4. Assumptions under which the design results are valid.

The assumptions made are related to income, rate level, rates of exchange, costs and cost levels, terms of financing and borrowing, capacity utilization and availability, laws and regulations, customers' demands and the market share.

5. The likelihood that the assumptions will prove true.

This part of the conclusion should contain brief discussions of past observations and the assumptions which were based on these observations. Short descriptions of the expected future development of all important parts of the system should also be given.

6. Consequences of assumptions if do not come through.

This part of the conclusion should contain the results of the sensitivity analysis, preferably in the form of break even conditions. The levels of freight rates, cargo inflow, on hire time, building prices, fuel costs, interest rates, loan repayment periods and exchange rates where cost and income would be equal and there would be no profit should be specified. These results should be illustrated as shown in Figure 21.1.

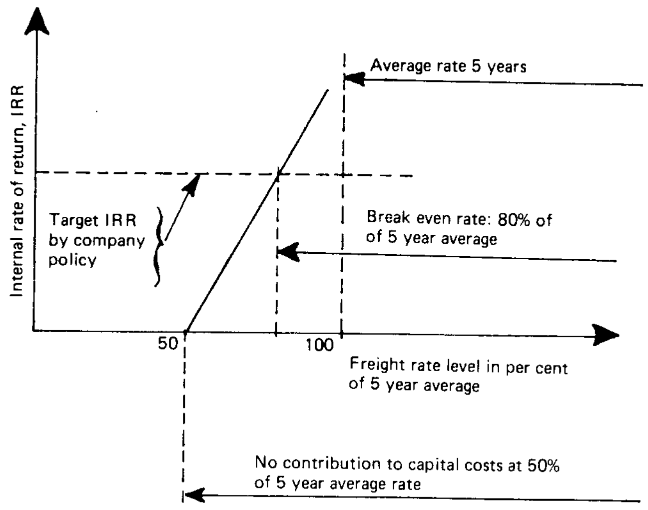


Figure 21.1 Sensitivity diagram: Internal rate of return against freight rate level

The conclusion should be limited to results only. The reasoning and calculations behind the results should not be included here. The conclusion should not contain anything that cannot be found in the report itself. It should not be necessary for those who have read the complete report to read the conclusion. Those who read the conclusion only should get an overview of all of the important results of the design work.

Many managers do not have time to read more than the conclusion. In many cases they have time to read only an Executive Summary, which is a summary of the conclusion.

21.5 PHRASES AND EXPRESSIONS

Do not try to demonstrate your professional insight by using engineering jargon in the report. Use only common words and plain language. The report is seldom read only by engineers. Economists, lawyers, market researchers, traders, marine professionals and many other types of people may be involved in the decision to accept or reject your design. The good quality of your work will mean nothing if your report cannot be understood. Therefore, write so that everyone can understand what you are saying.

21.6 ILLUSTRATIONS

There are three main types of illustrations:

- Photographs which show all visible details of the object.
- Drawings, which are formalized presentations of how the object will look.
- Diagrams, which are representations or models of reality. Diagrams can be used to illustrate the relationships between variables or different parts of a development. They can also be used to illustrate the magnitude of the variables and the distribution of properties. The use of diagrams is discussed in Section 12.3.1.

Illustrations are generally used to present *overviews*. Detailed information should be presented in tables. Some readers will look only at the illustrations when they first review the report. Therefore, the illustrations must be independent of the report text. Each illustration should contain short explanations as well as a caption below which describes the illustration and explains why it has been included. Figure 21.3 is an example of this.

Figures 21.2, 21.3 and 21.4 are examples of overview diagrams which are commonly found in technical and economic reports.

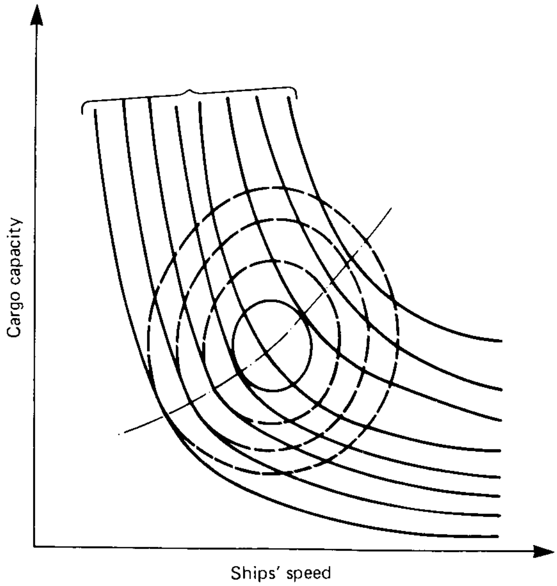


Figure 21.2 A typical 'Overview Diagram' is the Isocost/Isoquant diagram. The diagram has two variables, and cost and capacity are expressed as functions of these. Lines are drawn through points of equal cost and through points of equal quantity or capacity. The former is called isocost, the latter isoquants. — Isoquants, lines through combinations of speed and cargo capacity that render the same transport capacity; — · — line through points of minimum unit cost; and --- isocosts, lines through combinations of speed and cargo capacity that have the same unit cost per unit carried.

In marine transportation, cargo deadweight capacity and speed are as a rule the two variables. In such diagrams, points of minimum unit costs will be on the locus of tangent points between isocost and isoquant curves. The diagram illustrates the cost consequences of not selecting the minimum cost solution.

Data for establishing diagrams of this type may be obtained by calculating capacities and costs for a range of deadweights combined with a set of speeds and vice versa.

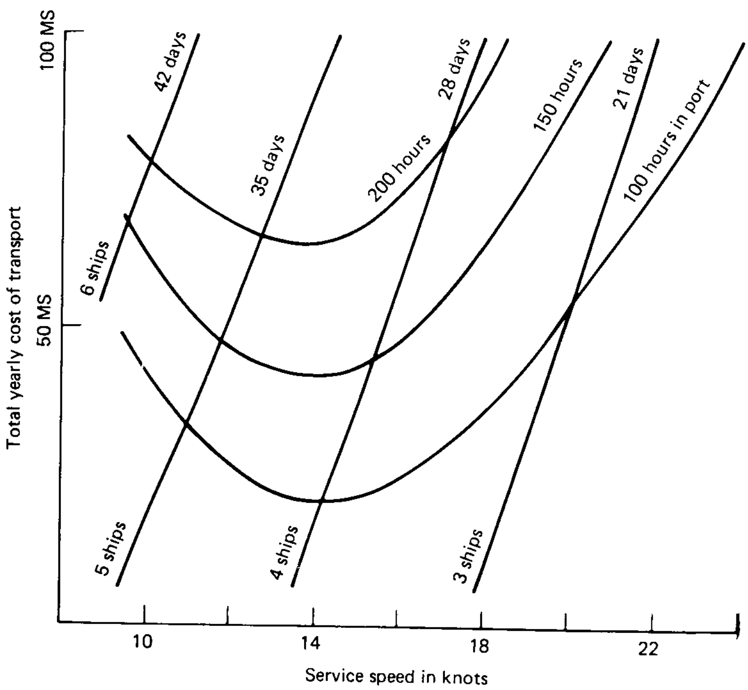


Figure 21.3 Visualization of interrelations between number of ships, speed and time in port. The 'days' are the days required per round trip for the corresponding number of ships where one call per week per port is assumed. The hours in port (h) are the total number of hours assumed to be spent in port per ship per round trip.
The diagram shows the interrelations between speed, number of ships in the fleet, and time in port per round trip. The total cost of transport is a function of these variables. All curves are for a given transport and ship capacity. A basic assumption is that the ships shall maintain a service that provides each port with one call per week. The example has been taken from (Getz et al (1968)).

21.7 TABLES

Tables should be used to present precise and detailed information. Any set of variables whose exact values may be required for further calculations or use in other projects should be listed in tables. Tables are for the specialists.

In many cases illustrations should be supplemented by tables. Tables should also be used to store data produced in the course of the design project. This includes information which is not necessarily of use to the project in hand but may be useful for other purposes.

All tables should be included in the appendices, except those tables which summarize the important results of the project. These summary tables should be made easy to read.

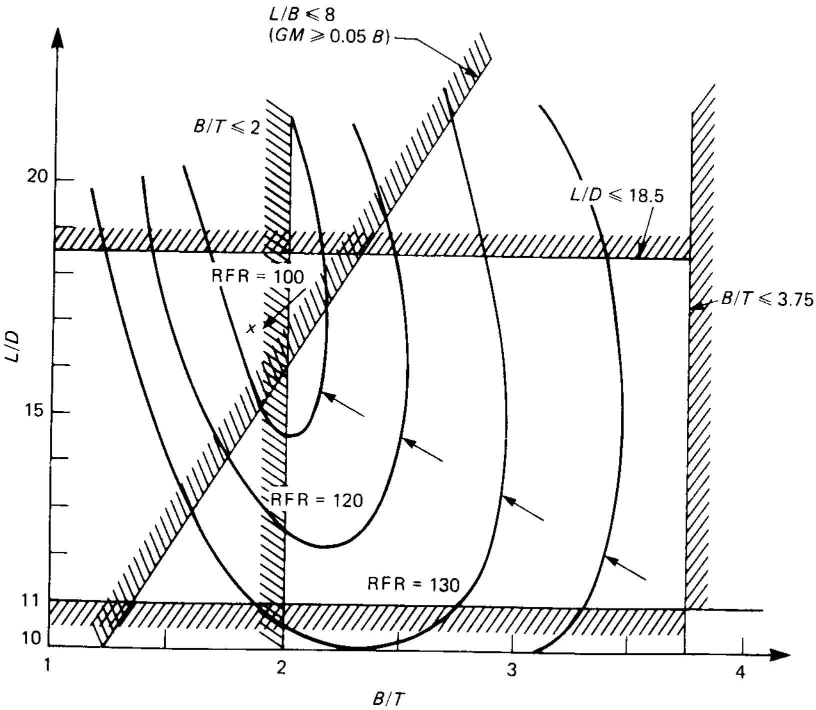


Figure 21.4 Ship optimization. Restrictions on *L/D*, *B/T* and *L/B* (due to requirements of initial stability) superimposed on curves of equal RFR, Required Freight Rate (Isocost). Minimum Required Freight Rate is at a combination of *L/D* and *B/T* that is outside the limit set by the constraints. The example is based upon (Nowacki et al (1970)).
B = Beam, *T* = Draft, *L* = Length between perpendiculars

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INDEX

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Professor Erichsen is a distinguished expert in marine design from the Institute of Technology at Trondheim, a leading centre in this field. His book provides a comprehensive guide to all stages of the design tasks - office organization, staffing, market evaluation, design attitudes and tactics, generation of ideas, assessment of cost, estimating weights and volumes, contracts, quality assessment, implementation of designs and report writing - essential information for managers, naval architects and designers.

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