THE POWER OF A CEM IN INNOVATIVE SHIP DESIGN

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'While most futurists believe that we are at the beginning of an Information Age, most engineers believe and act as though they are still living in the Machine Age, which began over a century ago', ref. [1].

1. INTRODUCTION

The above statement suggests a gap between 'what is technically possible', and 'what is supposed to be economically attractive' in daily practice. Although a wide variety in both hardware and software is available to support the designer in his difficult task, the implementation in a practical environment seems to proceed very slowly. At least for those who are involved in the development of design systems. To try closing a part of this gap, a prototype Concept Exploration Model (CEM) was implemented at the Government Vessels Dept. of the Directorate General of Shipping and Maritime Affairs of the Netherlands.

The Concept Exploration Model consists of a closed design program, supplemented with an interactive preprocessor and postprocessor. It offers a high calculation speed, thereby allowing a vast design space to be explored quickly and systematically.

Purpose of the present paper is to inform those who are involved in ship acquisition and conceptual design processes, about both the possibilities and the limitations of a CEM. This is aimed at by presenting a short review of the underlying design methodology, followed by an introduction in the structure and possibilities of the CEM. To test the viability of this tool in the acquisition process of a ship, a prototype CEM has been used parallel to the existing method in the acquisition process of a new patrol vessel. An account of this experience is given.

2. WHAT IS A CEM

2.1. Characteristics of the Design Process

The design process can be regarded as a mixture of both structured and unstructured processes. It is one of the main objectives of the developing science of design, to identify the distinct processes and to structure these as much as is realistic and practical, in order to allow a maximum support by the computer in the design process. This leads to a situation where the designer will be involved more with the unstructured or partially structured parts of problems (that is with establishing goals and requirements, defining selection criteria, modelling the system in terms of its subsystems, etc.), and less with the structured part (that is e.g. analysis and evaluation), which will be automated.

Mistree [1] characterizes the design of most engineering systems by the following descriptive sentences:

- The problems are multi-leveled, multi-dimensional and multi-disciplinary in nature.
- Most of the problems are loosely defined, open-ended, virtually none of which has a singular, unique solution, but all of which must be solved. The solutions are less than optimal and are called satisfying solutions.

- There are multiple measures of merit for judging the "goodness" of the design, all of which may not be equally important.
- All the information required may not be available.
- Some information may be hard that is, based on deterministic principles, and some information may be soft being based on the designer's judgement and experience.

To be able to more easily recognize the structured from the unstructured activities in the design process, a general design philosophy has been developed at the University of Twente. Van Harpen [2] considers the design process as a process of reworking information, which can be described by an iteration of a basic process for the parent system and each subsystem of the object under consideration (multi-leveled character). This basic process can be described by a classification in time (phase model) and a description of the activities in the process (decision model).

Fig. 1 gives the scheme of the basic methodical design process. This process can be classified in three major phases, i.e.:

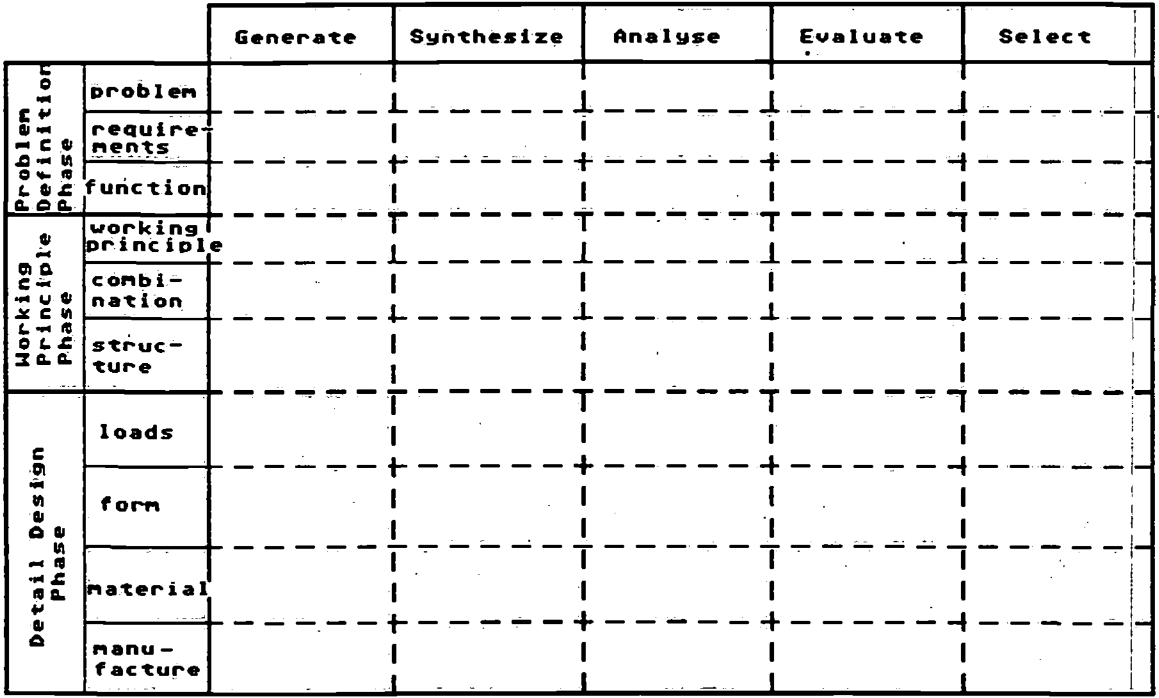
- the problem definition phase;
- the working principle phase;
- the detail design phase.

These phases can subsequently be divided into subphases. The rows in the model represent the subphases (according to the phase model), and the columns represent the activities that are to be carried out in each subphase (according to the decision model).

This model gives some hold as how to proceed in a design process. It is by no means meant to prescribe a certain fixed path through the phases and activities. Iterations and omissions of activities or (sub)phases may occur, up to the insight of the designer. Iterations may often be necessary as the required input for a subphase may not be sufficient to conduct the process with the required accuracy.

2.2. The Function of a CEM

At the start of the ship design process, the parent system is considered first. Information about this parent system is compiled, in order to be able to adequately define the design problems for



		Generate	Synthesize	Analyse	Evaluate	Select
Problem Definition Phase	problem					
	requirements					
	function					
Working Principle Phase	working principle					
	combination					
	structure					
Detail Design Phase	loads					
	form					
	material					
	manufacture					

Figure 1:
The methodical design process according to the University of Twente

the subsystems on the next level of complexity.

To be able to specify realistic requirements, goals and weight factors, knowledge about the effects of operating conditions and properties of the design on its performance should be available. Knowledge that comes only available in the course of the design process. The goals, weights and requirements should therefore continuously be refined during the design process. However, the more information that is available in the early stages of the design, the more limiting goals and requirements can be set, and consequently the more efficient the design process will lead to an optimal design.

It is this parent system and this phase in the design process for which a CEM is specifically designed. Returning to the three major phases of the methodical design matrix, the CEM can effectively be used in the problem definition phase and at the start of the detail design phase of the parent system (Fig. 2). It can, in due course, be helpful in comparing several working principles of the parent system, such as for example a catamaran with a monohull.

In the detail design phase, the CEM is especially suitable in locating one or more optimal subspaces in the feasible design space. Within these constrained subspace(s), the design can be elaborated further in more detail.

2.3. The CEM Structure

The heart of the Concept Exploration Model consists of a closed design process which offers a high calculation speed. In this way, a vast design space can be explored quickly, thereby quantifying the most relevant properties.

For each phase in the design process, a set of generic activities, also called 'decision model', can be identified: generation, synthesis, analysis, evaluation and selection. The first of these activities consists of the generation of a number of partial or complete solutions to the problem. Subsequently, the synthesis activity composes partial so-

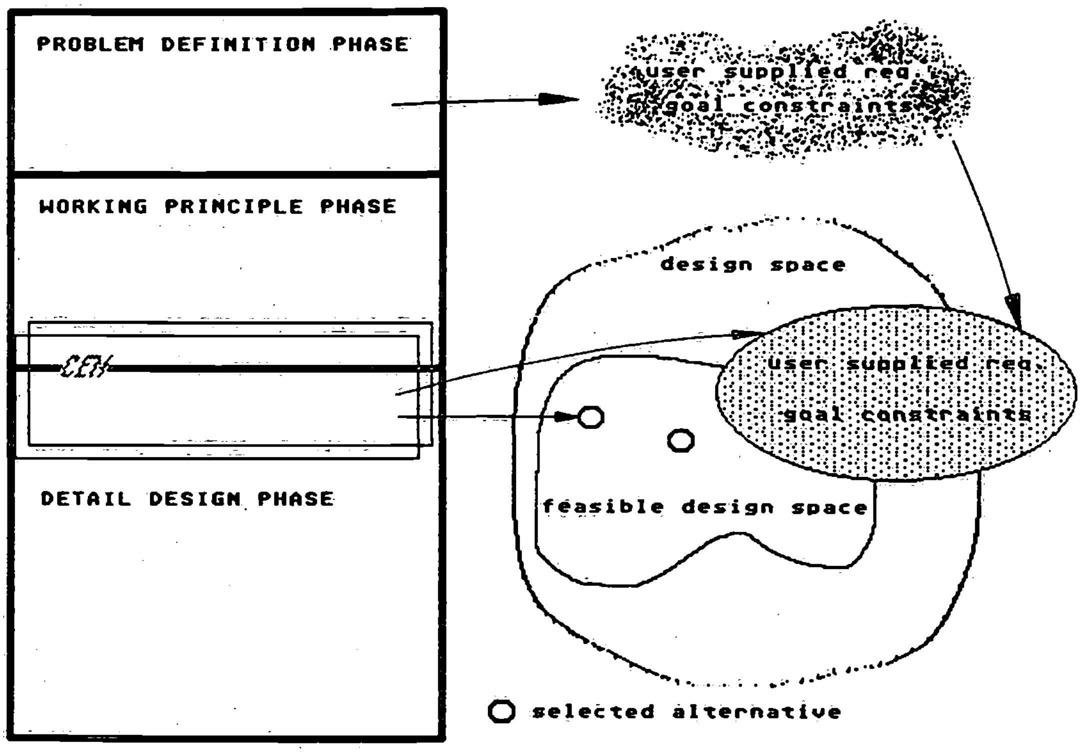


Figure 2:
The function of a CEM.

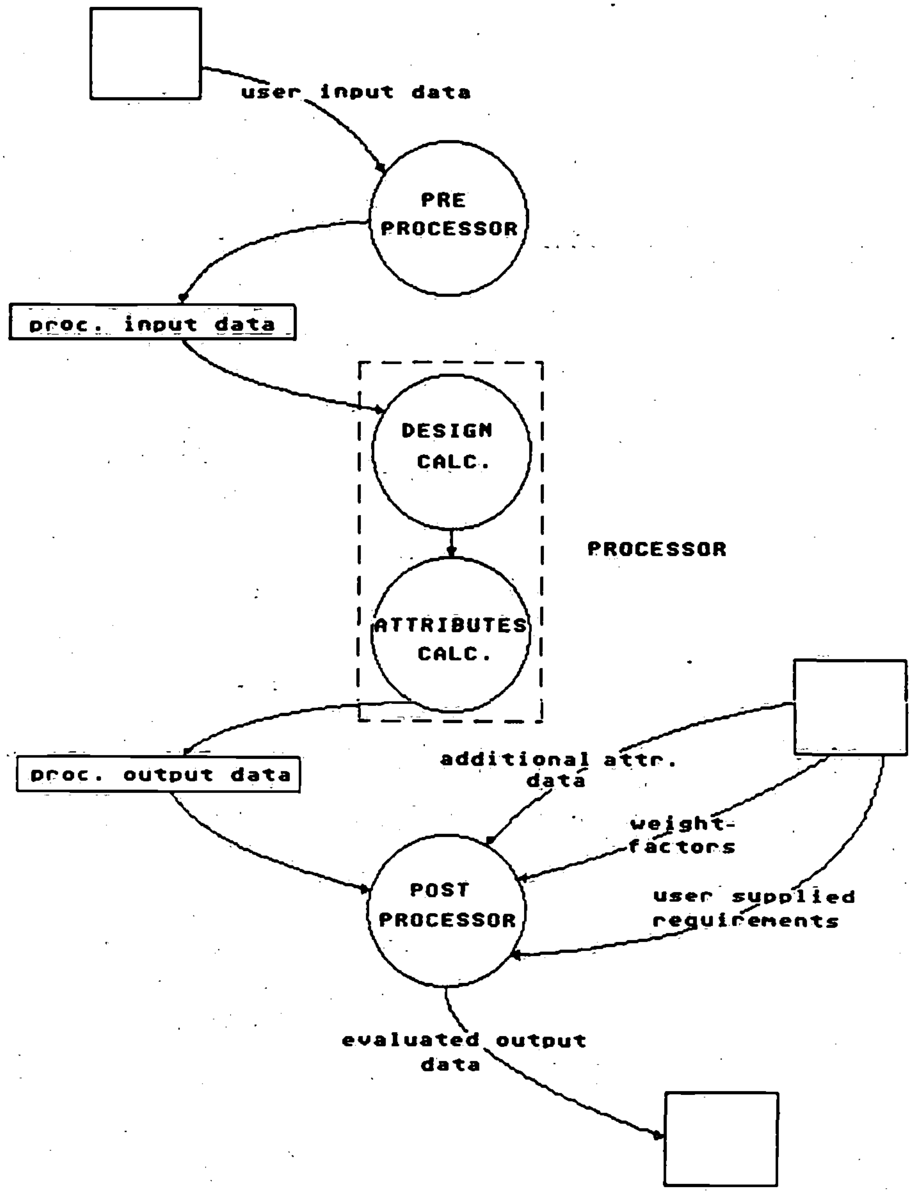


Figure 3:
Data flow diagram of the complete CEM system.

lutions to a higher order system solution. Analysis then provides relevant attributes on the basis of which a selection should be made. In the evaluation activity, all alternatives and appropriate attributes are compared, and a selection is finally made by the designer.

The user communicates with the program through an interactive preprocessor and an interactive postprocessor (Fig. 3). In the preprocessor, the user is assisted in creating an input file, defining roughly the alternatives that are to be designed and analyzed by the processor (generation). The input for the CEM processor typically consists of about fifty parameters. This set includes some 5 to 10 so-called 'Independent Design Parameters', for which a range of values can be input in one run of the program. The other parameters are optional. This means that a large number of alternatives can be designed and analyzed in one run of the program.

Each alternative, defined in gross terms by the input parameters, is elaborated in the processor. Purpose of the design calculations is to describe the design in more detail, the degree of which being dependent on the attributes required for the evaluation (for example, a propeller is designed because the required power has to be known). This means that both synthesis and analysis activities are conducted by the design calculations. After the design is determined in more detail, it is analyzed with respect to its most relevant attributes, i.e. static stability and seakeeping behaviour.

In the processor only those decisions necessary are taken by the program. The emphasis is therefore placed on straight analysis of the attributes. This restriction is deliberate and is intended to keep the CEM as problem-independent as possible, so that each problem formulation can be approached with a different solution strategy.

The processor adds parameters to each alternative roughly defined by the designer as input. After calculation, each alternative is typically described by about 80 parameters, yielding a complete description of the alternative.

The decisions that necessarily have to be taken are, as far as possible, postponed to the postprocessor, where the designer can decide directly for himself. He can make selections on any known attribute, e.g. length, payload, seakeeping properties, etc. An advantage of this postponed selection is that the effect of the appropriate requirements on the design becomes immediately apparent.

Another important feature of the postprocessor is the ability of the designer to add attribute values or functions, not calculated within the processor. These attribute values may for example refer to costs, which can be expressed as a function of the available parameters.

To select the best starting point(s) for further elaboration at the next design stage, the designer may define a merit function. This function adds one value to each alternative, so that all alternatives can be mutually compared on the same basis. This function is based on the relevant attributes and their priority. A frequently used form of this function is expressed as:

$$MF_i = \sum_j v_j . A_{ij}$$

where:
MF_i = merit function of alternative i
v_j = weight factor of attribute j, indicating its priority
A_{ij} = attribute j of alternative i.

At this moment, the processor is implemented on a VAX mainframe computer. The projected preprocessor is yet lacking, but an input file can simply be edited on any editor. The postprocessor of the prototype CEM consists of a comprehensive spreadsheet program, running on a PC. This program meets all the requirements imposed. New attribute values and functions can simply be added by the designer, selections can be made and relations between arbitrary design parameters can easily be visualized.

3. APPLICATION OF THE CEM; A CASE STUDY

To illustrate the possibilities of a CEM in the preliminary design stage, an example is worked out. First, the design problem is discussed by deriving a set of basic staff requirements (section 3.1). Secondly, the preliminary design is worked out, using the classical design approach (section 3.2). Finally, the possible support by a CEM is demonstrated in a few applied examples (section 3.3).

3.1. Program of Requirements

The presented case deals with the design of a seagoing patrol vessel. The design is based on the operational requirements, which are defined in the so-called 'program of requirements'. Apart from these technical requirements, the available financial funds and the expected exploitation costs have to be taken into consideration.

The vessel can be regarded as the tool to perform the required task. The shipowner, whether this is a governmental organization or a private enterprise, has to convert the operational requirements into a program of 'basic staff requirements'.

In determining the staff requirements, the following has to be known:

- the required tasks,
- the conditions that can be expected during service,
- the social conditions for the crew, e.g. working hours, and
- the required equipment, e.g. machinery.

In practice, requirements and goal constraints appear often to be based on experiences, obtained from former projects, and accidentally available information. Requirements are also affected by external situations, such as social/economical impulses and sales activities of shipyards. Operational requirements are thus affected both by internal and external factors.

The definition of the basic staff requirements can be regarded as the first activity of the design process. During this activity, each basic staff requirement should be given a priority. The following list shows the program of basic staff requirements, as drafted for the present case.

Summary of operational requirements

1. Function of the vessel:
   - patrol
2. Area:
   - up to 30 nautical miles offshore
3. Wind force restriction:
   - none
4. Seakeeping behaviour:
   - good seakeeping behaviour, up to at least Bf 5-6
   - surveillance task up to Bf 8, sea state 6
   - inspection task Bf 5, up to sea state 4
   - the vessel has to maintain a speed of 20 knots in waves with a height of 1.90 m
5. Rules and regulations:
   - governmental laws/classification rules
6. Type of journey:
   - basically 1-day journeys (24 hrs)
7. Ship speed:
   - maximum speed of 23 knots
   - cruising speed of 14 knots
8. Range:
   - fuel capacity for 24 hrs at maximum speed continuously
   - at least 350 nautical miles at a continuous speed of 14 knots
9. Crew:
   - 6 (dependent on character of mission)
10. Accommodation:
    - berths for 8-10 persons
    - galley and wet space
    - dining room for at least 6 persons
    - store, office and control room
11. Material:
    - hull; steel
    - superstructure; steel or aluminium
12. Miscellaneous:
    - rubber dinghy with a length of approximately 6 m
    - limited SAR equipment

The operational requirements can subsequently be converted into basic staff requirements. A subdivision in four groups is given:

Basic staff requirements

Group 1 - General
- * type of journey
- * number of passengers and crew accommodation; noise criteria
- * equipment, dinghy

Group 2 - Powering performance
- * ship speed(s)
- * range

Group 3 - Rules and regulations
- * patrol area
- * limitations
- * relevant rules and regulations

Group 4 - Seakeeping
- * seakeeping behaviour; criteria
- * workability

3.2. Preliminary Design by the 'Classical Approach'

Based on the basic staff requirements, conclusions can be drawn relative to the design form parameters and the general plan. The conclusions, together with a short argumentation are given below. The subdivision into groups is maintained. The design procedure referred to is described in more detail by de Beer [3].

Group 1

Based on the staff requirements and considerations of length, area and volume, it is concluded that the vessel needs a deck length of approximately 29 to 32 m.

Group 2

In this group, the ship speed is the dominant requirement. There are three possibilities:

a. displacement vessel, length > 50 m
b. semi-displacement vessel, length 30-50 m
c. semi-planing vessel, length 25-30 m.

Vessels with a length under 29 m can be left out of consideration with regard to the conclusions based on the Group 1 requirements.

Group 3

With regard to the area of operation, safety regulations play a dominant role. Especially those regulations related to wind force restrictions. If the vessel should not have any wind force limitation, it follows from statistical information that the length should be greater than 30-35 m (a).

Based on the operational requirements, the following limitations are also applicable:

b. Surveillance restriction at Bf 8, length > 20-25 m
c. Inspection restriction at Bf 5, length > 10-12 m.

With reference to the requirement that the vessel should not have any restriction, the length requirement under (a) is representative.

Group 4

From a wave scatter diagram of the area of operation, it can be derived that the requirement about the surveillance task to be conducted up to Bf 8, means a workability of the vessel of 85 to 90% of the total operating time. Based on strip theory calculations and experience, the following workabilities as a function of length are estimated:

Length [m]	Workability [%]
15	49
25	83
35	91

From the above considerations, it is clear that the requirements related to wind force restrictions and workability are decisive for the length of the vessel. Based on the staff requirements, the ship should have a waterline length of at least 29 m.

Budget requirements are generally decisive whenever choices have to be made, as is the case for the present project. An appropriate decrease in workability has than to be accepted. Taking into account the available budget, the ship's length over all should not exceed 35 m.

The above process of the determination of the ship's length is schematically depicted in Fig. 4.

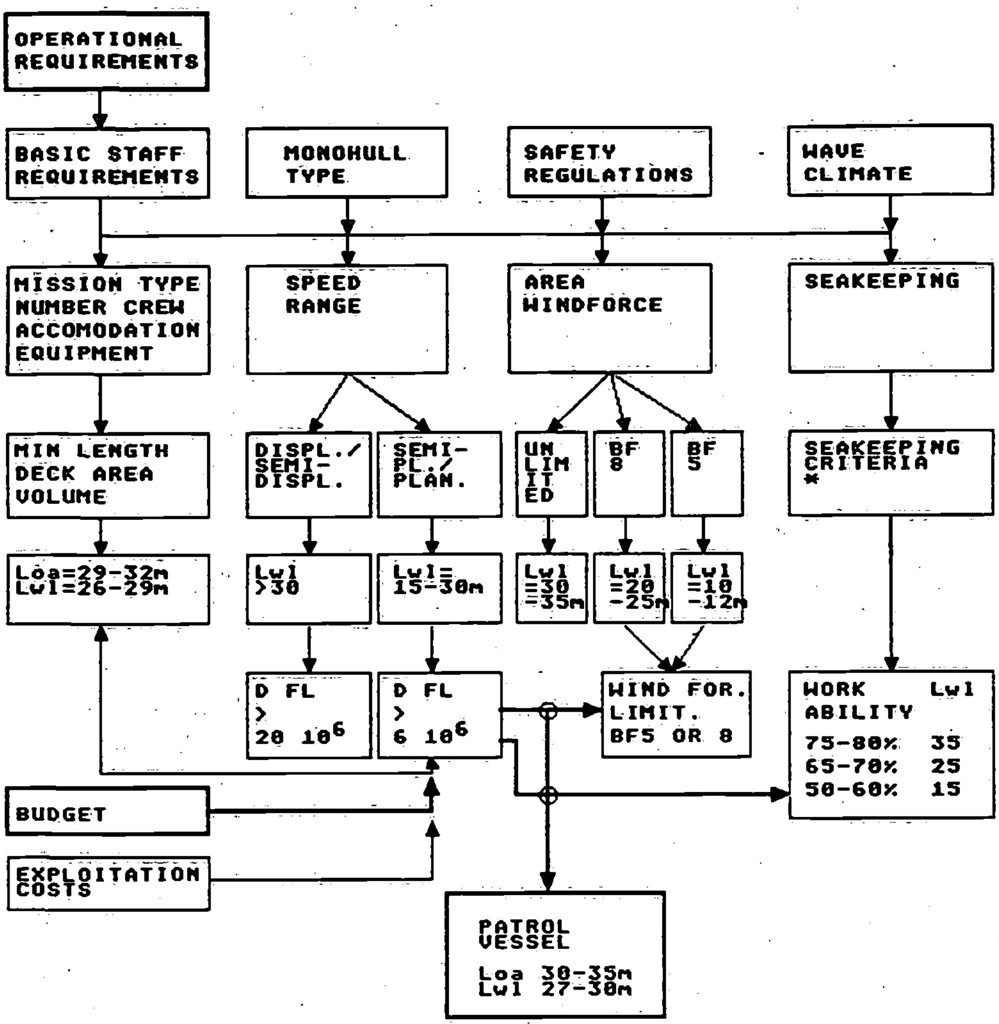
General arrangement

An optimal general arrangement can now be determined schematically (Fig. 5). Considerations relative to seakeeping, noise level, compartmentation and deck area requirements were decisive.

Main dimensions and coefficients

The main dimensions, such as beam, depth and draft, are, given a certain length, determined by safety regulations, hydrodynamic aspects and technical possibilities. Variations in these parameters are limited as a function of speed and material for example.

Based on experience and the above considerations, the main dimensions are supposed to vary between the following limitations:



* applied criterion: $\ddot{z}_{a1/3} < 0.35$ g on bridge

Figure 4:
From operational requirements to length.

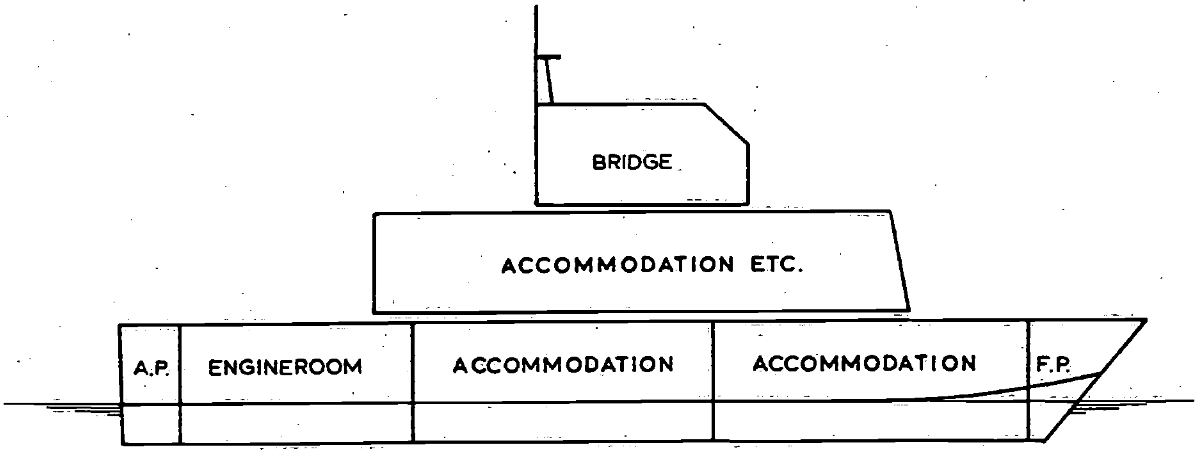


Figure 5:
General arrangement of the design.

Beam on waterline	[m]	6.80 - 7.20
Depth at midship	[m]	3.50 - 4.00
Average draft	[m]	2.30 - 2.40

Based on a design Froude number Fn=0.64, it is advantageous to choose a round bilge hull form. With regard to the seakeeping behaviour, including slamming, a preliminary deadrise distribution is chosen:

Longitudinal position	Deadrise angle
Transom	> 15 deg
Midship	> 20 deg
0.25 L forward of midship	> 35 deg

Appropriate hull forms can for example be obtained from the NPL series, Series 64 or the MARIN High Speed Displacement Hull Form Series.

On the basis of open literature, an optimal block coefficient Cb is expected between 0.32 and 0.38. The displacement DISW may not exceed 180-200 tonnes at the required maximum speed.

To determine an optimal waterline length LWL, powering calculations have been performed in the displacement range of 150-190 tonnes at an L/B ratio of 4.4. This resulted in the following lengths:

DISW [tonnes]	LWL [m]
150	35
190	38

A reduction of the waterline length from 38 to 33 m for the 190 tonnes displacement, results in a resistance increase of approximately 3-4%. The shorter length of 33 m is chosen for budgetary reasons.

For a number of displacements between 150 and 200 tonnes, the resistance/displacement ratio is calculated as a function of L/B. L/B has been varied from 4.3 to 4.7. It appeared that this had hardly any consequences on the required propulsion power.

The effect of the longitudinal centre of buoyancy LCB on the resistance/displacement ratio was subsequently studied. It appeared that the optimal LCB position is at about 6.4% LWL aft of 1/2 LWL. Deviations from this optimal position may result in a resistance increase of 4-8%.

Using the above data as input for the powering calculations, the following power requirements are found:

DISW [tonnes]	Delivered power PD [kW]
200	3940
190	3650
180	3430
170	3170

The required fuel capacity is now estimated, based on a 72 hrs continuous operation. A mission profile of 24 hrs at 20 knots and 48 hrs at 14 knots is assumed. A consumption of 14.4 and 10.4 tonnes respectively is estimated. The minimum fuel capacity is set at 30 tonnes (including a margin of 20%).

The maximum deadweight is now estimated as follows:

Fuel	30 tonnes
Fresh water	7
Dirt water	1.5
Used oil	1.5
Lubricating oil	1.5
Stores	3
Persons, including luggage	1.5
Miscellaneous	3
Total deadweight	49 tonnes

Using the 190 tonnes displacement as a starting point, the empty ship weight may not exceed 140 and may not be less than 130 tonnes. Using a length overall of 35 m and the greatest possible beam and depth (7.2 and 4.0 m respectively), an envelope volume LBD can be calculated. With this volume, a mass density (empty ship) of 129-138 kg/m3 is obtained. As steel has a mass density of approximately 190 kg/m3 for this type of ship, it is concluded that another, lighter, material has to be used for the construction of the hull and superstructure. A combination of steel and aluminium may also be possible.

A rough estimate for the stability (metacentric height GM) can be obtained from:

$$GM = C_1B^2/T + C_2T - C_3D$$

The metacentric heights are calculated for three beam variations:

B [m]	GM [m]
6.80	0.92
7.00	1.08
7.20	1.24

A minimum GM value of 0.90 m is required. The risk of broaching in following waves can amongst others be reduced by a sufficient static stability. A GM value of 0.90 at a Froude number Fn of 0.7 is assumed to be satisfactory.

The result of the first iteration of the design, based on the basic staff requirements and their appropriate priorities, is summarized in the table below.

The preliminary design phase is concluded, now that the operational requirements are converted to a set of global hull form parameters. It is clearly illustrated, that an approach of sequential optimization is used in determining the distinct parameters. Furthermore extensive use is being made of insight based soft information.

3.3. Support by the CEM

The input data of the MARIN CEM, applicable to High Speed Displacement Hulls, consist of global operational and hull form parameters. For four hull form parameters, a range can be defined together with the number of alternatives that should be calculated within that range. These parameters are considered to have a significant effect on the performance of this type of hull, i.e. length/beam ratio L/B, beam/draft ratio B/T, block coefficient Cb and one of the main dimensions, either length, beam, draft or displacement.

In addition, also a range of desired cruising speeds can be input. For the search mode of the program, suitable to quickly design and analyse a large number of designs, another 25 optional parameters can be input. If unknown, default values that are based on the MARIN High Speed Displacement Hull Forms are used in the program.

Furthermore, a number of about 15 so-called correlation parameters can be input. These parameters are used to correct the values calculated by the program, once systematic deviations with the correlation data of the user have been established. They can be used to correct the calculated weight of each weight group, the calculated resistance components or required power, or the specific fuel consumption.

Based on the basic staff requirements, and the conclusions related to the length of the ship, the following input data were used:

LPP	[m]	29.00-35.00	(3)
L/B	[-]	4.00-6.00	(4)
B/T	[-]	2.50-5.50	(5)
Cb	[-]	0.30-0.40	(3)
Vcruise	[kt]	14.00	(1)

The numbers in brackets refer to the number of alternatives that is to be calculated. In addition, the following optional parameters were input:

Result of the classical design approach

Hull form parameter			Range
Length overall	LOA	[m]	30.00- 35.00
Length waterline	LWL	[m]	28.00- 33.00
Beam waterline	B	[m]	6.80- 7.20
Depth midship	D	[m]	3.50- 4.00
Draft average	T	[m]	2.30- 2.40
Block coefficient	Cb	[-]	0.33- 0.38
Displacement weight	DISW	[tonnes]	180 - 195
Empty ship weight		[tonnes]	130 - 140
Deadweight		[tonnes]	49 - 52
Required power	PD	[kW]	3400 -3900

Vmax	[kt]	23.00
Vendurance	[kt]	4.00
Range	[nm]	1250
Number of days at sea	[-]	7
Service allowance	[%]	15
Mission profile	[-]	4% at Vmax 57% at Vcruise 29% at Vendurance
Significant wave height	[m]	2.15
Construction material	:	steel

With these input data, a number of 120 alternative designs was roughly defined. These alternatives were further elaborated and analyzed by the CEM, taking a few system seconds of a VAX mainframe computer. After the calculations, each alternative was described by about 80 operational and hull form parameters. The parameters describe attributes related to the ship's geometry, propulsive characteristics, weight groups, static stability and seakeeping behaviour.

As this is only one run of the program, yielding already 120 alternatives to be evaluated by the designer, a spreadsheet program, offering graphics, sorting and selection functions, can be used effectively as a postprocessor. Attribute data or functions of available parameters can be added to each alternative. Weight factors can be assigned to each attribute and merit functions can be defined.

Only the alternatives that are not rejected are imported in the postprocessor. Of the total of 120 alternatives, only 75 appeared feasible, i.e. they met the basic requirements. Selections on user supplied requirements and goal constraints should be made in the postprocessor.

A comparison of the CEM results with the results obtained by the classical design approach can now be made.

Main dimensions

Feasible designs were found in the ranges listed below. The ranges listed under 'classical approach' were determined before choices regarding optimal parameters were made.

		CEM	Classical approach
Length	[m]	29 - 35	29 - 35
Beam	[m]	5.3- 8.8	6.8- 7.2
Draft	[m]	1.4- 3.5	2.3- 2.4
Depth	[m]	2.1- 4.8	3.5- 4.0
Displacement weight	[tonnes]	110 -390	150 -190

It is illustrated that the feasible design space, scanned by the CEM, is significantly greater than the same scanned by the 'classical approach'.

Selection of optimal designs

In selecting the optimal alternatives, the designer should first make a further selection of alternatives on the user supplied requirements. Some user supplied requirements can be controlled through the input data definition, such as a maximum length or a required maximum speed. It may however be possible that additional user supplied requirements are to be imposed in the postprocessor. An example of such a requirement can e.g. be a minimum required beam on deck of 6 m with regard to the berth of the dinghy. It is in this example assumed however, that no additional user supplied requirements are appropriate.

A selection should now be made, based on the goal constraints and their respective priorities. The goal constraints mentioned in the basic staff requirements are an optimal seakeeping behaviour, against the lowest possible costs. With regard to the seakeeping behaviour, only vertical accelerations in the centre of gravity and at ordinate 20 (Fore Perpendicular), as well as the added resistance in waves are estimated for head seas in the CEM. Costs are not estimated.

To be able to take these attributes into consideration, a normalized seakeeping attribute and a costs attribute should be defined in the postprocessor. This can be done on the basis of the available parameters. To this end, a normalized seakeeping parameter SEAK is defined as:

$$SEAK = w_1 ACZG_N + w_2 ACZ20_N + w_3 RAW_N$$

where:

w_i = weight factor, indicating the relative importance; $w_1=0.6$, $w_2=0.2$, $w_3=0.2$

$ACZG_N$ = average 1/10 highest acceleration in the Centre of Gravity - normalized

$ACZ20_N$ = average 1/10 highest acceleration at ordinate 20 - normalized

RAW_N = added resistance in waves - normalized.

Normalization of the distinct attributes is necessary as soon as different quantities are to be compared mutually. In this example the attributes are normalized to a value between 0 and 1, the higher number indicating a preference. In the case where the greater value of an attribute represents preference, the normalized rating R_I can be calculated from:

$$R_I = (A_I - A_{MIN})/(A_{MAX} - A_{MIN})$$

where:

A_I = attribute value of alternative i

A_{MIN} = lowest possible attribute value

A_{MAX} = highest possible attribute value.

In case a smaller value of an attribute indicates preference, R_I is defined as

$$R_I = 1 - (A_I - A_{MIN})/(A_{MAX} - A_{MIN})$$

In doing so, the higher value of a normalized attribute always indicates preference.

In the same way, a normalized costs parameter COSTS is defined as:

$$COSTS = w_4 ENVOL_N + w_5 PDD_N$$

where:

w_i = weight factor; $w_4=0.6$ and $w_5=0.4$

$ENVOL_N$ = envelope volume of the hull; LPP*B*D - normalized

PDD_N = delivered power at design speed - normalized.

The first term on the right hand side is a measure for the building costs of the ship, the second affects both the building costs and the operating costs.

The relation between normalized seakeeping behaviour and normalized costs can now be visualized (Fig. 6). It is clearly seen, that the length of the ship has the greatest effect on seakeeping in comparison to the other parameters that were varied (L/B, B/T and Cb). The greatest length of 35 m has the best seakeeping performance. Furthermore, the best seakeeping performance is not coinciding with the best cost figure (equal to 1). The relative effect on seakeeping of cutting down on costs is also quantified.

Another interesting relation is the one between the required power PDD and the envelope volume (Fig. 7). The envelope volume determined the building costs to a large extent. Here, the effect of the block coefficient on the power requirements is clearly illustrated. Although alternatives with a block coefficient of 0.40 were also defined in the input, none of these designs appeared to be feasible.

A more detailed comparison is presented in Fig. 8, showing the required power as a function of the length/beam ratio L/B. To reduce the variation in required power, only the five best rated alternatives at each L/B value were taken into account.

Based on the normalized seakeeping and costs parameters, a merit function was defined as:

$$MF = w_6 SEAK + w_7 COSTS$$

where:

w_i = weight factor; $w_6=0.4$ and $w_7=0.6$.

The merit function value of each feasible alternative is plotted against the normalized costs parameter in Fig. 9. It is clear that the length and the costs have a big effect on the effectiveness of the design.

All alternatives were sorted on their merit function value, and the three best alternatives are compared with the result obtained by the classical approach:

Parameter		Obtained from	
		CEM	'Classical approach'
Length overall	[m]	approx. 37.00	30.00- 35.00
Length waterline	[m]	approx. 35.00	28.00- 33.00
Beam waterline	[m]	5.80- 6.60	6.80- 7.20
Depth midship	[m]	2.30- 3.20	3.50- 4.00
Displacement weight	[tonnes]	120 - 140	180 - 195
Empty ship weight	[tonnes]	75 - 105	130 - 140
Deadweight	[tonnes]	40 - 65	49 - 52
Installed power	[kW]	1900 -2000	3400 -3900
Block coefficient	[-]	approx. 0.30	0.33- 0.38

Through the selection by the CEM, longer ships are found, having a smaller displacement (smaller slenderness ratio). The empty ship weight is also significantly less, probably caused by a smaller depth of the hull, and a smaller power requirement.

Two more activities are essential in the selection process as applied above. One is a validation of the results, which should take into account both the validity of the attribute analysis and the relevance of the attributes incorporated in the merit function. The second activity is aimed at an investigation of the stability of the solution for small changes in weight factors (relative importance) and in attribute ratings. The post solution analysis will not be worked out here.

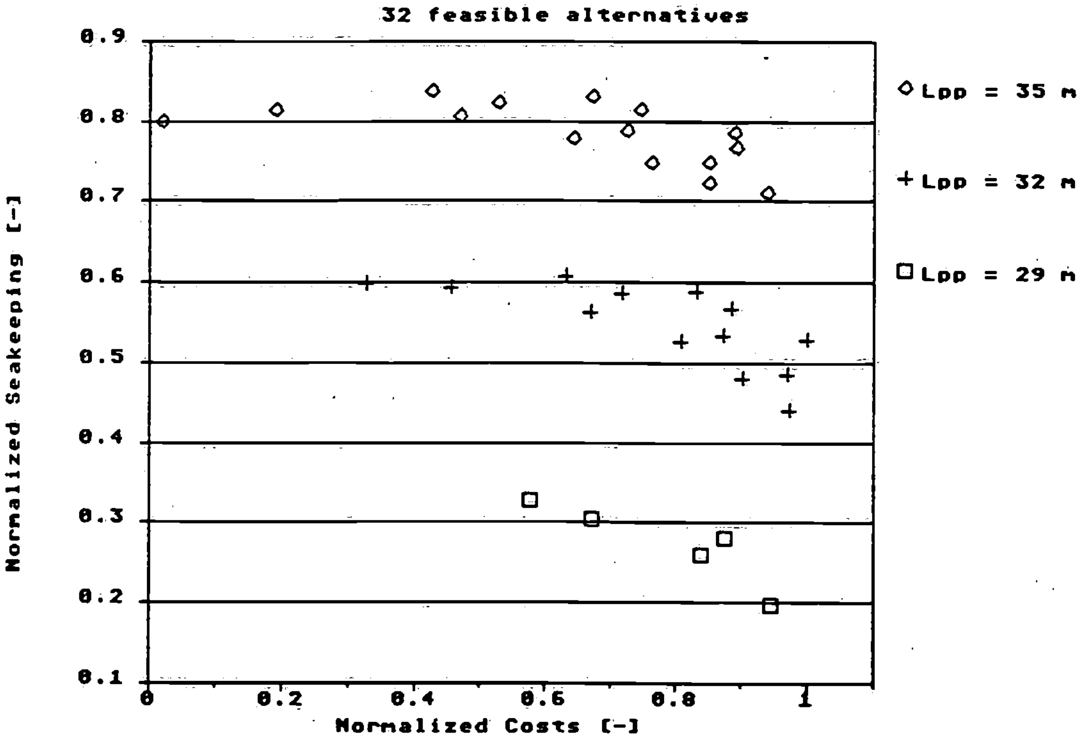


Figure 6:
Relation between seakeeping behaviour and costs.

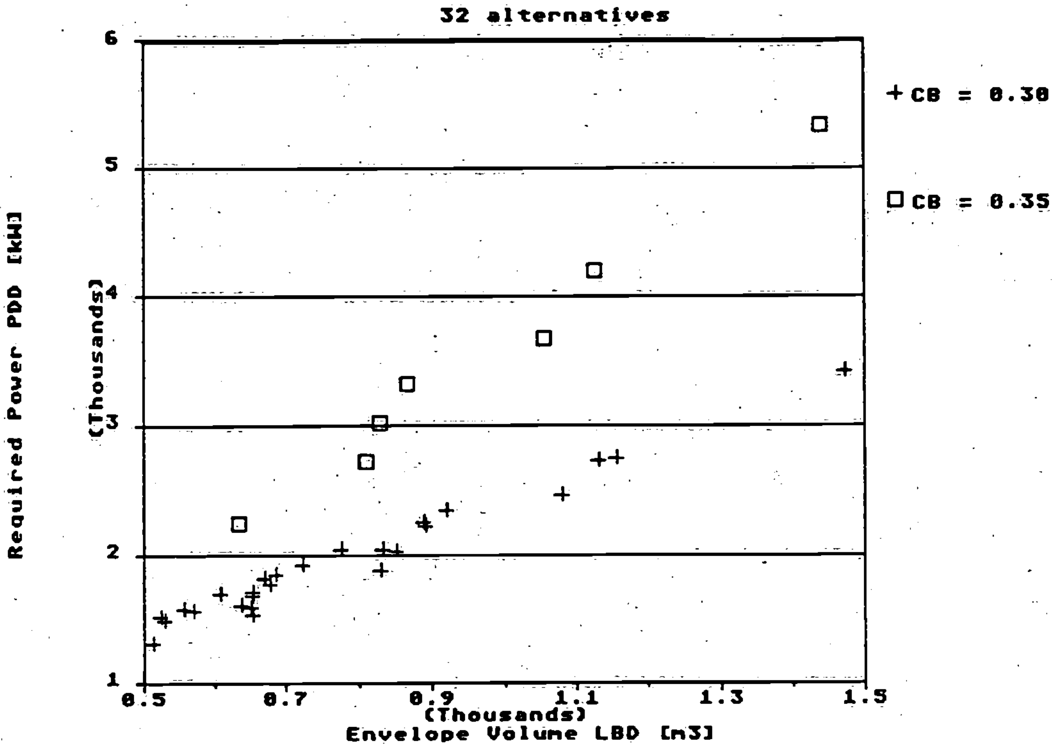


Figure 7:
Relation between required power and envelope volume LBD.

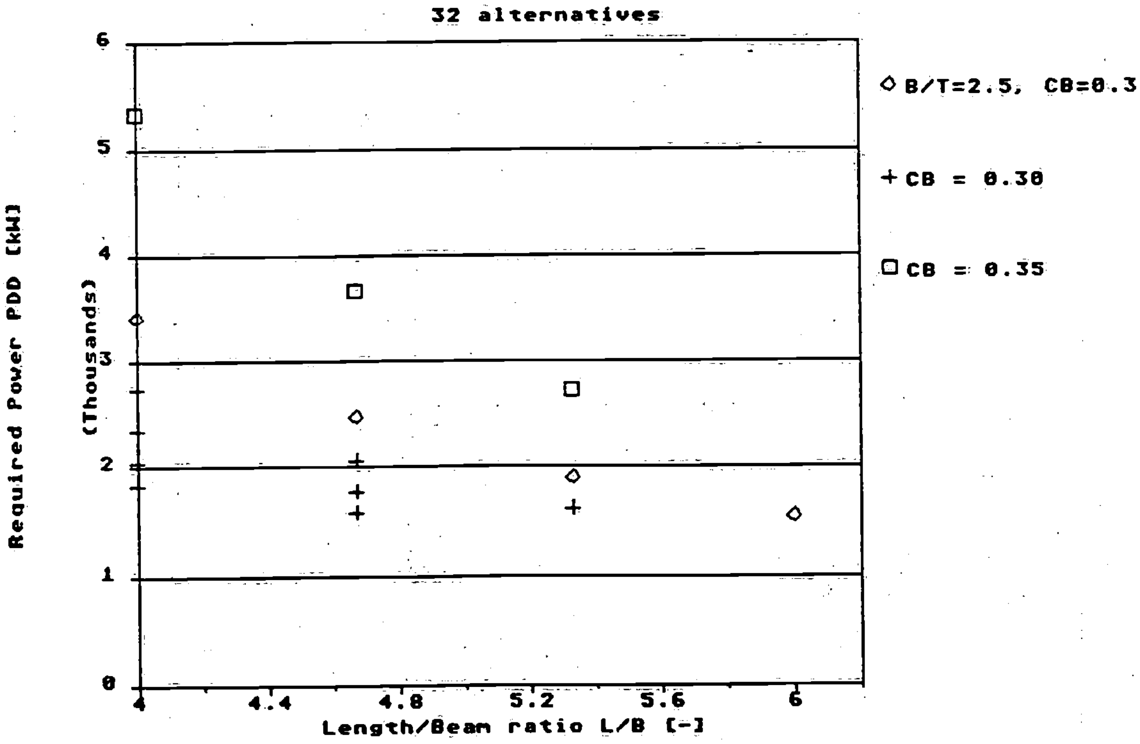


Figure 8:
Relation between required power and length/beam ratio L/B.

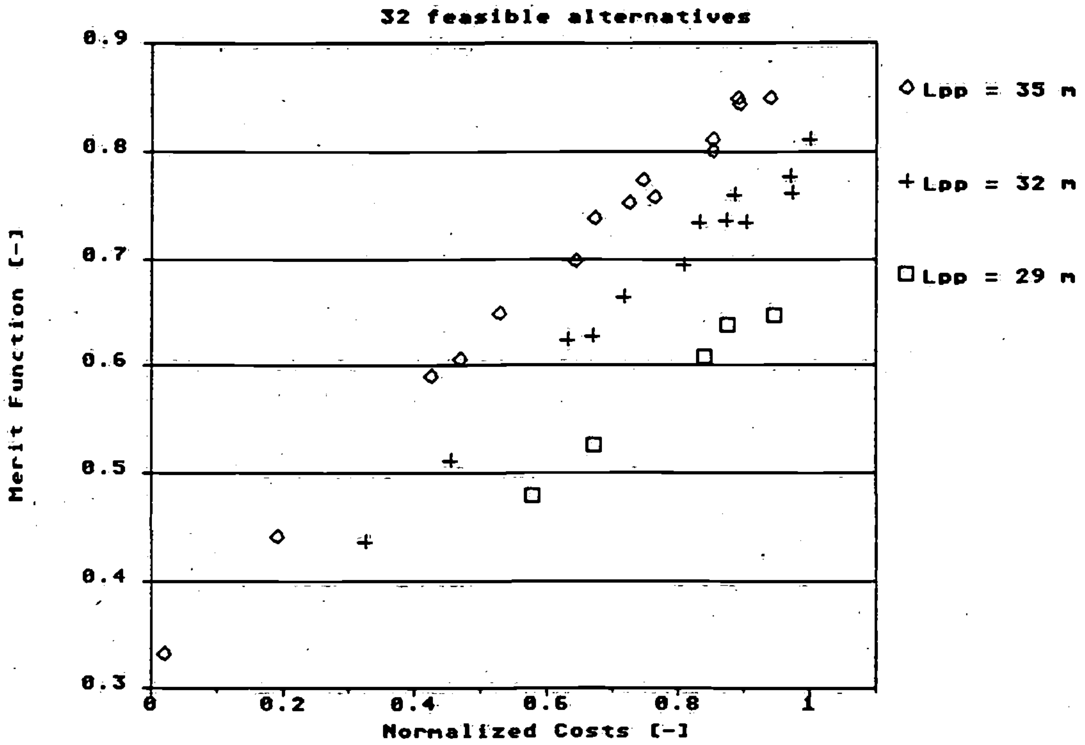


Figure 9:
Relation between the merit function and the costs.

4. CONCLUSIONS

A prototype CEM has been described, the design of which being based on the design methodologies as developed by the University of Houston [1] and by the University of Twente [2].

The CEM offers a high flexibility to the designer. This is obtained by postponing decisions and choices as much as possible to the interactive postprocessor. Only a minimum of necessary decisions is taken by the processor, which operates in batch mode.

By postponing the decisions as much as possible to the postprocessor, the designer is able to directly see the consequences of certain requirements and goal constraints, as well as the sensitivity of the designs to changes in requirements and constraints. He furthermore obtains information about their relevance.

By using a CEM, the designer has the possibility to quickly and systematically explore the feasible design space. In this way, the many decisions taken during the preliminary design, can be justified.

Systematic deviations in the program's prediction and the user's experience should be accounted for. This can either be done through the use of correlation parameters that can be defined as input, or by implementing another algorithm. Provided the algorithm needs the same input parameters, the algorithms can be replaced relatively simple.

In using a CEM, the designer can concentrate on defining a merit function and associated weight factors for the relevant attributes. This means, in correspondence to the decision model, that the accent is shifted from analysis to evaluation, from the structured part of the problem to the unstructured part. In this way, the quality of the decisions can be improved.

It is emphasized that a prototype of the CEM has been used for this study. Although for most algorithms a good indication about their accuracy in a large parameter space is available, more experience with the CEM is required to give a proper judgement about the accuracy of the whole set of algorithms. This may result in the improvement or replacement of algorithms. Furthermore, the algorithms may be adapted according to the experience of the user.

REFERENCES

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[2] Harpen, N.T. van, "The demands and preferences which the design process places upon CAD-technology", contribution to CAPE 1985, Alphen a.d. Rijn, Samsom, 1985.

[3] Beer, F. de, "The relation of technical and economical aspects in the design process for civil seagoing (governments) vessels', Government Vessels Dept., Jan. 1990 (in Dutch).

GLOSSARY OF TERMS

BASIC REQUIREMENTS: A requirement placed on the design that necessarily has to be satisfied to obtain a feasible design. If not, the design is rejected immediately. The basic requirements can be imposed by physical or juridical laws.

DESIGN FORM: The shape of a design including its components.

DESIGN FORM PARAMETERS: Those parameters which determine a design form; e.g. length, weight, etc.

DESIGN PARAMETERS: The total set of parameters describing a design.

DESIGN REQUIREMENTS: The sum of the basic and user supplied requirements.

DESIGN SPACE: A multi-dimensional space which is described by the design parameters.

FEASIBLE DESIGN SPACE: That region which is defined by the basic and user supplied requirements, within which all points satisfy these requirements.

GOAL CONSTRAINT: It represents the aspiration level of a designer for a particular quality in a design. When multiple goal constraints are specified for a design, they collectively represent the aspiration space.

OPERATIONAL PARAMETERS: Those parameters which determine an operating condition; e.g. speed, wave height, performance effectiveness, etc.

OPTIMAL SOLUTION: The best solution attainable, given the information available.

USER SUPPLIED REQUIREMENT: A requirement placed on the design by the user/designer. These requirements can be fixed or variable. A fixed requirement imposes one value to a parameter. A variable requirement imposes a range to a parameter.