UNIVERSITY OF SOUTHAMPTON

TECHNICAL DESIGN METHODOLOGIES FOR ADVANCED FAST FERRIES

by

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Master of Philosophy

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ABSTRACT

FACULTY OF ENGINEERING AND APPLIED SCIENCE
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The objective of the work has been to establish a technical design methodology for high speed ferries. The research programme comprised the development of a technical design framework for concept design of high speed ferries.

The approach has been to extend and build upon an existing research programme. In particular, this has entailed a fundamental examination and update of the section of the methodology dealing with estimation of dimensions, together with the establishment and manipulation of an effective mass estimate. Improvements and updating in the cost estimate have also been carried out.

Overall, the technical design framework has been established. It uses a flexible modular structure, allowing the quick generation of feasible designs. One of its major characteristics is that it uses a novel area based approach for the generation of a set of main dimensions, based on carrying capacities.

As high speed ferries are a relatively recent development, there is a lack of available systematic data and relevant techniques. Most major calculations are therefore performed using specialised data and tools created in the research programme, together with further modifications and updates. This allows the full investigation of the two most common hull configurations, namely monohulls and catamarans, which currently make up the majority of fast ferries.

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NOMENCLATURE AND UNITS

English Alphabet

A_P	Total passenger area (m^2)
A_S	Seating area (m^2)
A_V	Vehicle area (m^2)
B	Breadth (m)
b	Demihull breadth (m)
C_B	Block coefficient
C_F	Coefficient of frictional resistance (ITTC-57 Correlation line)
C_H	Hull costs (million US$)
$C_{M/C}$	Monohull / Catamaran total building costs (million US$)
C_{MA}	Machinery costs (million US$)
C_O	Outfit costs (million US$)
C_R	Coefficient of residuary resistance $\left[R_R / 0.5\rho A V^2\right]$
D_{OA}	Overall depth (m)
E_C	Equipment numeral for catamarans
E_M	Equipment numeral for monohulls
F_N	Froude number
L_{OA}	Length overall (m)
L_{WL}	Length on waterline (m)
N_{CAR}	Number of cars
N_{CREW}	Number of crew
N_{DECK}	Number of decks
N_{PAX}	Number of passengers
P_B	Installed power per propulsion unit (kW)
P_I	Total installed power (kW)
P_S	Total service power (kW)
R	Range (nautical miles)
R_n	Reynolds number (VL/ν)
S	Separation of centrelines of demihulls (m)
SFC	Specific fuel consumption (kg/kW.h)
T	Draught (m)
V_S	Service speed (knot)
W_D	Diesel engine weight (tonne)

W_{GB}	Gearbox weight (tonne)
W_{GT}	Gas turbine weight (tonne)
W_H	Hull weight (tonne)
W_O	Outfit weight (tonne)
W_P	Propulsion weight (W_D (or W_{GT}) + W_{GB} + W_{WJ}) (tonne)
W_{RM}	Remaining machinery weight (tonne)
S_A	Wetted surface area (m^2)
W_{TM}	Total machinery weight (tonne)
W_{WJ}	Water jet weight (tonne).

Greek Alphabet

Δ	Displacement (tonne)
ν	Kinematic viscosity (m^2/s)
ρ	Density (assumed 1.025 t/m^3 for salt water)
∇	Displacement volume (m^3)

Abbreviations Used in the Computer Program & Examples of the Methodology

ABC	Approximate building cost (million US$)
AP	Total passenger area (m^2)
AS	Seating area (m^2)
AV	Vehicle area (m^2)
B	Breadth (m)
BC	Building cost (million US$)
BH	Demihull breadth (m)
BHOT	B_H / T
BOT	B / T
CB	Block coefficient
CGB	Gearbox cost (million US$)
CH	Hull cost (million US$)
CM	Total machinery cost (million US$)
CME	Main engine cost (million US$)
CO	Outfit cost (million US$)
CP	Propulsion cost (million US$)
CRM	Remaining machinery cost (million US$)
CWJ	Water jet cost (million US$)

D	Depth overall (m)
DIAM	Propeller diameter (m)
DISP1	$\Delta_1 = L_{WL} \times B \times T \times C_B \times \rho$ (for monohulls), $\Delta = 2 \times L_{WL} \times b \times T \times C_B \times \rho$ (for catamarans) (tonne)
DISP2	$\Delta_2 = LS + DWT$ (tonne)
DW	Deadweight (WFL+WFW+WCR+WPAX+WVEH) (tonne)
EFF	Efficiency (η)
FN	Froude number
LB	$L_{WL} \times B$
LOA	Length overall (m)
LOB	L_{WL} / B
LOBH	L_{WL} / B_H
LOD	$L / \nabla^{1/3}$
LS	Lightship (WH+WM+WO) (tonne)
LWL	Length on waterline (m)
NCAR	Number of cars
NCREW	Number of crews
NDECK	Number of decks
NE	Number of engines
NPAX	Number of passengers
PD	Delivery power (kW)
PE	Effective power (kW)
PI	Installed power (kW)
R	Range of vessel (nautical miles)
RN	Reynolds number
RPM	Engine speed (rpm)
S	Separation of centrelines demihulls (m)
SFC	Specific fuel consumption (kg/kW h)
SOL	S / L_{WL}
T	Draught (m)
VS	Service speed (knots)
WCAR	Car weight (tonne)
WCREW	Crew and effects weight (tonne)
WFUEL	Fuel weight (tonne)
WFWPROV	Fresh water and provisions weight (tonne)
WGB	Gearbox weight (tonne)

WH	Hull weight (tonne)
WM	Total machinery weight (tonne)
WME	Main engine weight (tonne)
WO	Outfit weight (tonne)
WP	Propulsor weight (tonne)
WPAX	Passenger and luggage weight (tonne)
WSA	Wet surface area (m^2)

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1. INTRODUCTION

1.1 DEFINITION OF RESEARCH

High speed marine vessels include all those craft used for marine transportation requiring a high cruise speed. In recent years they have received huge attention due to owners increasing demands for achieving faster and more efficient vessels. Designers quest is therefore to obtain suitable innovative designs.

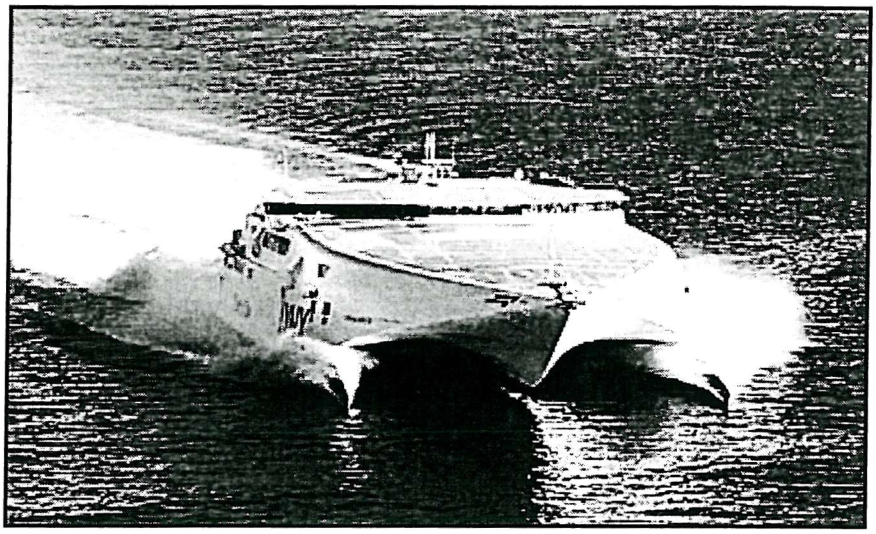


Figure 1.1: A Vehicle-Passenger Catamaran.

The ferry industry has, in the past few years, seen strong competition amongst builders and designers to obtain the best vessel for potential owners which has resulted in many different and varied designs, including hydrofoils, air cushion vehicles, and wing in ground effect craft. However, monohull and catamaran vessels still seem at present to be the most commercially effective.

The process of designing a vessel follows a series of iterations repeated a number of times until a final optimum design is achieved. The initial iterations could be termed the preliminary design of the vessel. From initial parameters defined by the owner, such as maximum payload, cruise speed, or others, the naval architect must determine dimensions for this new design, and develop from there the full design for a vessel. With the rapid increase in the use of high speed vessels it is apparent that there is a need for research in this area. As a result of these developments a research programme was initiated at the University of Southampton, aimed at addressing this subject and defining possible ways of arriving at rationalised solutions.

Previous research, Karayannis [16], was concerned with preliminary technical ship design and decision making processes for high speed displacement vessels. The current work extends this study including the form of data, regressions and formulae that can be used for the initial design estimations of feasible monohull and catamaran high speed ferries.

Figure 1.2 illustrates the overall framework for the whole methodology of the technical design process in the current research programme. The dotted boxes represent issues to be addressed in the future (work ongoing as separate research programmes) out of the scope of this thesis.

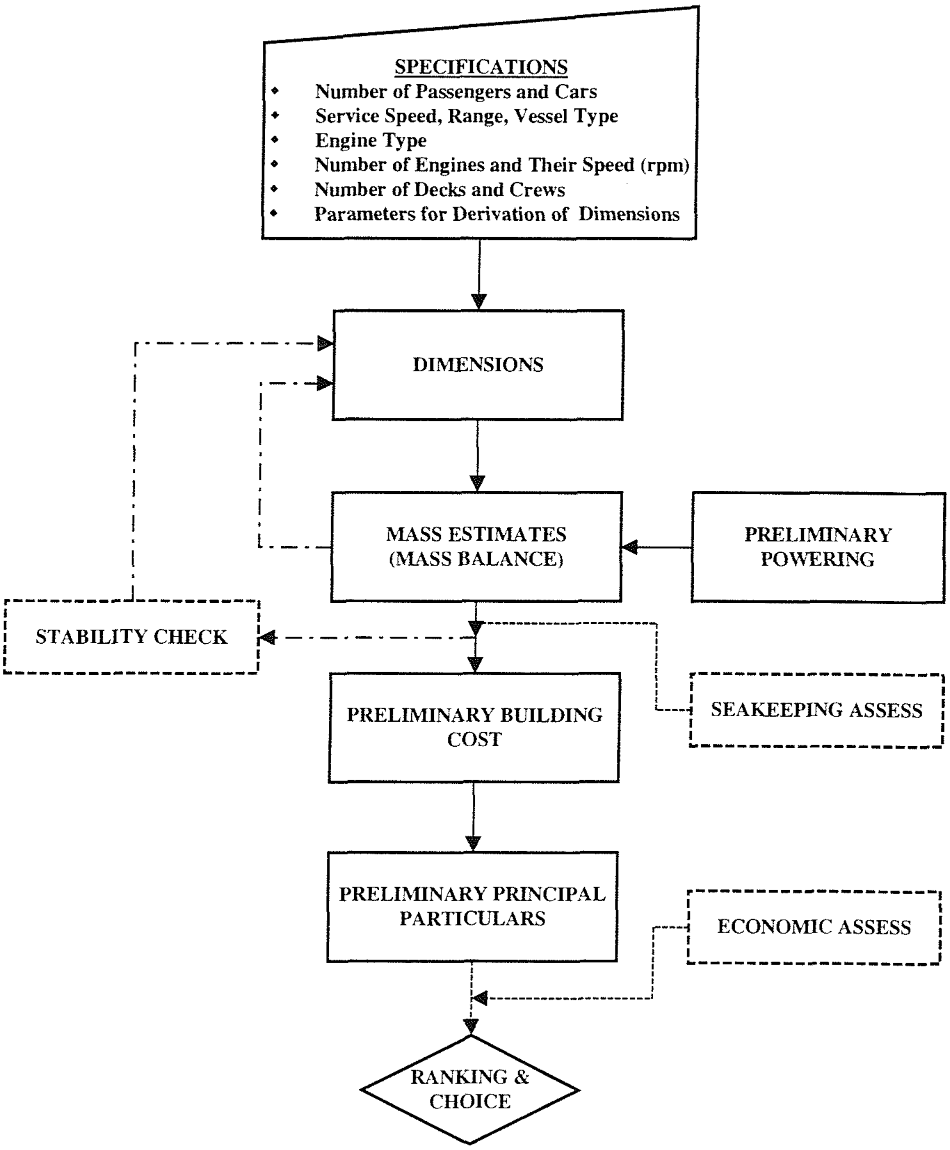


Figure 1.2: Overall Framework Flowpath.

A general methodology for the derivation of dimensions is presented in the chapter 2. The attached source database contains a comprehensive number of fast ferries of current technology operating around the world, as well as proposed new designs. The main objective has been to develop an algorithm for the derivation of main dimensions, which will ensure reliable estimates of initial dimensions employed in the overall design of fast ferries.

The estimation of power is described in chapter 3. The proposed methodology provides reliable results for the initial development of feasible monohull and catamaran high-speed ferry designs as well as an estimation of machinery masses.

Chapter 4 describes in detail the estimation of masses. The approach has been based on a database generated from historical data as well as parametric hull estimates based on classification society rules for parent monohulls and catamarans. Machinery mass data has been assembled together with data for performing outfit mass estimates. These masses and the estimation of total mass are included as feedback in the dimensions algorithm in order to verify a balance of masses, or to modify the dimensions accordingly until a balance is achieved.

A detailed building cost estimation is presented in chapter 5. The chapter contains hull, outfit and machinery costs. Chapter 6 embraces parametric design studies and a discussion of the results whilst chapter 7 draws together conclusions and recommendations.

The generated design database is given in Appendix I.

The design methodology is integrated in a computer program, which contains the main components of the preliminary technical design of a high speed ferry. The program provides main dimensions, estimation of masses, powering and building costs for monohulls and catamarans. A more detailed description of the program is included in Appendix II.

1.2 LITERATURE REVIEW

1.2.1 Background

The principal objective of this work has been to establish a design methodology for high speed ferries. The overall research programme comprises developing a technical design framework for high speed ferries.

The approach has been to extend and build upon the earlier work of Karayannis [16]. In particular, this has entailed a fundamental examination and update of the section of the methodology dealing with estimation of dimensions of fast ferries, together with the establishment of an effective mass estimate. Improvements in the estimate of building costs have also been introduced. Other important contributing topics, such as seakeeping, are to be dealt with in separate but complimentary research programme. These developments have been achieved by means of various references and sources of information which are critically reviewed in the following paragraphs.

Overall, a technical design framework is established. It employes a flexible modular structure, allowing the quick generation of feasible designs which can then be compared using the decision making module for further study.

As high speed ferries are a relatively recent development, available systematic data and relevant design techniques are sparse. Most of the current major calculations are therefore performed using data and tools created within the Department of Ship Science, together with further modifications and updates. Currently, this allows the full investigation of the two most common hull configurations, namely monohulls and catamarans, which make up the majority of fast ferries. In the event that further data becomes available, other investigations could be conducted for different hull configurations using the same methodology. The following paragraphs review published material of particular relevance to the present study.

A description of a parametric design trade-off study and the results of a preliminary design for a 50 knots SES passenger car ferry is given by Joo et al [14]. The parametric analysis presented begins by determining the optimum dimensions and subsystems for an initial set of design requirements. A trade-off study is then conducted to evaluate the influence of changing the design requirements, including variations in design speed, sea state and operational range. Parameters investigated include ship length, ship beam, engine type, propulsor type and type of structural material. This particular study proves that rational designs could be developed for conditions up to sea state 5. Following the trade-off study, a set of final design requirements were established and ship dimensions were selected for further design development. The preliminary design for an SES passenger car ferry currently being developed and some leading particulars of this design were presented in the paper.

A similar approach has been used by Litai [18]. The author gives an introduction to the design, trial and operation of the "Hong Xiang" an SES ferry. Concept analysis and calculations are followed by a model test programme. Several technical features were adopted in the design.

Litai considers the design to be a success, and advocates the implementation of an air cushion catamaran in situations where conventional catamarans had previously been used. The benefits envisaged are those of improved seakeeping ability and economic results.

Kraus et al [17] present a basic cargo catamaran design. The design has been created by means of comparative studies of three chosen systems. Cost and freight rates are both comparative factors to determine the best system. The main dimensions and required freight rates for this vessel are calculated and compared with actual air freight and shipping rates on specific routes.

Trincas et al [28] focus on the analysis of passenger and car traffic moved by shortsea shipping connecting Greece to Italy, using an improved multi-criterial decision making methodology for concept design of fast monohulls. This paper is a useful reference for outfit mass data and should be considered in future analyses.

Trincas et al [29] use a similar design tool as that of Joo et al [14]. It deals with a concept development and feasibility study of a large catamaran designed for the fast sea transport of passengers and vehicles in the medium range Mediterranean routes, intended to be more profitable than present fast monohulls. The concept design was carried out by means of a multi-attribute decision-making procedure to generate and select the best possible solution. Two variants of the selected design, one assuming a gas turbine as a faster solution and the other one assuming a diesel engine for the slower alternative, were then submitted to a feasibility study. An economic trade off study was accomplished to compare the investment worth of the projected catamaran to the 'Aquastrada' fast monohull. It is stated that the feasibility study provides good economic results. As the previous reference, this paper is also a useful source of outfit mass data, and should be taken into account in future studies.

Warren et al [30] concentrate on the choice and installation of water jets from a ship designer's point of view. It is extremely useful to expand knowledge on water jets.

The classical, Watson et al [31], reviews the design methods presented in 1962. It extends the proposed changes in ship design, and suggests some further developments to them. It considers how the relationships between dimensions, the coefficients and quoted approximate formulae have changed and why. This classic early paper is noted mostly for the much used formulae and initial weight estimations for conventional displacement vessels. Although, it was originally developed for conventional vessels, with caution and suitable alterations this work can be adapted for fast vessels as will be shown throughout this work.

1.2.2 Technical Design Studies

1.2.2.1 Creation of Database

An initial database was created employing data obtained from an extensive literature search. The database, included in Appendix I, was generated by modifying and expanding an initial database from a previous research programme, Karayannis [16]. The vast majority of data on existing fast ferries and new constructions as well as proposed new designs was found in journals, mainly from the Fast Ferry International journal, but also Ship and Boat International and Naval Architect journals. Measurements, calculations and manipulation of the original data were required in order to derive sets of comparable vessel data suitable for the database.

A large number of high speed ferries are logged into the database. Most of them are already operating throughout the world, while some are at the stage of construction, or at least completed design. The vessels are divided into two major categories, passenger-only and vehicle-passenger carriers. A secondary distinction is made between monohulls and catamarans. Therefore four separate databases were created, namely for passenger-only monohulls (PM), passenger-only catamarans (PC), vehicle-passenger monohulls (VM) and vehicle-passenger catamarans (VC). It should also be noted that the database concerning catamarans also includes separately the other multihull types even though no algorithms have as yet been developed for them.

All relevant information was included in the databases, namely dimensions, weights, capacities, speed, range, propulsive installations, and other additional information. Furthermore, ratios were derived in order to be used in the design procedure. A significant factor was the availability or not of general arrangement plans since passenger and vehicle areas can have important influence in determining the size of each vessel. Therefore, for the vessels whose general arrangement plans were available, areas were measured and ratios calculated.

The number of vessels in the database (also included in Appendix I) is adequate to allow reliable analysis of the relevant data. The significant features of the data are included in the thesis as tables or design equations.

1.2.2.2 Estimation of Dimensions

An introduction to alternative ways based on modern hull forms, to estimate main dimensions and coefficients in preliminary ship design for conventional ships is given by Guenther [2]. In this paper, the desired technical characteristics have been achieved with ships of greatly differing lengths. The length is determined from similar ships or from formulae and diagrams derived from a database of similar ships. The resulting length then provides the basis for finding the other main dimensions. Although the technique used in the paper is reasonably accurate, it is not suitable for research dealing with sparse data, such as the present one.

Karayannis et al [15] present systematic data and propose algorithms and formulae, which can be used for investigations of high speed ferry designs of monohull and catamaran configurations. These include initial estimations of technical aspects such as main areas and dimensions, and hull, machinery, outfit and total masses, as well as acquisition costs.

Molland et al [19] develop a global design model for the derivation of the technical and commercial attributes for monohulls and catamarans, together with the investigation of the potential of alternative decision making techniques and the implications of incorporating these into the overall concept exploration framework. Molland et al [20] describe the overall framework as well as details of the design modules and discuss the implications of applying different decision making techniques to select the more suitable vessel type and specification for a specific role.

1.2.2.3 Estimation of Masses

Cordano [5] gives a broad idea of the design criteria adopted in the development of the SES 500 – Fincantieri fast ferry. The author considers some special parameters for a technical selection and summarises these parameters as seakeeping with particular regard to the passenger comfort and transport efficiency. The paper contains costing estimations for construction and operation, and concludes with stating that the resulting design has an optimum size and high speed with a limited power and low operating cost.

Czimmek's [6] work is based on a conceptual design for a large surface effect ship (LSES), which was developed by Newport News Shipbuilding and Dry Dock Company (NNS) with the assistance of Marine Dynamics. Design optimisation and sensitivity studies were performed, using the NNS in-house surface effect ship optimisation program. In order to produce a viable design point, which could be evaluated for productivity and risk, computer-based parametric studies were performed with cushion length, cushion beam and cushion pressure as variables.

Both these last two papers contribute in expanding the understanding of the methodology in concept design.

In Daidola [7], a standard for weight definition and an approach to weight control are presented for modern motor yachts and other craft. It includes a definition of weight and loading conditions for these vessels, which can be related to attainable vessel speeds. The weight control plan addresses concept though detail design, construction, delivery and service life. The author states that the procedure is adaptable to all types of hull structural material. The weight curves developed in this paper are obtained from the regression of vessel data. The paper presents a formal approach to weight control of craft of all types. The author states that, although it may seem a substantial and onerous system to apply to all craft designs, especially where little has been done before, in reality the concepts are few and the analysis and reporting efforts can be tailored to the needs of any project.

Fan et al [10] investigate the options available to the designer dealing with the structure of a high speed vessel, under the current regime of prescriptive classification regulations. Three different classification societies were selected for the investigation. Their conceptual approach to structural design is identified and compared, and detailed scantlings are derived using their rules for a representative fast catamaran. Based on these, a rudimentary comparison of the structural weight of a unit length of midship section is then presented. The paper concludes with a proposal for a new unified philosophy for the design of efficient high speed craft with consistent levels of safety. The feasible design studies from this paper have been included into the current study. The results were very useful when considering mass estimations.

Hughes [12] presents a strategy for achieving a first principles optimum structural design of a ship using modern computer-based tools, and demonstrates its feasibility with a large monohull fast ferry. The paper has two major goals; first of all to present a strategy for achieving a first principles optimum structural design of a ship (especially a high performance ship) using modern computer-based tools and second, to demonstrate the strategy for a large (100 m, 1000 t) monohull fast ferry, first using all aluminium and then adapting the design to be all composite. Two designs are produced with the 'Maestro' program, which is capable of performing optimisation based on trade-off of cost and weight. This particular reference demonstrates how computer-based design tools and a first principles approach can be used to obtain an optimum structural design of a high performance ship such as a fast ferry, and how these tools are evolving to handle composites as well as metals.

The previous research carried out at the University of Southampton, in the Department of Ship Science for preliminary technical fast ferry design and decision making process provides the major basis for the present research programme. Karayannis et al [15, 16, 19, 20] contain the most useful information in estimation of masses as well as derivation of dimensions. These sources will be mentioned throughout the thesis where necessary.

In Sainz [23], a tool is developed to determine the components of a structural design, and a mass estimate, using the newly created Lloyd's register 'Special Craft' software. The estimations have been carried out only for monohulls and catamarans. This particular reference is a major source of hull mass estimation calculations, and uses a design tool similar to that of Fan et al [10] and Watson et al [31].

Vrontorinakis [29] assesses diesel engines and gas turbines rated for the propulsion of fast ferries though the use of nineteen common operating parameters. Their technical attributes are compared with each other in four power ranges, and in multiple installations specifically for chosen catamarans and monohulls. Elements of propulsors (water jets) are also generally discussed, and the matching requirements are investigated for all cases. It is, in general, an important reference of machinery mass and cost data.

Wood et al [32] provide a major contribution to the database generated in the current research programme, as it contains existing ship data for mass estimation and mass balance calculations. It discusses some of the design issues including the IMO High Speed Craft Code, classification and problems encountered when the British-designed 318 passenger, 45 knot TRICAT ferry was adapted for construction and operation in the United States. The paper also describes some of the design issues involved in implementing the high speed craft within the framework of passenger ferries under 100 GT, including lowering the tonnage to be less then 100 GT, the use of Det Norske Veritas for classification plan approval, and the use of US suppliers of materials and equipment.

1.2.2.4 Estimation of Powering

In the earlier stages of the research programme, Karayannis [16], the calculation of calm water resistance was performed using existing standard series data. The module included data from the NPL Series Bailey [1], Series 64 Yeh [34] and Southampton Extended NPL Molland et al [22] in monohull mode. A new catamaran mode was implemented including Series 64 and Molland et al [21]. Molland includes the catamaran series tested at Southampton, one of the most comprehensive sets of data available. The extension of the analysis to include catamarans, offers a wider range of block coefficients and higher $L/\nabla^{1/3}$ ratios. Detailed information about these particular sources of information is given in the following paragraphs.

A series of high speed monohull model hulls of round bilge shape designed for operation in the Froude number range, F_N=0.3-1.2 was tested at NPL Bailey [1]. The monograph presents data that can be used at the early design stages of marine vessels such as heavily loaded workboats, fast patrol craft and small naval ships. Resistance and source limited propulsion data are presented in a simple form enabling predictions to be made of the calm water speed and power requirements for a given design, a worked example is appended to illustrate the process. Stability underway, manoeuvring and seakeeping characteristics are discussed in the light model test results obtained from a representative selection of designs based on the series.

Yeh [34] reports the results of the hull resistance tests of Series 64 models. After preliminary investigation, 27 models of conventional round bilge hull forms were designed, constructed, and tested at the David Taylor Model Basin to gain information for a wide range of length-displacement ratios and speed-length ratio.

In Insel et al [13], a wide range of hull separations was tested and, overall, the experiments covered over 40 model configurations, each over a speed range up to a Froude Number of unity. Molland et al [22] extended the parametric investigation to cover changes in Breadth/Draught ratio (B/T) and a wider range of Length/Displacement ratios ($L/\nabla^{1/3}$).

Molland et al [22] summarizes an experimental investigation into the resistance components in calm water of high speed displacement catamarans with symmetric demihulls. The experimental programme was a development and extension of an earlier work in which a small series of three catamaran models were tested. Total resistance, running trim, sinkage and wave pattern analysis based on multiple longitudinal cut techniques were carried out for ten round bilge hulls derived from the NPL series. The tests were conducted over a Froude number range of 0.2 to 0.1 and separation to length ratios of 0.2, 0.3, 0.4, 0.5 and infinity. The results of the investigation provide a better understanding of the components of catamaran resistance including the influence of hull separation, length-displacement ratio and length-beam ratio over a wide range of Froude numbers.

These two main references on the resistance of high speed displacement catamarans have been used by Buckland [3] to provide data for the NPL and Series 64 round bilge series is an alternative form, using interference factors. Using the references as the sources of data, Buckland produced a rationalised resistance estimate procedure for both catamaran and monohull configurations to be utilized at the preliminary design stage. This procedure has been applied in the current work using the NPL Series for illustration.

Molland et al [21] describe further model tests on a catamaran in calm water with a hull form based on Series 64 round bilge hull form. The model was tested in monohull form and at two hull separations in catamaran configuration, in each case over a speed range up to a Froude number of unity. The information collected and represented in the report contributes to a further understanding of resistance of catamarans and provides resistance data for practical use at the preliminary design stage. The investigation provides an extension to the available resistance data for this vessel type, and the results are broadly similar to those for other round bilge forms. The catamaran/monohull resistance interference factors are also similar to other forms. This offers the potential for the development of general interference factors, which would not have a significant dependence on the particular hull shape.

To summarize, Bailey [1], Yeh [34], Molland et al [21] and [22] provide a wide range of data for round bilge monohulls and catamarans and provide the basis for the powering estimates in the current research programme.

Guenther [11] describes preferred prime mover choices for high speed marine transportation. It also gives details about compact high speed diesel engines and aero-derived gas turbines.

Svensson [24] and [25] provides information on water jets, and the advantages and disadvantages when selecting water jets as propulsors.

1.2.3 Costs Studies

The building cost of a ship is a function of several variable types such as technical, physical, managerial, financial, political and temporal. Its complete estimation calls for inputs from a range of disciplines. From the size of the vessel (L, B, D, T and C_B) and speed, V, the designer can estimate service propulsive power, P, and a first estimate of light displacement, consisting of separate values of steel, outfit and machinery weights. This stage is reached in the normal course of the early design procedure. At this point, given an indication of current labour and material costs, a preliminary costing can be achieved, as will be shown later. The reasons for costing at this early stage are to get an idea of the capital investment involved and to see how the cost might be affected by altering any of the principle variables, when the design is still sufficiently flexible.

The current research reported in this thesis involves costing at the building cost stage. Most of the calculations have been carried out by use of the methodology and data mentioned earlier. Other relevant references for the calculation of building costs are critically reviewed next.

Caryette [4] is a classical and much quoted work, which proposes a method for assessing the approximate capital cost of merchant ships at the very early stages of design. It is intended as a guide to ship designers and others who may wish to know the ship building cost at the beginning of a new project, and how it changes with alterations to principal design variables such as dimensions, weights, powering or carrying capacity. The outcome of the paper was to show that, there is an equation suitable for a wide range of merchant ship types, large or small, fast or slow. The author shows that the dimensions and weights largely determine the steelwork and outfit costs, and powering governs the machinery cost. The method described in this paper has been applied to merchant ships, but its philosophy can be expanded, and its costs adjusted and updated to suit fast ships, or any large marine structure.

Vrontorinakis [29] assesses diesel engines and gas turbines suitable for the propulsion of fast ferries though the use of 19 common operating parameters. Their technical attributes (power, mass, cost, etc.) are compared with each other in four power ranges, and in multiple installations specifically for chosen catamarans and monohulls. Elements of propulsors (water jets) are also generally discussed, and the matching requirements are investigated for all cases. The prime movers are utilized in their speed groups 35, 40 and 47 knots, which include a catamaran and a monohull each. Alternative engine installations are assessed technically, for the specific group requirements, and economically for a ten year period. Both average annual cost and net present value methods are used to choose the best installation for each ship. The thesis concludes by giving information about the advantages and disadvantages of the prime movers, as well as of the alternative engine installations for the catamarans and monohulls. Wright [33] describes the various types of high speed craft (air supported, foil supported, displacement hull, planing hull), and analyzes their suitability for certain passenger routes in different operating environments. The author also compares the transport and commercial efficiencies of a number of existing craft of mixed sizes and services. It concludes with a discussion on the economics of high speed craft service and the many factors that bear upon optimum craft selection for a particular route and operating environment.

1.2.4 General Discussion

A survey of relevant literature on the fields related to this research programme has been critically reviewed. This includes references on the various aspects of design, particularly in the conceptual and preliminary stages.

High speed ferries require a specialised approach to their concept design. This is due to a number of special characteristics these craft possess, mainly; the wide variety of hull configurations and types available for high speed ferry services and the subjective nature of passenger requirements which can affect the commercial potential of high speed ferries.

There is a lack of available historic data or systematic data as well as design tools and techniques for high speed ferries. Existing published data and tools for conventional vessels cannot be directly applied to high speed ferries since they possess distinct characteristics such as lightweight construction materials and different economic parameters. These vessels represent a relatively recent development. There is therefore scope for a systematic design methodology for high speed ferries. The methodology must be both robust and flexible in order to cope with this relatively recent but rapidly developing vessel category.

2. DIMENSIONS

2.1 BACKGROUND

The first step in the ship design process generally entails the calculation of an initial set of main dimensions. Main dimensions can have significant effects on major design aspects of the vessel, such as masses, powering and costs. Determining these main dimensions and ratios is therefore particularly important for the overall design. Historic data provide the starting point in their estimation process. Once a set of these dimensions has been selected it may then be modified if basic aspects such as masses are not adequate.

The main parameter influencing the initial set of main dimensions is the capacity of the vessel. This is obvious since carrying capacity directly affects the overall size of any ship. The use of this main parameter is also desirable from a practical point of view as it is, probably together with speed and range, the more likely basic requirement of a shipowner or an operator.

Karayannis's [16] study revealed that passenger and vehicle capacities seem to be the only parameters influencing the derivation of an initial set of main dimensions. Froude number, as a function of speed, did not show any significant correlation with the main hull ratios, such as L/B, B/T or $L/\nabla^{1/3}$. This can be clearly seen by the data plots of L/B against Froude number in Figures 2.1 and 2.2. The effect of speed on hull coefficients and ratios is therefore not included in the first estimate of dimensions although it is included indirectly in the power estimate and mass balance.

Further analysis of the database made it clear that an area based approach should be applied for the estimation of an initial set of main dimensions, Karayannis [16]. The effect of cargo capacity on main dimensions of the vessel that can be seen in Figures 2.3 to 2.6 follows this approach. All these figures are dealt with in sections 2.1.1 and 2.1.2. An overall description of the approach is described in section 2.2.

Karayannis's method for deriving an initial set of main dimensions was modified to incorporate the estimation of an initial depth (D), which, as will be seen later, increased the accuracy of the preliminary mass calculations. New modified estimated dimensions can then used to calculate an initial lightship and deadweight for passenger-only monohulls, passenger-only catamarans, vehicle-passenger monohulls and vehicle-passenger catamarans.

As stated earlier, a database including a reasonable number of high speed ferries had been created from the analysis of historic data. The database was modified and extended (around 40%) during the current study. Detailed explanation about the database can be found in Appendix I. The new database coefficient ranges are given in Table 2.1.

2.1.1 Passenger-Only Monohulls and Catamarans Database

The parameters employed during the derivation of initial main dimensions are related to the cargo capacity of the vessels. As mentioned earlier, the estimation method is based on a cargo area based approach. The parameters corresponding to passenger monohulls and catamarans are seating area (As), passenger number (Np), passenger area (Ap) and $L_{WL}\times B$. The following part of this section explains the use of these parameters and how are they included into the study.

As/Np coefficient determines the level of accommodation quality in terms of area provided to passengers. Figures 2.3.a and 2.4.a display the correlation between seating area (As) and number of passengers (Np) for passenger-only monohulls and catamarans respectively. In the database, this coefficient ranges between As/Np=0.55 to 0.75 for passenger-only monohulls, and As/Np=0.55 to 0.85 for passenger-only catamarans. This is shown in the figures by including the linear As/Np=0.55, 0.65 and 0.75 trend lines for passenger-only monohulls and As/Np=0.55, 0.70 and 0.85 trend lines for passenger-only catamarans.

The As/Np range is not the same for passenger catamarans and monohulls. The difference could show that the quality of accommodation on passenger catamarans might be higher than on passenger monohulls. This could be caused by fare prices, journey range, or the frequency of use by certain group of passengers.

The coefficient Ap/As allows the designer to select the desired amount of additional spaces used by passengers. The correlation between seating area (As) and total passenger area (Ap) for passenger-only monohulls and catamarans is included in Figures 2.3.b and 2.4.b respectively. This coefficient varies between Ap/As=1.1 and 1.3 for both passenger-only monohulls and catamarans. This is reflected in the linear Ap/As=1.1, 1.2 and 1.3 trend lines.

Figures 2.3.c and 2.4.c illustrate the relationship between $L_{WL}\times B$ and total passenger area (Ap) for both passenger-only monohulls and catamarans. The obtained regression equations 2.1, 2.2 give a very good correlation between prediction and response (in most cases $R^2>0.9$). The value R^2 representing the reliability of the trend line, $R^2=1$ indicating a perfect correlation.

This means that the algorithm is reliable and its outcome can be trusted as a good initial set of dimensions for the current method of estimating mass, hence high values of R^2 are indication of a good fit to data for the equation.

The regression for passenger-only monohulls is given as follows.

$$L_{WL} \times B = 146 + 1.86 \cdot 10^{-3} \cdot A_P^2 \qquad R^2 = 0.99 \qquad 2.1$$

Whereas the regression for passenger-only catamarans is,

$$L_{WL} \times B = 138 + 0.910 \cdot A_P \qquad R^2 = 0.76 \qquad 2.2$$

The design algorithm is covered in section 2.2.

2.1.2 Vehicle-Passenger Monohulls and Catamarans Database

The design parameters for vehicle-passenger monohulls and catamarans are seating area (As), passenger number (Np), passenger area (Ap), vehicle number (Nv), vehicle area (Av) and product $L_{WL} \times B$.

Figures 2.5.a and 2.6.a display correlation between number of passengers (Np) and seating area (As) for vehicle-passenger monohulls and catamarans respectively. This part of the database data ranges between As/Np=0.9 to 1.3 for both vehicle-passenger monohulls and catamarans. This is shown in the figures by including the linear As/Np=0.9, 1.1 and 1.3 trend lines.

The variation of Ap/As coefficient is shown in Figures 2.5.b and 2.6.b for vehicle-passenger monohulls and catamarans. It varies between Ap/As=1.1 to 1.5 for both vehicle-passenger monohulls and catamarans. This is again shown in the figures with the linear Ap/As=1.1, 1.3 and 1.5 trend lines.

Figures 2.5.c and 2.6.c display the correlation between number of vehicles (Nv) and vehicle area (Av) for vehicle-passenger monohulls and catamarans respectively. L_{WL}xB is then estimated as a function of total passenger and vehicle areas (Ap and Av). The regressions give again a very good correlation between predictor and response (in most cases R^2>0.9). The algorithm is therefore reliable enough so as to be used in the mass estimation.

Regression equations for vehicle-passenger monohulls are as follows.

$$A_V = 156 + 10.2 \cdot N_V \qquad R^2 = 0.92 \qquad 2.3$$

$$L_{WL} \times B = 121 + 0.27 \cdot A_P + 0.60 \cdot A_V \qquad R^2 = 0.98 \qquad 2.4$$

The corresponding equations for vehicle-passenger catamarans are given as.

$$A_V = 12.4 \cdot N_V \qquad R^2 = 0.99 \qquad 2.5$$

$$L_{WL} \times B = 471 + 0.55 \cdot A_P + 0.28 \cdot A_V \qquad R^2 = 0.80 \qquad 2.6$$

The design of the algorithm is explained in section 2.2.

Calculations have been carried out for passenger-only monohulls, passenger-only catamarans, vehicle-passenger monohulls and vehicle-passenger catamarans. The forms of the formulae are the same for each vessel, while the numerical factors vary. The derived formulae and data limits are given in Table 2.2. The table also displays database ranges of main design ratios and particulars of the vessels. These are as follows;

- Separation of centrelines of demihulls, length ratio (S/L)
- Length displacement ratio ($L/\nabla^{1/3}$)
- Breadth, draught ratio (B/T)
- Demihull breadth, draught ratio (b/L)
- Block coefficient (C_B)
- Length overall, length waterline ratio (L_{OA}/L_{WL}).

Table 2.2 also displays the overall depth values for monohulls and catamarans. Estimation of depth is explained in section 2.2.

2.2 ESTIMATION OF MAIN DIMENSIONS

Two design flowpaths were created by Karayannis [20], which illustrated the area-based approach. A new improved version is shown in Figures 2.7.a and 2.7.b, where a mass balance is now included within the procedure for the derivation of dimensions.

In these flowcharts, the number of passengers (Np) and vehicles (Nv) are the inputs. Seating area (A_S) is calculated as a function of passenger number (N_P), but variations are possible within reasonable limits dictated by the existing data, allowing the designer to select the desired level of seating comfort. In the same way, variations are possible for the passenger-seating area ratio (A_P/A_S) used for the calculation of passenger area (A_P).

A three-stage calculation ($N_P \rightarrow A_S \rightarrow A_P \rightarrow L_{WL} \times B$) was preferred by Karayannis as it allowed more freedom in providing the vessel with the desired level of accommodation quality, in terms of areas provided to passengers. Instead of the three stage procedure used here, a two-stage ($N_P \rightarrow A_P \rightarrow L_{WL} \times B$) or even one stage process ($N_P \rightarrow L_{WL} \times B$) could have been applied. This would make the algorithm much simpler, but would not allow for variations from the default areas.

2.2.1 Passenger-only and Vehicle-Passenger Monohulls

To obtain a solution for L and B, suitable first estimates of the L/B ratio and L×B product are input.

L/B is based on hull hydrostatic and hydrodynamic requirements and assumptions for $L/\nabla^{1/3}$, C_B and B/T;

$$\frac{L}{B}=\left[\left(\frac{L}{\nabla^{1/3}}\right)^{3}\times C_B\times\frac{T}{B}\right]^{1/2} \qquad 2.7$$

LxB is a function of required passenger and vehicle areas;

$$L\times B=f(A_P,A_V), \qquad 2.8$$

where $A_S=f(N_{PAX})$, $A_P=f(A_S)$ and $A_V=f(N_{CAR})$.

Suitable forms of equations 2-7 and 2-8, as well as ranges of the design parameters, can be derived from the data presented in Table 2.2. From this a solution for both length and displacement can be determined as follows;

$$L = \left[(L \times B) \times \left(\frac{L}{B} \right) \right]^{1/2} \tag{2.9}$$

B can be determined from L/B, and T from B/T,

$$\Delta = L_{WL} \times B \times T \times C_B \times \rho \tag{2.10}$$

2.2.2 Passenger-only and Vehicle-Passenger Catamarans

In the case of catamarans, instead of the overall beam (B) for the initial calculations, the demihull beam (b) has been used. The separation of the demihull centrelines (S) is used as an additional parameter in the form of an S/L ratio, varied within the range dictated by the data in the database. Overall beam is then simply derived as $B = S + b$. For catamarans, L/B is derived as;

$$\frac{L}{B} = 1 / \left[\frac{S}{L} + \frac{b}{L} \right] \tag{2.11}$$

L/b is then derived as;

$$\frac{L}{b} = \left[\left(\frac{L}{\nabla^{1/3}} \right)^3 \times C_B \times \frac{T}{b} \right]^{1/2} \tag{2.12}$$

In this case displacement volume (∇) refers to one of the hulls, and the catamaran displacement then becomes;

$$\Delta = 2 \times L_{WL} \times b \times T \times C_B \times \rho \tag{2.13}$$

From the equations and database, an initial set of main dimensions of the vessel and the other parameters can be established using mid-range values in Table 2.2 as starting points.

Depth is an important parameter for hull mass estimates and stability calculations, although it has no significance for hydrodynamic performance calculations. In the current work, overall depth, D_{OA}, (including the superstructure) is calculated as a function of B, by using the available data in the database. This study is explained in section 2.3. It should be emphasised that the overall depth D_{OA} is an approximate value used primarily in the equipment numeral for hull and superstructure mass estimates.

As discussed earlier, the principal hull parameters did not show any reliable trends with speed. Thus, the initial estimate of dimensions is based only on passenger and vehicle requirements. This does create an anomaly in the design procedure in that, for example, a change in speed for a particular design, whilst retaining the same passenger and vehicle requirements, results in a change in propulsive power and machinery mass and hence overall mass balance. This problem is overcome by incorporating a mass balance directly within the procedure for the derivation of dimensions as shown in Figures 2.7.a and 2.7.b.

In the design path, Figures 2.7.a and 2.7.b, suitable values for $L/\nabla^{1/3}$, C_B and B/T are chosen and introduced into equation 2-7. These may then be modified in further design iterations in order to achieve a satisfactory balance of masses. There are several ways in which the parameters may be modified, but an approach which has been found to be efficient and satisfactory is to retain overall constancy of L/B, hence constant L (from equation 2-9), which results in constancy of equation 2-7. Hence for constant L/B, combinations of $L/\nabla^{1/3}$, C_B and B/T within equation 2-7 may be chosen depending on any other design constraints. For example, for fixed ∇ and $L/\nabla^{1/3}$, C_B and B/T can be increased to retain constant ∇. Allowing a change in ∇, C_B and $L/\nabla^{1/3}$ may be changed with B/T constant, or B/T and $L/\nabla^{1/3}$ changed with C_B constant or suitable changes to both B/T and C_B. The procedure for catamarans is similar, but using equations 2-11, 2-12 and 2-13. These procedures are demonstrated later in chapter 6 by comparing similar vessel requirements but at different speeds. Details of the mass estimates are given in chapter 4.

The dimension module has been developed to a reliable level. It must be kept in mind, however, that as the method is based on data from existing vessels it may not be safe to use outside the limits of the database, as extrapolations may not be reliable.

The database can be constantly updated and expanded, as new vessels are added to it. This would enhance the strength of the database and, in consequence, that of the method.

2.3 ESTIMATION OF DEPTH

Length, beam, draught and depth are the four main ship dimensions. The existing method was not capable of finding all of them. Only three of these main parameters were obtained, namely length, beam and draught. To complete the estimation of these four main dimensions, a study carried out for the calculation of an initial depth. Depth is crucial for the derivation of hull mass estimation. A fast ferry's structure is made up of a combination of hull and superstructure. As opposed to conventional cargo ships. the superstructure of a fast ferry takes a big part from the whole structure of the vessel. Depth is therefore a main requirement in the hull mass estimation process. The estimation of hull mass is explained in more detail in section 4.1. In this section the duty of depth is clearer.

Depth has been correlated with overall length, overall beam and draught using data available from the database. Each correlation is repeated for catamarans and monohulls individually. The plots for monohulls are shown in Figures 2.8.a, 2.8.b and 2.8.c, and the plots for catamarans are Figures 2.9.a, 2.9.b and 2.9.c.

Since a fast ferry's superstructure takes the biggest part of the vessel and is built as part of the hull, the overall depth is taken as the height between keel and the highest point of the superstructure. This is illustrated in Figure 10.

From the correlations, the good linear relationship between overall depth and overall beam for both monohulls and catamarans was evident as Figures 2.8.b and 2.9.b show. The plot between overall depth and draught and overall length however, did not show a very good correlation. The data plots look very sparse.

Two equations were obtained from Figures 2.8.b and 2.9.b for monohulls and catamarans as follows;

$$D_{OA} = 4 + 0.6 \cdot B_{OA} \text{ for monohulls} \qquad 2.14$$

$$D_{OA} = 4 + 0.44 \cdot B_{OA} \text{ for catamarans} \qquad 2.15$$

Predicted results have been obtained from the above regression equations and have then been compared with actual ship depths included in the database. This study was undertaken to test the accuracy of the predicted results against actual data. The predicted results and actual data plots are shown in Figures 2.11.a and 2.11.b for monohulls and catamarans respectively.

A computer program written in FORTRAN has been developed to include all these main components of the concept design of fast ferries, for passenger monohulls, passenger catamarans, vehicle monohulls and vehicle catamarans. More detailed information about this program is given in Appendix II.

Vessel Type	**N_P**	**N_V**	**Vs (kn)**
Passenger-only Monohull	49-925	-	24-60
Passenger-only Catamaran	50-650	-	25-45
Vehicle-Passenger Monohull	400-1800	<450	28-45
Vehicle-Passenger Catamaran	150-1500	<450	28-43

Table 2.1: High Speed Ferry Database Range.

Item	**Passenger-only Monohulls**	**Passenger-only Catamarans**	**Vehicle-Passenger Monohulls**	**Vehicle-Passenger Catamarans**
LxB	$146+1.86\text{x}10^{-3}A_P^2$	$138+0.91A_P$	$121+0.27A_P+0.60A_V$	$471+0.55A_P+0.28A_V$
A_S/N_P	0.55-0.75	0.55-0.85	0.85-1.25	0.80-1.40
A_P/A_S	1.10-1.30	1.10-1.30	1.15-1.45	1.30-1.70
A_V	-	-	$156+10.2N_V$	$12.4N_V$
S/L	-	0.20-0.25	-	0.20-0.25
$L/\nabla^{1/3}$	5.0-7.5	8.0-10.5	6.5-9.0	8.5-11.0
majority	5.5-6.5	8.5-9.5	7.0-8.5	9.5-10.5
B/T	3.5-8.5	-	3.5-7.5	-
Majority	4.0-6.5	-	4.5-6.5	-
b/T	-	1.5-3.0	-	1.5-3.0
D_{OA}	4+0.6B	4+0.44B	4+0.6B	4+0.44B
C_B	0.35-0.45	0.40-0.55	0.35-0.45	0.40-0.55
L_{OA}/L_{WL}	1.13-1.15	1.13-1.15	1.13-1.15	1.13-1.15

Table 2.2: Design Equations and Range of Parameters for Derivation of Dimensions.

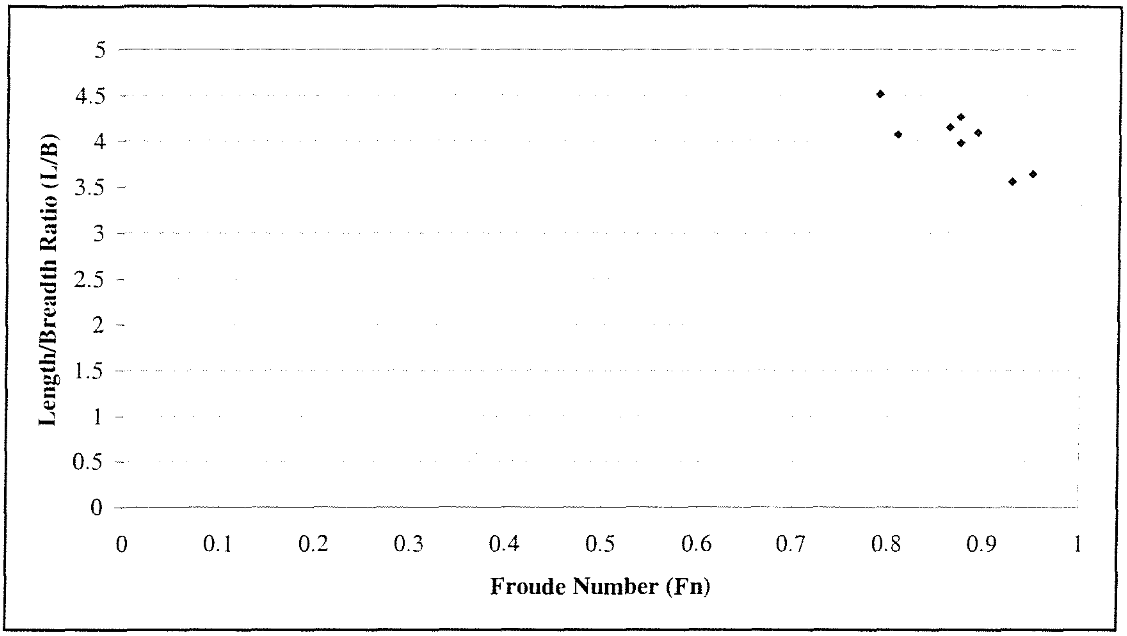


Figure 2.1.a: Relation between Fn and L/B for Passenger-Only Monohulls.

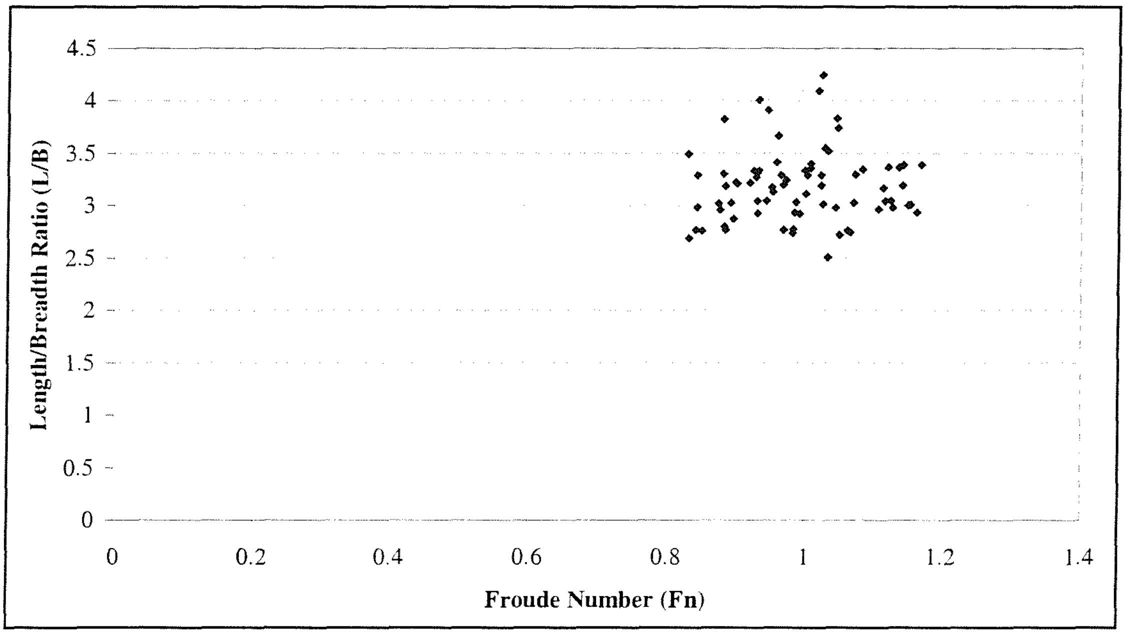


Figure 2.1.b: Relation between Fn and L/B for Passenger-Only Catamarans.

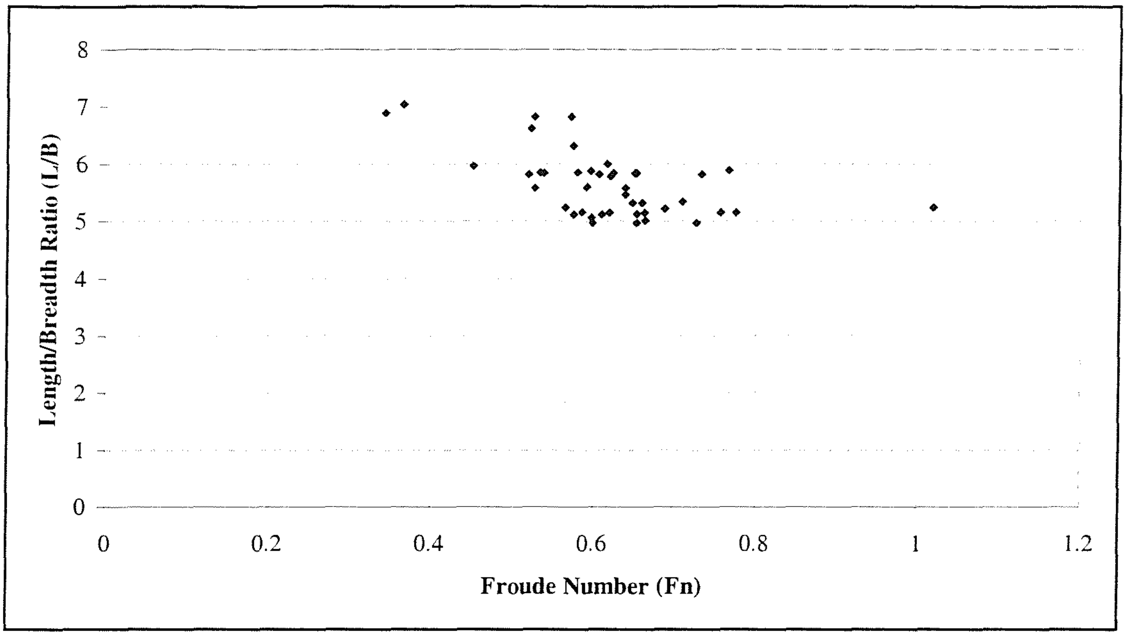


Figure 2.2.a: Relation Between Fn and L/B for Vehicle-Passenger Monohulls.

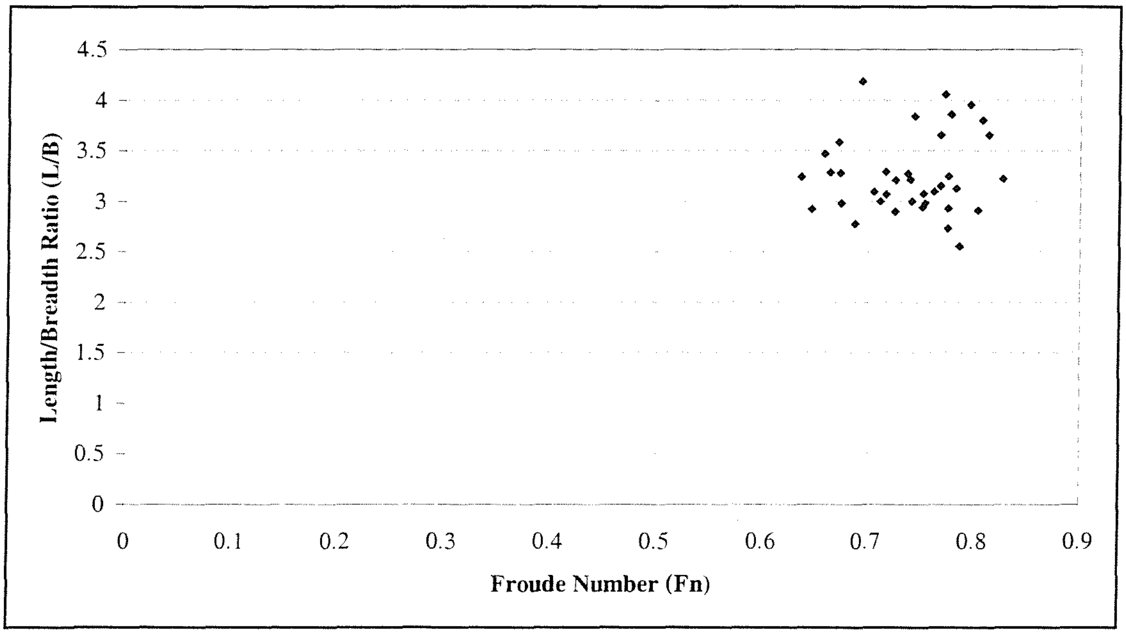


Figure 2.2.b: Relation between Fn and L/B for Vehicle-Passenger Catamarans.

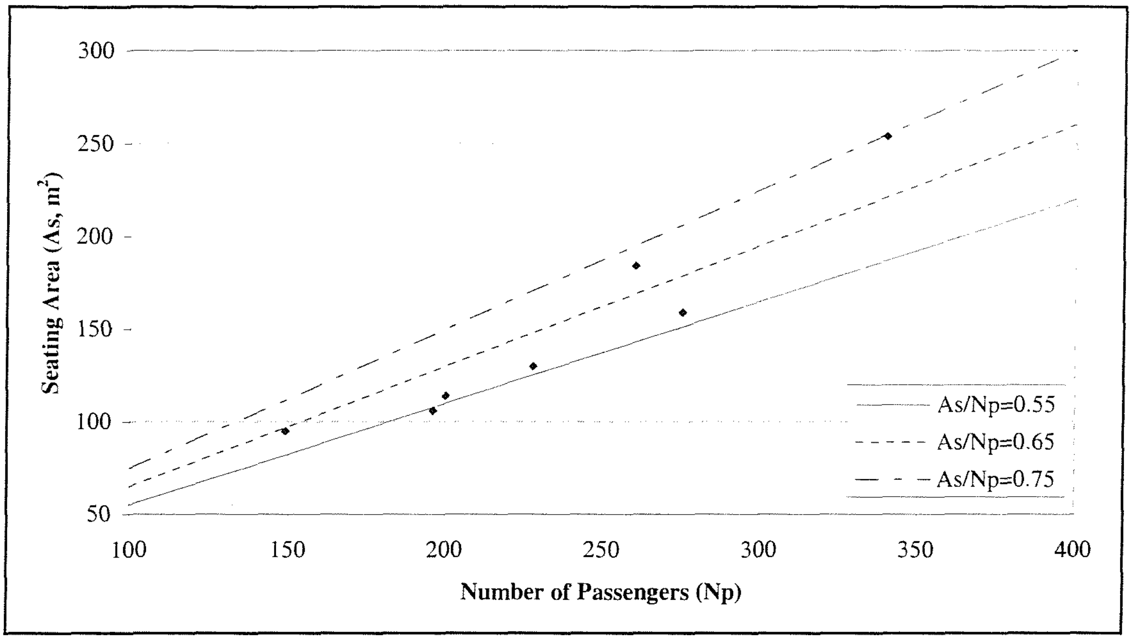


Figure 2.3.a: Data Plots of Dimensions for Passenger-Only Monohulls.

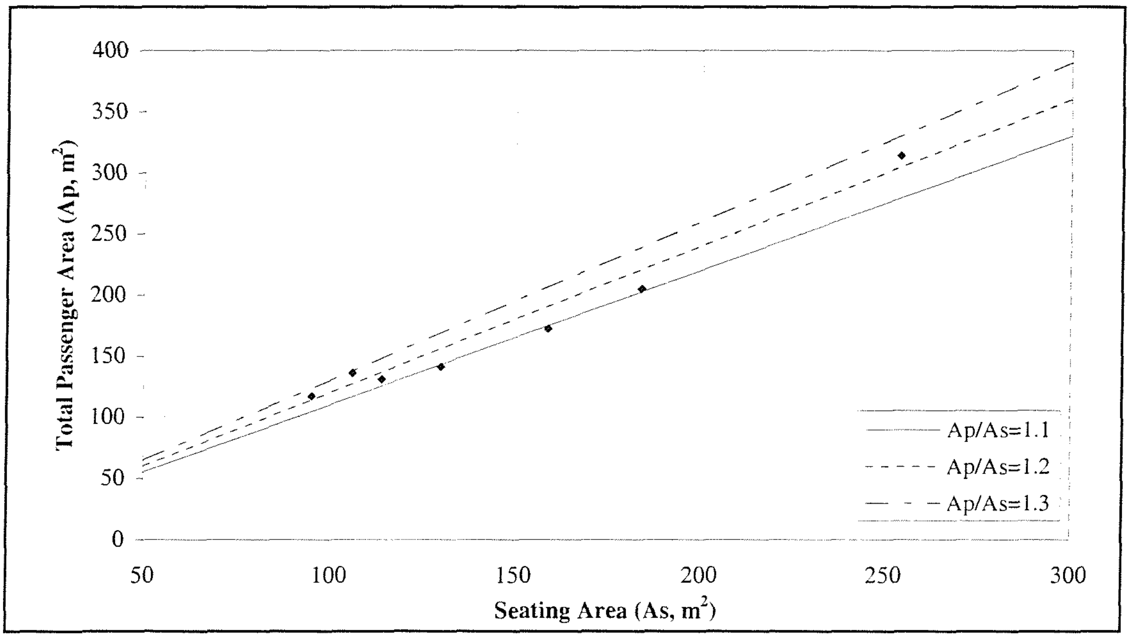


Figure 2.3.b: Data Plots of Dimensions for Passenger-Only Monohulls.

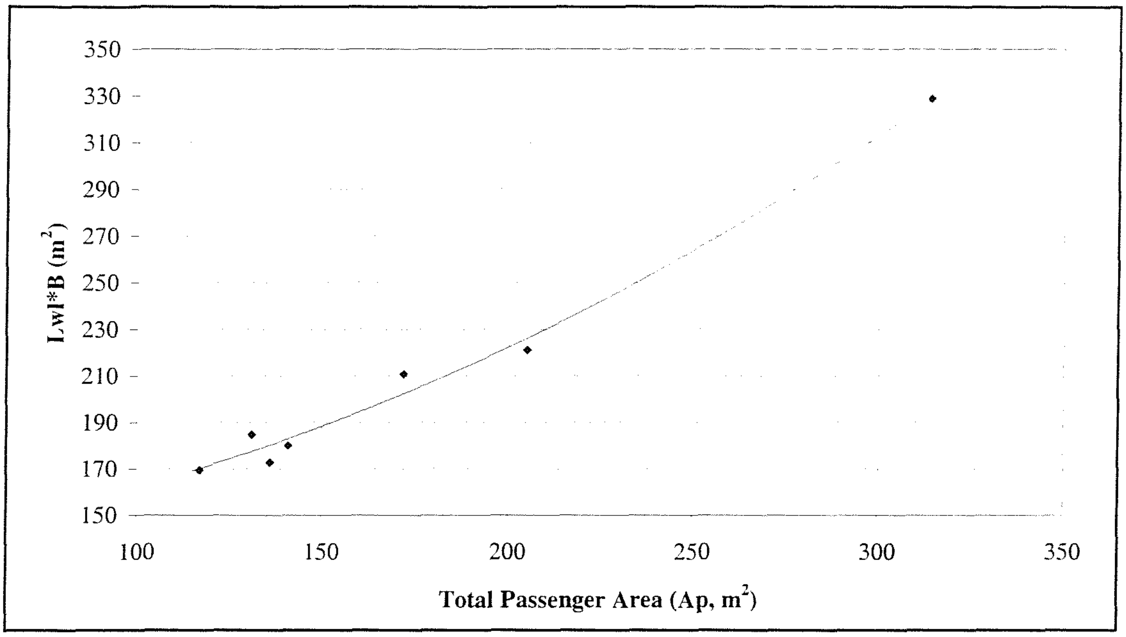


Figure 2.3.c: Data Plots of Dimensions for Passenger-Only Monohulls.

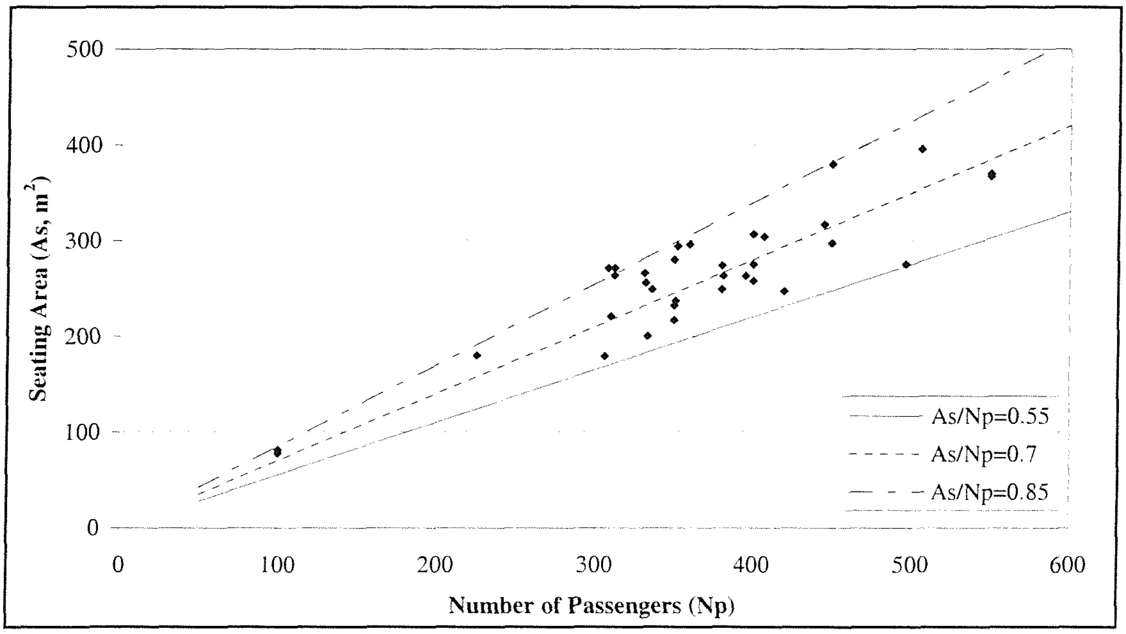


Figure 2.4.a: Data Plots of Dimensions for Passenger-Only Catamarans.

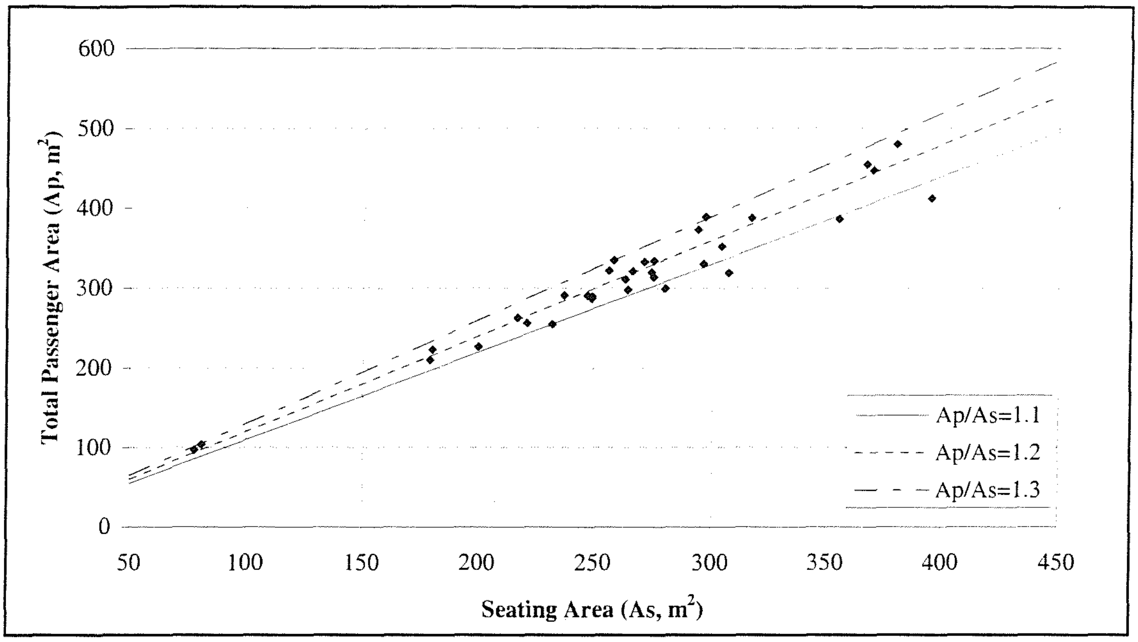


Figure 2.4.b: Data Plots of Dimensions for Passenger-Only Catamarans.

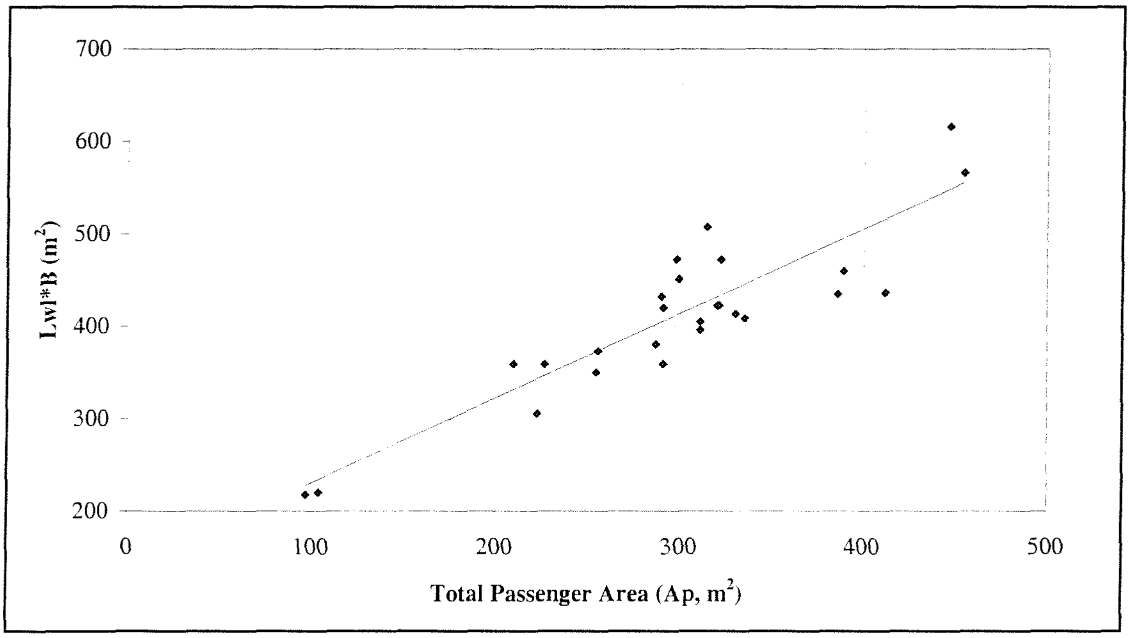


Figure 2.4.c: Data Plots of Dimensions for Passenger-Only Catamarans.

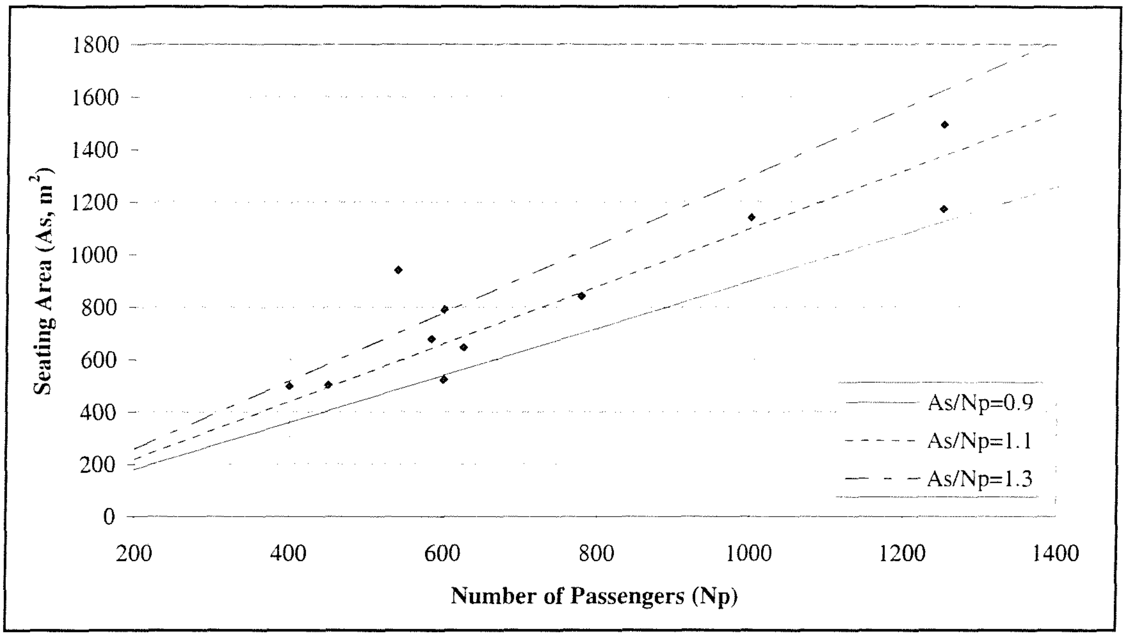


Figure 2.5.a: Data Plots of Dimensions for Vehicle-Passenger Monohulls.

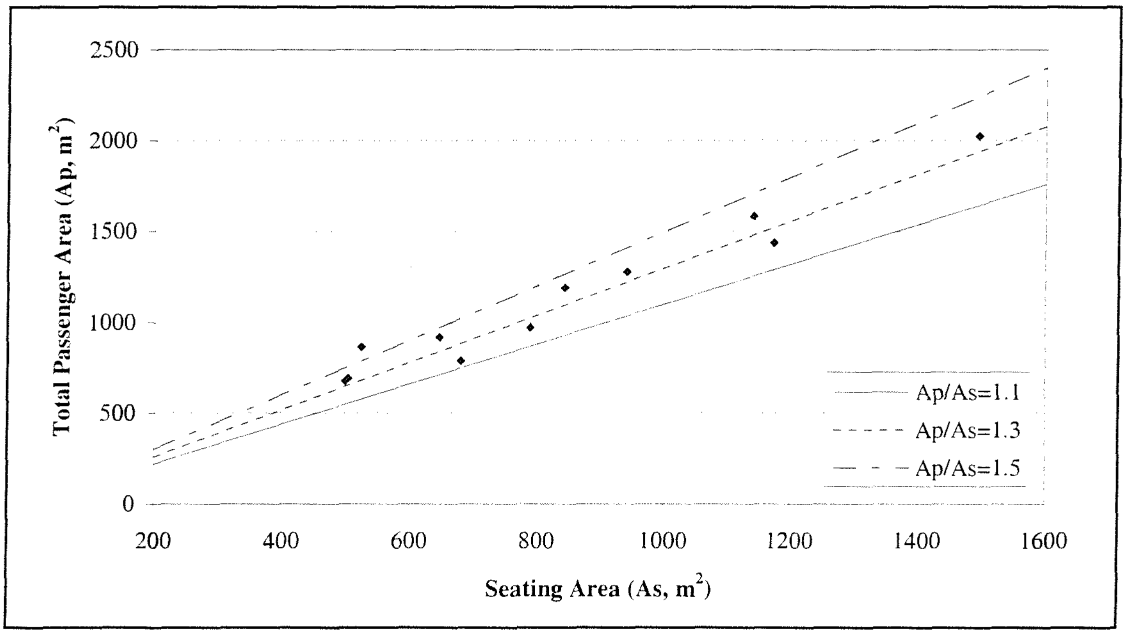


Figure 2.5.b: Data Plots of Dimensions for Vehicle-Passenger Monohulls.

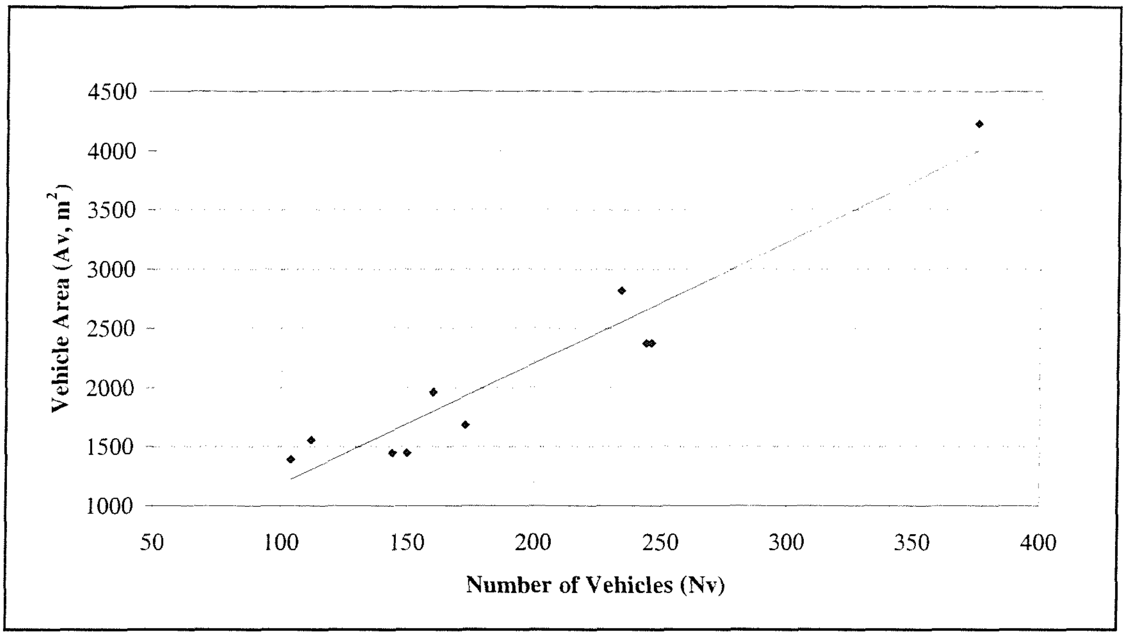


Figure 2.5.c: Data Plots of Dimensions for Vehicle-Passenger Monohulls.

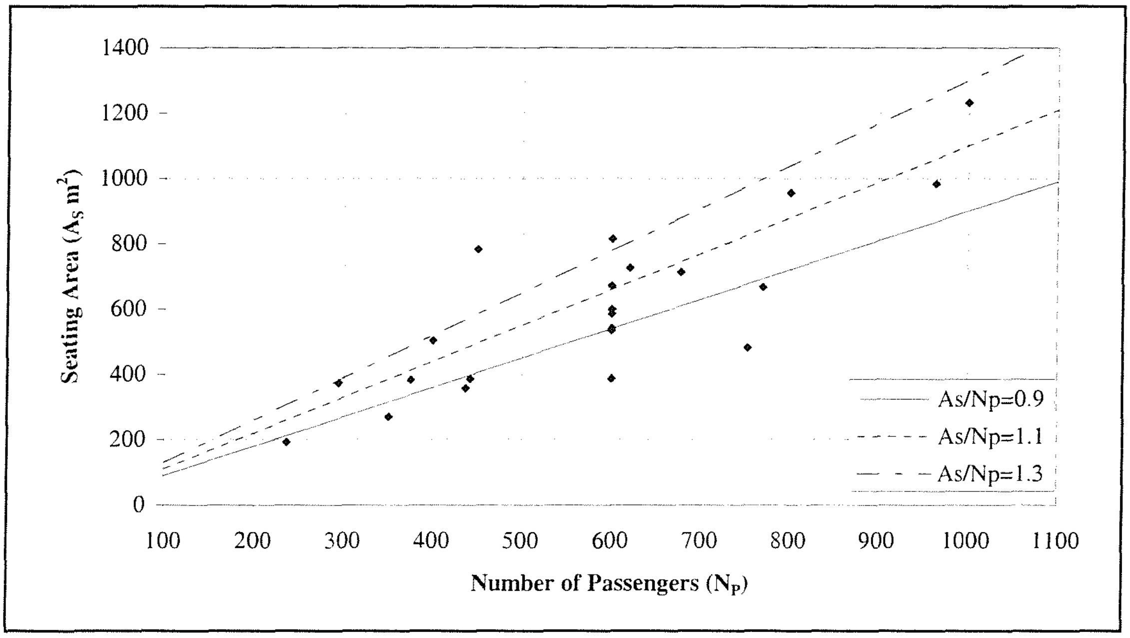


Figure 2.6.a: Data Plots of Dimensions for Vehicle-Passenger Catamarans.

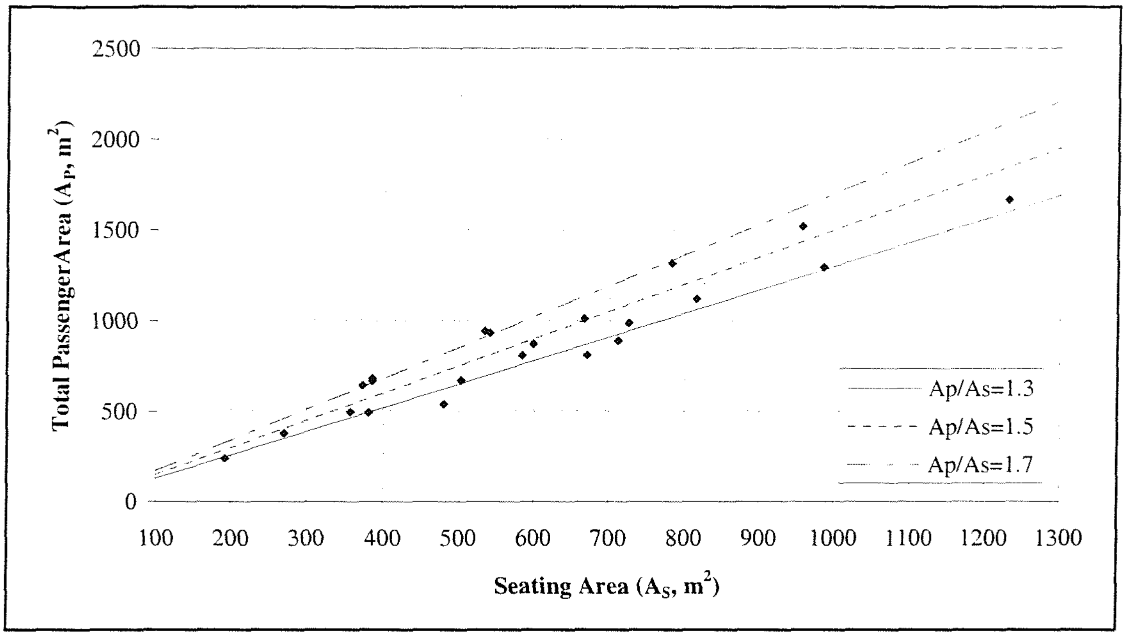


Figure 2.6.b: Data Plots of Dimensions for Vehicle-Passenger Catamarans.

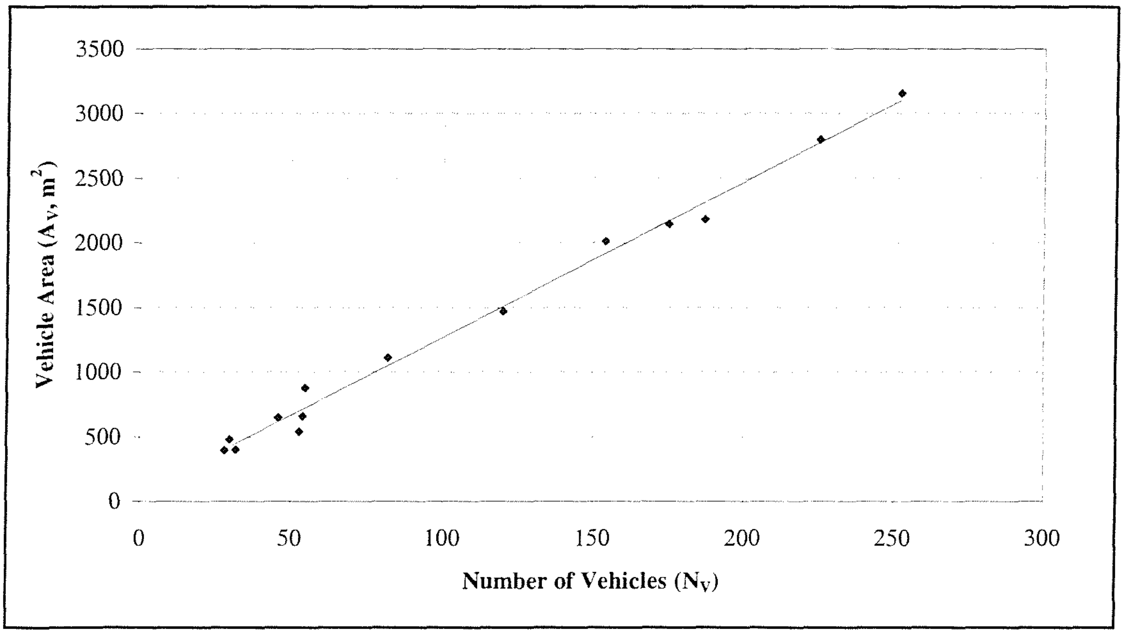


Figure 2.6.c: Data Plots of Dimensions for Vehicle-Passenger Catamarans.

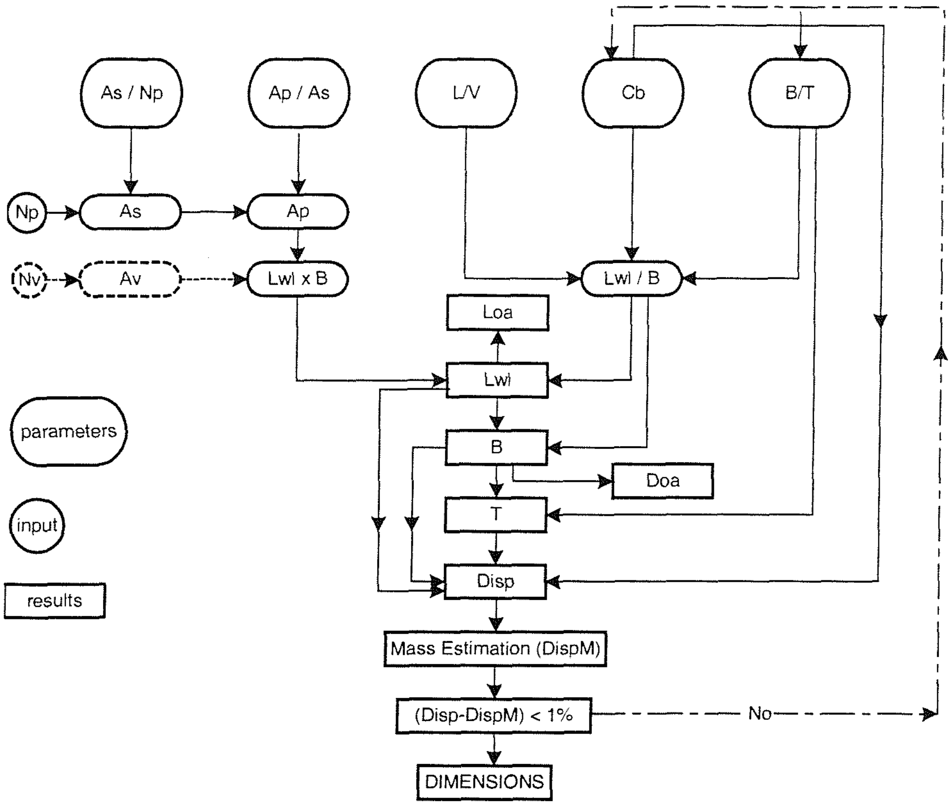


Figure 2.7.a: Flowpath for Initial Estimation of Main Dimensions for Monohulls.

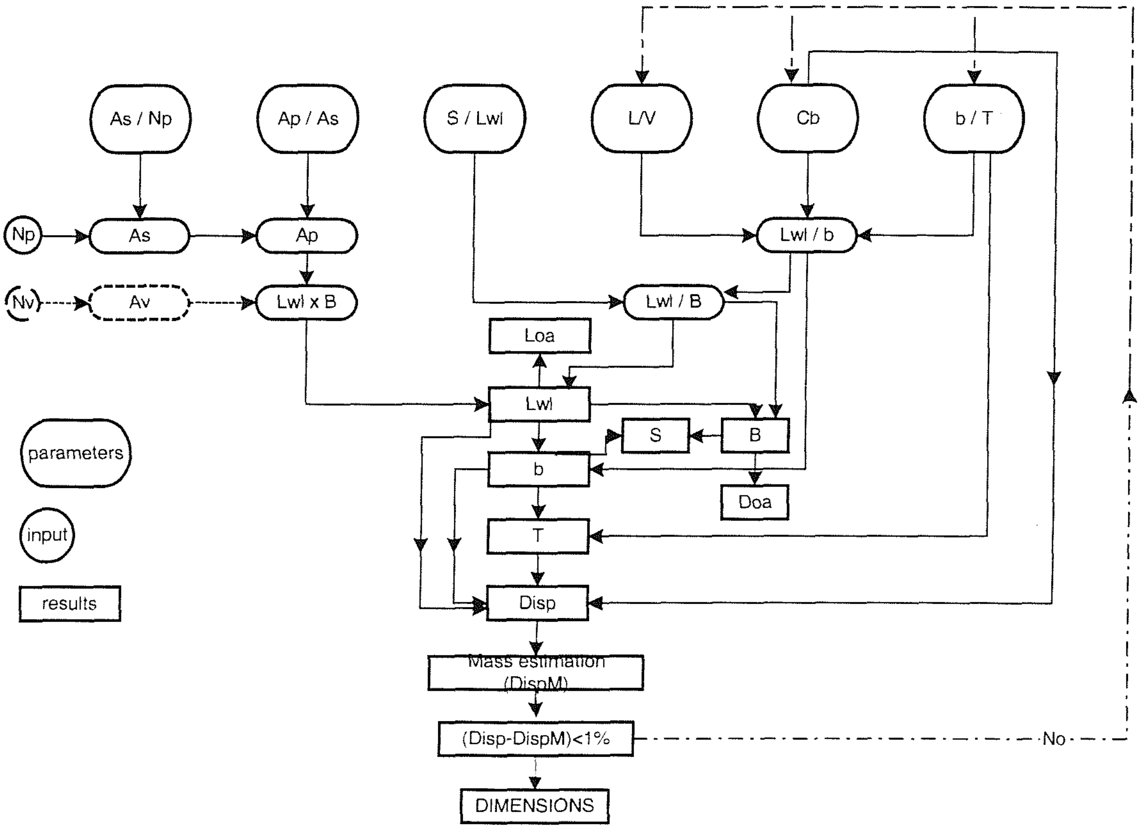


Figure 2.7.b: Flowpath for Initial Estimation of Main Dimensions for Catamarans.

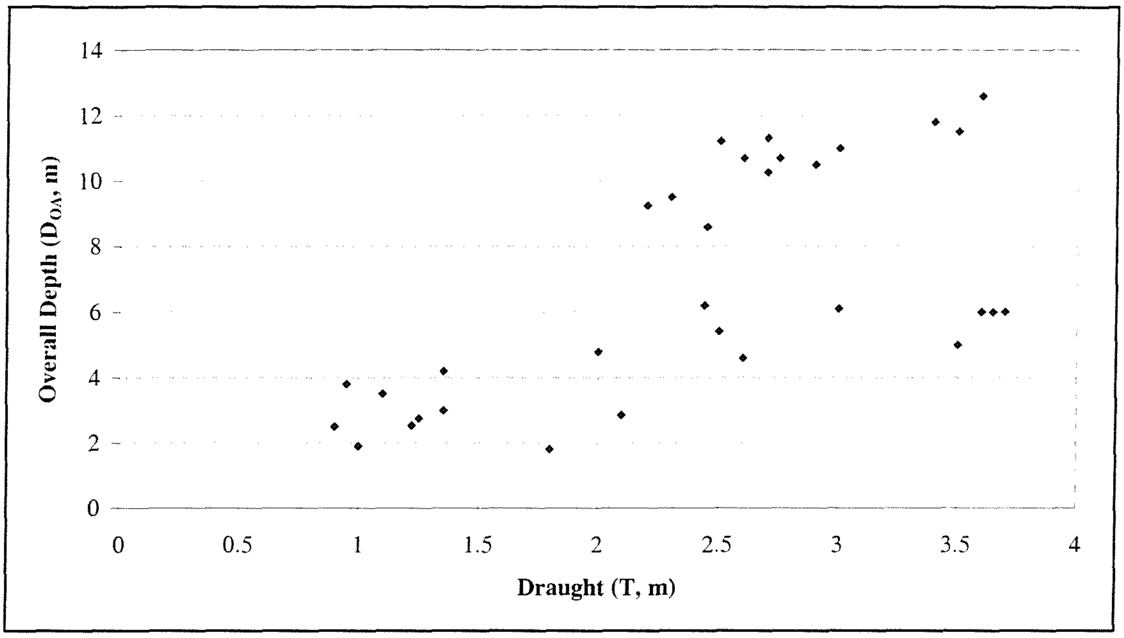


Figure 2.8.a: The Correlation Between Overall Depth and Draught for Monohulls.

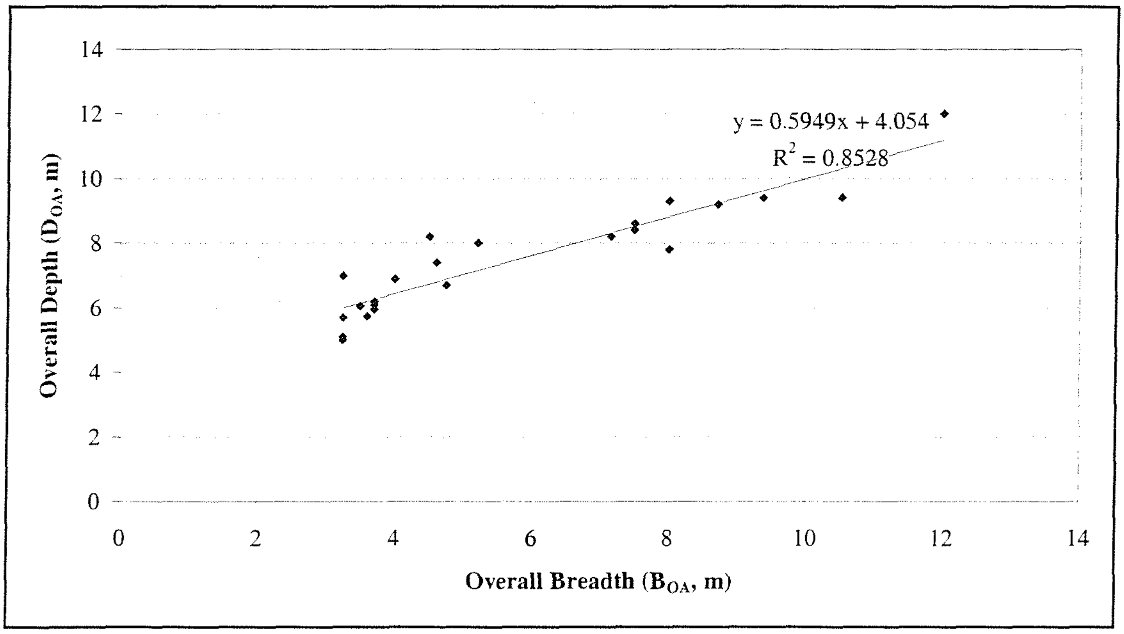


Figure 2.8.b: The Correlation Between Overall Depth and Breadth for Monohulls.

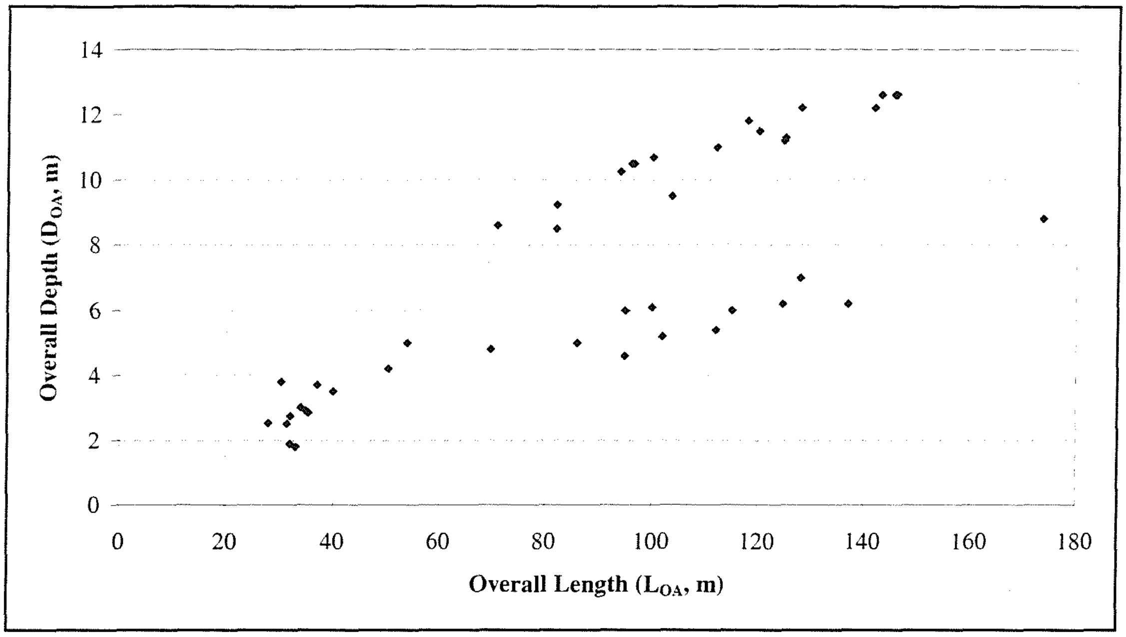


Figure 2.8.c: The Correlation Between Overall Depth and Overall Length for Monohulls.

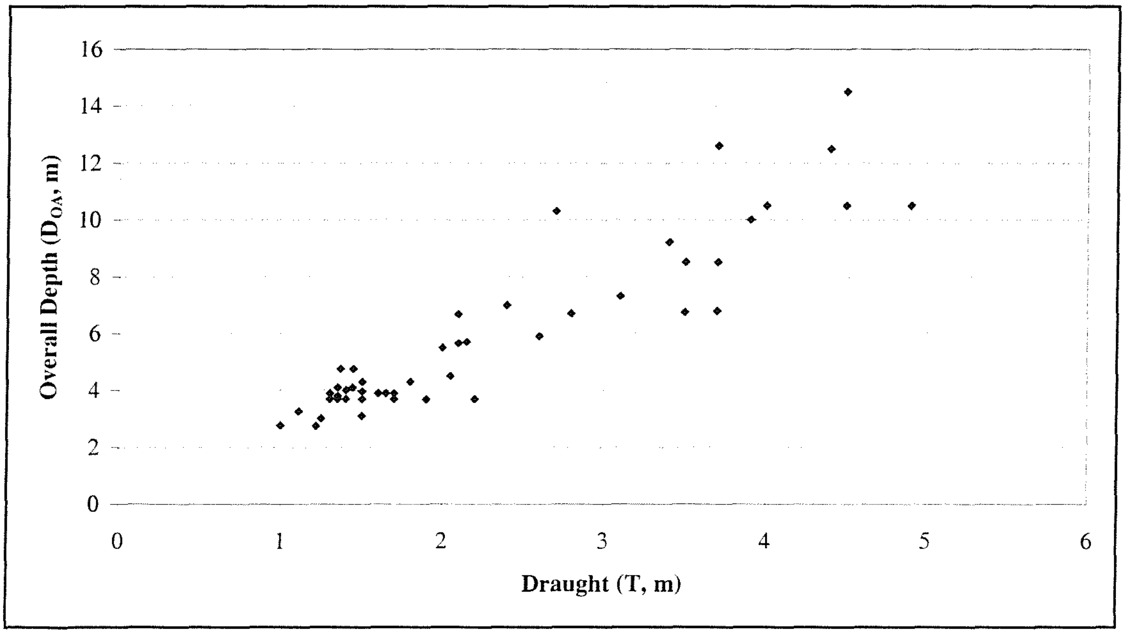


Figure 2.9.a: The Correlation Between Overall Depth and Draught for Catamarans.

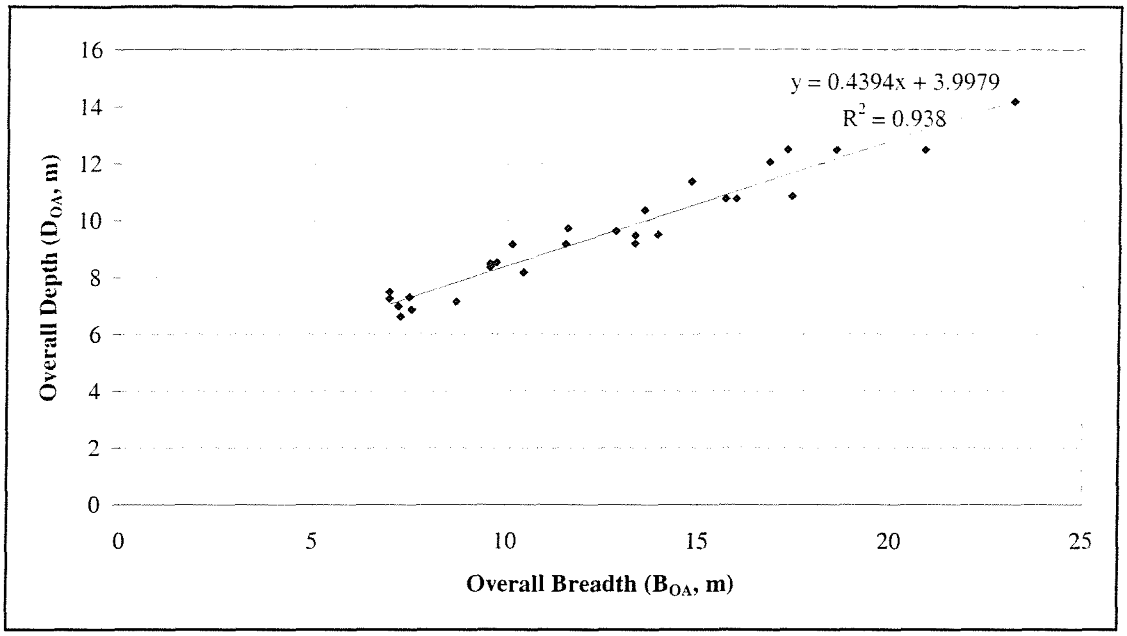


Figure 2.9.b: The Correlation Between Overall Depth and Overall Breadth for Catamarans.

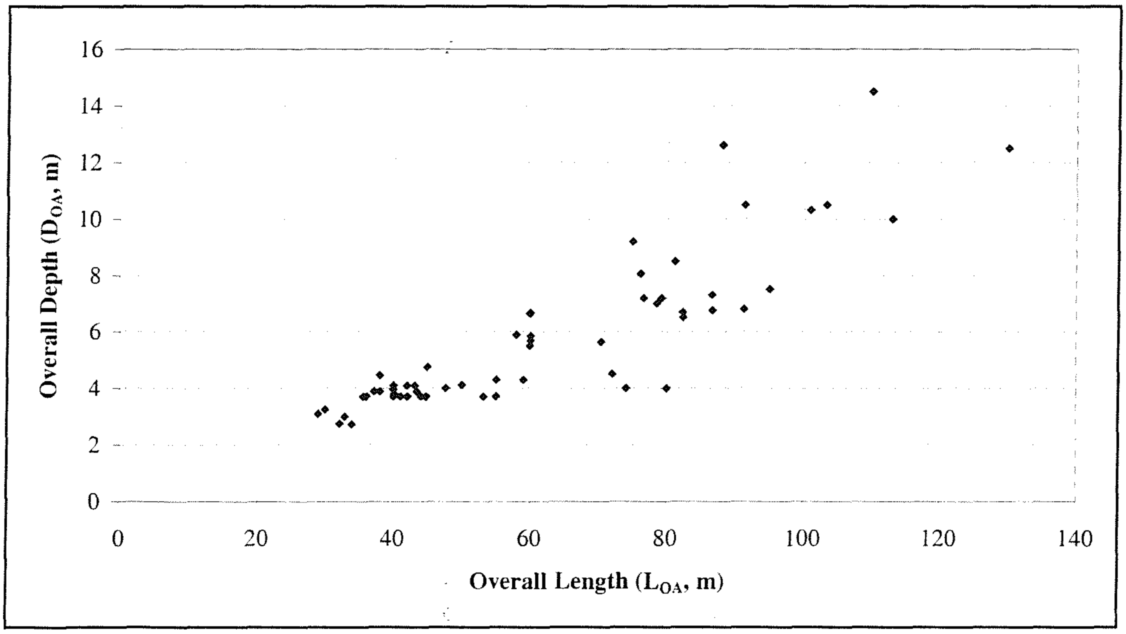


Figure 2.9.c: The Correlation Between Overall Depth and Overall Length for Catamarans.

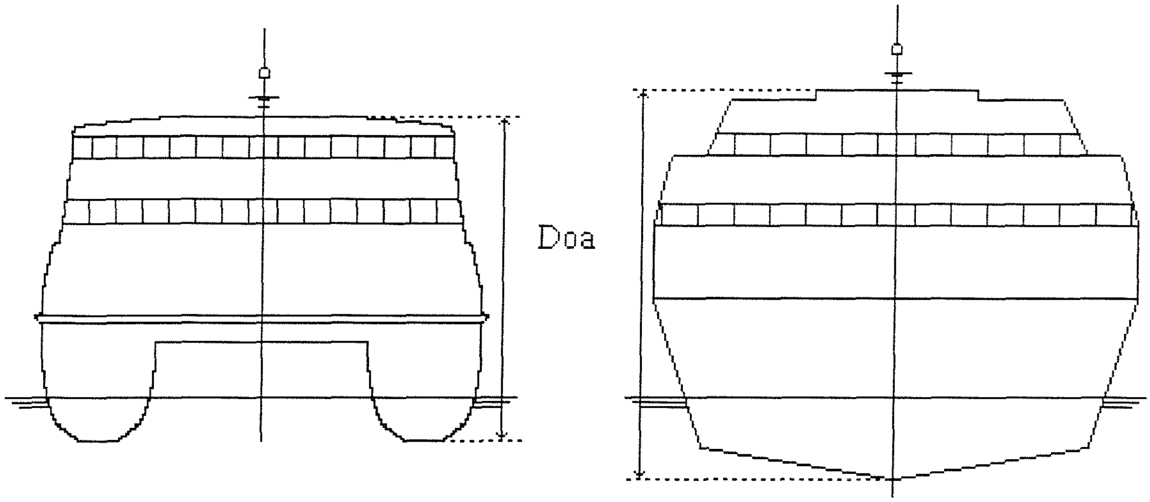


Figure 2.10: Definition of Depth for Catamarans and Monohulls for the Current Study.

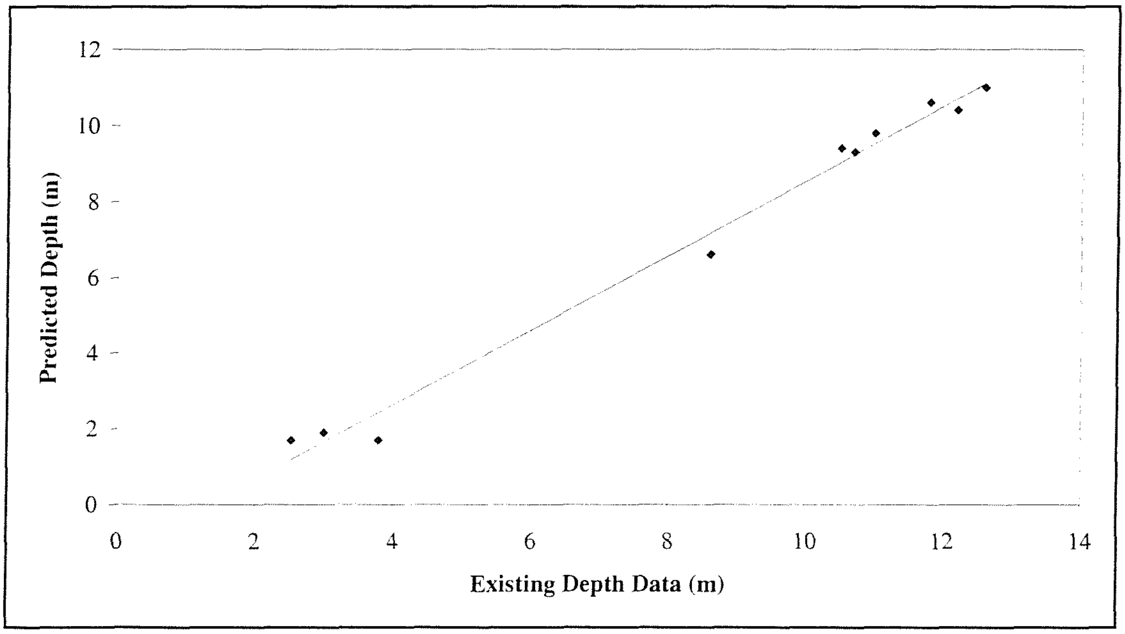


Figure 2.11.a: The Comparison Between Predicted and Existing Depth Data for Monohulls.

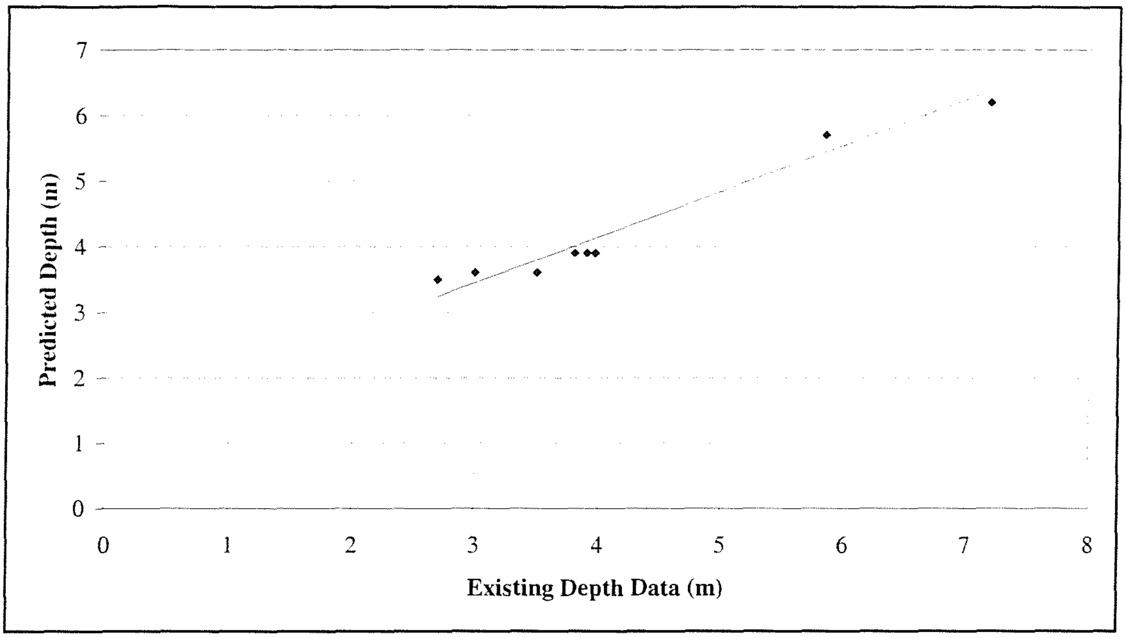


Figure 2.11.b: The Comparison Between Predicted and Existing Depth Data for Catamarans.

3. POWERING

3.1 GENERAL

A reliable power estimate is important in order to provide an estimation of machinery and fuel masses. A reliable database is also essential for carrying out powering estimates but unfortunately information is relatively limited, particularly in the higher speed range. To find suitable data for high speed monohull displacement crafts and multihulls some previous studies have been looked into. These are as follows:

Monohull mode; The NPL Series Bailey [1], Series 64 Yeh [34] and the Southampton Extended NPL Series Molland et al [22]. These collectively provide a good coverage of parameters for powering estimates and they also offer the facility to investigate a reasonable range of fast monohull ferries.

Multihull mode; Systematic resistance data for multihulls is more limited. The catamaran series tested at Southampton Molland et al [22] offers at present one of the most extensive sets of data, and provides a good basis for resistance estimates.

The current work's interest is the estimation of an initial set of main dimensions, masses and costs. The estimation of an initial set of main dimensions was dealt with in the previous chapter. This chapter deals with the estimation of initial power. Information on initial power is fundamental to obtain machinery and fuel masses. Presented databases help in providing an initial power. Presentation of data and the procedure behind this estimation is given in sections 3.2, 3.3 and 3.4.

3.2 PRESENTATION OF DATA

Work on the resistance of high speed displacement monohulls and catamarans has been ongoing over a number of years at the University of Southampton, Insel et al [13] and Molland et al [22], in an effort to improve the understanding of their resistance components and to provide design data.

Molland et al [22] describes a large series of model tests on catamarans in calm water. The experimental programme was a development of the earlier work Insel et al [13] in which a small series of three catamaran models were tested. In Molland et al [22], total resistance, running trim, sinkage and wave pattern analyses were carried out for ten round bilge hull derived from the NPL Series. The tests were conducted over a Froude Number range of 0.1 to 1.0 and corresponding Reynolds number (R_N) range for the models 0.5×10^6 to 5.5×10^6 with separation to length ratios of 0.2, 0.3, 0.4, 0.5 and infinity.

In an earlier work, Insel et al [13] tested a wide range of hull separations. Overall, the experiments covered over 40 model configurations, each over a speed range up to a Froude Number of unity. Molland et al [22] has extended the parametric investigation to cover changes in breadth/draught ratio (B/T) and a wider range of length/displacement ratios ($L/\nabla^{1/3}$).

These two main works on the resistance of high speed displacement catamarans have been used by Buckland [3] to provide data for the NPL and Series 64 round bilge series is an alternative form, using interference factors. Using these references as the sources of data, Buckland produced a rationalised resistance estimate procedure for both catamaran and monohull configurations to utilize at the preliminary design stage. This procedure has been applied in the current work using the NPL Series for illustration as described in the next section.

3.3 CALM WATER RESISTANCE

The basic presentation of the experimental data from Molland et al [22] was as follows:

$$C_{T_{cat}} = (1+\beta k)C_F + \tau C_W \qquad \textbf{3-1}$$

where;

C_F is obtained from the ITTC-1957 correlation line.

C_W is the wave resistance coefficient for the demihull in isolation.

(1+k) is the form factor for the demihull in isolation.

β is a viscous interference factor.

τ is the wave resistance interference factor.

It is noted that for the demihull in isolation, $\beta=1$ and $\tau=1$.

Form factors (1+k) for monohulls and form factors for catamarans including viscous interference ($1+\beta$k) were obtained by deducting the wave pattern resistance from total resistance Insel et al [13] and Molland et al [22]. Various research programmes have been carried out in order to provide guidance as to the selection of a suitable form factor. Due mainly to the lack of definitive values of form factors for high speed displacement craft, the 22nd ITTC in September 1999, recommended the use of (1+k)=1.0 and ($1+\beta$k)=1.0 for such craft Buckland [3]. Buckland [3] and Molland et al [19] state that for practical application, suitable values of form factor can be used. They also mention that these values may be adequately reliable for preliminary estimates of power at the early design stage. These form factor values are summarised in Table 3.1, and depend only on length-displacement ratio ($L/\nabla^{1/3}$), and are independent of hull separation S/L.

From a practical point of view it is not necessary to confine the user to the particular values of (1+k) or (1+βk) proposed in Table 3.1. These factors may not necessarily be used directly for design or resistance scaling purposes, but they do provide a broad indication of changes in viscous resistance and viscous interference due to changes in Length/Displacement ($L/\nabla^{1/3}$). Thus they have been applied by the current work.

Buckland [3] took residuary resistance coefficients C_R (derived from $C_T - C_{F_{ITTC}}$) from Insel et al [13] and Molland et al [22]. He then evaluated the relationship between residuary resistance and each design parameter. The effects of each design parameter on C_R are given in Table 3.2.

The relationship between C_R and $L/\nabla^{1/3}$ is sufficiently predictable to form a basis for regression between F_N=0.4-1.0. Therefore the data is only regressed between F_N=0.4-1.0. It is made sure that for the current work the range of F_N is between 0.4-1.0. This range is 0.6,0.8 and 1.0 as can be seen in Table 3.3.

The effects of B/T and C_P on C_R have been found to be small in this F_N range, and therefore have not been considered as regression parameters. Buckland [3] has also shown that the effect of S/L on C_R is as significant as a change in $L/\nabla^{1/3}$ ratio, and has been used as a regression parameter. Therefore the regression has been performed at each value of S/L for the catamaran configuration. It should be mentioned that the current work uses the regressions for the NPL Series data and thus will only be directly applicable to these hull forms.

Table 3.3 shows the result of the regression for calculation of C_R in terms of $L/\nabla^{1/3}$ and S/L along with the R^2 value for each trendline fit. The trendline fits can be found in Buckland [3]. This value indicates how well the regression model fits the observed data, and it is seen that good fits are achieved in all but the high speed, low S/L data.

For a chosen speed, an estimate of ship total resistance coefficient can be made using the following relationships. These estimation relationships have been employed in the current study by introducing them into a computer program. The program results in an initial power value for a chosen speed. It is further explained in Appendix II.

For monohulls:

$$C_{T_{ship}} = C_{F_{ship}} + C_{R_{model}} - k\left(C_{F_{model}} - C_{F_{ship}}\right), \tag{3-2}$$

and for catamarans:

$$C_{T_{ship}} = C_{F_{ship}} + C_{R_{model}} - k\beta\left(C_{F_{model}} - C_{F_{ship}}\right). \tag{3-3}$$

These are based on the assumption that:

$$C_T = C_F + C_R \text{, or } C_T = (1+k)\times C_F + C_W . \tag{3-4}$$

Model C_F has to be known to use these equations. Based on the model length of 1.6 m for models in Insel et al [13] and Molland [22], a kinematic viscosity for fresh water of 1.14×10^{-6} and using the ITTC correlation line, C_F can be derived as follows;

$$C_F = \frac{0.075}{\left[\log_{10} R_n - 2\right]^2} \tag{3-5}$$

$$R_n = \frac{V\cdot L}{\upsilon} \tag{3-6}$$

$L = 1.6$ m., $\upsilon = 1.14\cdot10^{-6}$ m^2/s, $g = 9.81$ m/s^2

$$R_n = \frac{V\cdot L}{\upsilon}\times\frac{F_n}{V/\sqrt{g\cdot L}} = \frac{V\cdot L}{\upsilon}\times\frac{F_n}{V}\times\sqrt{g\cdot L} = \frac{L^{3/2}}{\upsilon}\times\sqrt{g}\times F_n$$

$$\Rightarrow R_n = \frac{1.6^{3/2}}{1.14\cdot10^{-6}}\times\sqrt{9.81}\times F_n = 5.56\cdot10^{6}\times F_n \tag{3-7}$$

$$C_{F_{model}} = \frac{0.075}{\left[\log_{10}\left(F_n\times5.56\times10^{6}\right)-2\right]^2} \tag{3-8}$$

Once the $C_{T_{ship}}$ has been calculated, the total ship resistance can be calculated using the following equation;

$$R_{T_{ship}} = C_{T_{ship}} \cdot 0.5 \cdot \rho_{SW} \cdot V_{ship}^2 \cdot W_{SA} \qquad \textbf{3-9}$$

Wetted surface area may be calculated using a wetted surface coefficient (C_S), which is derived from breadth-draught ratio (B/T) and block coefficient (C_B) using regression formulae provided for the NPL and Series 64 forms Karayannis [16]. As a further approximation, the Denny Mumford formula gives reasonable results and is used in the current approximate estimate. The following formulae provide the wetted surface area of the vessel [the first is for monohull configurations and the second is for catamarans).

$$\begin{aligned} W_{SA} &= (1.7 \times L_{WL} \times T) + (\nabla / T) \\ W_{SA} &= 2 \times [(1.7 \times L_{WL} \times T) + (L_{WL} \times b \times C_B)] \end{aligned} \qquad \textbf{3-10}$$

Hence, using equation 3-9 the total ship resistance of the vessel can be calculated. Effective power P_E is then calculated directly as $R_T \cdot V_S$.

3.4 PROPULSION

The efficiency of an engineering operation is generally defined as the ratio of the useful work or power obtained to that expended in carrying out the operation.

In the case of a ship the useful power obtained is that used in overcoming the resistance to motion at a certain speed, which is represented by the effective power P_E.

Mechanical efficiencies, gear losses and shaft transmission losses all vary from ship to ship, according to the type of machinery and general layout. It is difficult to define the hydrodynamic efficiency of a hull propeller combination in terms of such an overall propulsive efficiency.

A more meaningful measure of efficiency of propulsion is the ratio of the useful power obtained, P_E, to the power actually delivered to the propeller, P_D. This ratio has been given the name quasi-propulsive coefficient, and is defined as:

$$\eta_D = \frac{P_E}{P_D} \qquad \textbf{3-11}$$

$$P_E = R_T \cdot V_S \qquad \textbf{3-12}$$

$$P_D = \frac{R_T \cdot V_S}{\eta_D} \qquad \textbf{3-13}$$

$$\eta_D = \eta_H \cdot \eta_B = \eta_H \cdot \frac{\eta_B}{\eta_O} \cdot \eta_O \qquad \textbf{3-14}$$

The overall efficiency can then be established, as follows:

$$\eta_D = \eta_H \cdot \eta_R \cdot \eta_O \qquad \textbf{3-15}$$

where η_H is defined as the hull efficiency, η_R is the relative rotative efficiency and η_O as the open water efficiency.

The required total installed power (P_I) is estimated assuming a margin for resistance increases due to hull roughness, fouling and weather. In the present work, for design purposes, a margin of 15% resistance increase due to hull roughness, fouling and weather is assumed. Hence:

$$P_D = P_E / \eta_D \text{ and } P_I = P_D \times 1.15. \qquad \textbf{3-16}$$

An overall propulsive efficiency (η_D) is calculated, leading to an estimate of the required installed power. At present, the overall efficiency is based on that for water jets which are the most widely used propulsion systems for high speed ferries.

Thus, resistance and propulsion calculations can be performed for any selected speed, allowing any desired operational speed to be investigated.

More detailed information about water jets and the calculation of overall propulsive efficiency is given in the following section.

3.4.1 Water Jets

The basic operating principle of the water jet is similar to that of the propeller. The propelling force is generated by adding momentum to the water by accelerating a certain flow of water in an astern direction. In the water jet, water from beneath the vessel is fed through an inlet duct to an inboard pump, usually mounted at the transom, which adds head to the water. This head is then used to increase the velocity when the water passes through an outlet nozzle into the ambient atmospheric pressure. Deflecting the jet by means of a manoeuvring gear, usually hydraulically operated, generates steering and reversing forces Svensson [24,25].

In the case of water jets, overall efficiency in the current work is estimated from available statistical data from manufacturers Karayannis [16]. This is shown in Figure 3.1 and an approximate relationship that was found to fit the data adequately is as follows:

$$\eta_D = \frac{1}{1+\left({}^{16.8}\!/_{V_S(kn)} \right)} \qquad \textbf{3-17}$$

As before, delivered power is then calculated directly as:

$$P_D = P_E \, / \, \eta_D \qquad \textbf{3-18}$$

3.5 SUMMARY

Assessing different research studies and using their results and database, the estimation of initial power is achieved. The current study is useful to find a power value at the preliminary ship design stage. For a chosen speed estimation of an initial power will help for the derivation of machinery and fuel masses and also costs.

The current estimation method is for monohulls and catamarans, but future study can be carried out to estimate the initial power of different hull configurations.

A computer program has been written to perform the powering calculations, for both monohulls and catamarans, by calculating main dimensions, masses and costs of a ship. The program incorporates routines for resistance calculations based on the regression equations for the systematic series for propulsive efficiency equation 3-17. The program is fully described in Appendix II.

$L/\nabla^{1/3}$	**Form Factors**	
	Monohull (1+k)	**Catamaran (1+βk)**
6.3	1.35	1.48
7.4	1.21	1.33
8.5	1.17	1.29
9.5	1.13	1.24

Table 3.1: Typical Form Factor Values.

Parameter	**B/T**	**$L/\nabla^{1/3}$**	**C_P**	**S/L**
Effect on C_R	5-10% change	40-50% change	5-10% change	0-40% change
Predictability	Poor	Good	Poor	Poor

Table 3.2: Effect of Each Parameter on C_R (NPL Series).

Froude Number (F_n)	**0.6**	**0.8**	**1.0**
Monohull	$1702\cdot\left(L/\nabla^{1/3}\right)^{-2.96}$	$533\cdot\left(L/\nabla^{1/3}\right)^{-2.58}$	$122\cdot\left(L/\nabla^{1/3}\right)^{-1.96}$
R^2	0.991	0.982	0.950
S/L=0.3	$1774\cdot\left(L/\nabla^{1/3}\right)^{-2.87}$	$180\cdot\left(L/\nabla^{1/3}\right)^{-1.97}$	$48\cdot\left(L/\nabla^{1/3}\right)^{-1.41}$
R^2	0.974	0.955	0.852
S/L=0.2	$5084\cdot\left(L/\nabla^{1/3}\right)^{-3.30}$	$130\cdot\left(L/\nabla^{1/3}\right)^{-1.82}$	$22\cdot\left(L/\nabla^{1/3}\right)^{-1.06}$
R^2	0.973	0.932	0.782

Table 3.3: NPL Series Residuary Resistance Coefficient ($C_R \times 10^3$).

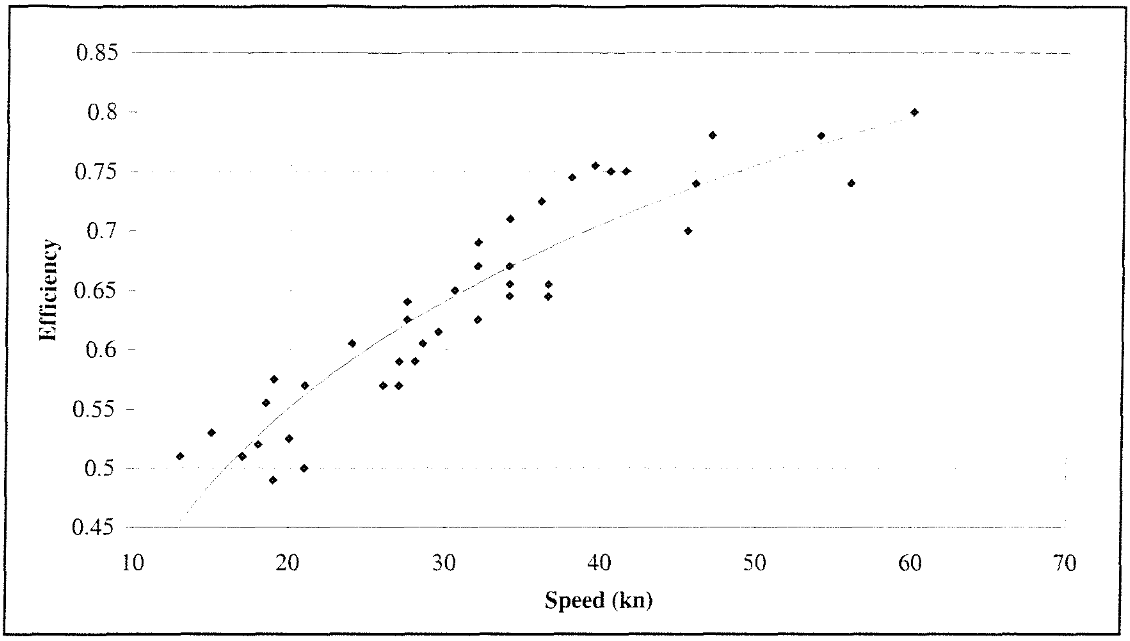


Figure 3.1: Overall Water jet Efficiency.

4. MASSES

4.1 GENERAL

One of the most important design factors in concept design is the estimation of the mass of the craft. Small changes in mass may have a significant effect on vessel performance, particularly for high speed craft. Therefore, estimating mass as accurately as possible is important for an effective and economic design.

It is often difficult to carry out an accurate mass estimation at the preliminary design stage because of the lack of data. Some of the data used for the calculations in the current work are from real ships, while other ships have been created from classification society rules. To carry out all the estimations, empirical methods are adopted. The following sections describe the techniques used in the empirical method developed in the current study.

For the estimation method, ship mass is divided into two major parts, lightship and deadweight. The further breakdown of masses is shown in Figure 4.1. Lightship is subsequently divided into three parts namely hull, outfit and machinery masses. Deadweight comprises cargo, crew, provisions and fuel weights.

The following sections describe the methods developed for estimating each of these masses. Section 4.2 covers hull mass, section 4.3 outfit mass, section 4.4 machinery mass and, finally section 4.5 deals with deadweight.

4.2 HULL MASS

4.2.1 Background

The structural design of high speed ferries can be seen as a crucial part in their design since any changes in mass can result in decreases or increases in powering and costs. Also, the importance of structural mass is reflected in that it can comprise up to 35% of the vessel's full mass.

The main purpose of this part of the research has been to estimate the preliminary structural mass of fast monohulls and catamarans. Structural mass includes the weight of all the platings, stiffeners, brackets, welds, etc. which comprise the structure of a vessel.

Several methods have been developed in the past to determine the hull structural mass of conventional hulls. Two of these methods are investigated in the current research, Taggart [26] and Watson et al [31]. Watson & Gilfillan's method is the most widely used for the preliminary structural mass of conventional displacement ships. This method is also used in the current work with a careful adaptation for fast ferries and is described in more detail later.

The most difficult part of the current study is finding reliable mass data. For business secrecy reasons it has been extremely difficult to obtain any real data from ship builders or operators. The only data obtained this way was under the promise of keeping its source secret. For this reason the current method has been developed mainly with generated data.

Some data for hull mass estimation is obtained from Sainz [23]. Sainz developed ship data by using Lloyd's Register classification society rules for small craft. A number of assumptions and calculations were undertaken to generate data. A software package has been developed by Lloyd's Register which carries out these processes automatically.

The process may be described in simple terms as firstly designing a typical midship section for a hull using a set of rules from a classification society. From this a mass per metre can be achieved for a position amidships and the distribution of weight along the length of the craft can later be determined, thereby establishing the total mass of the vessel. The approach parametrically investigates the hull mass estimates for several vessels of different dimensions.

For monohulls, two data sources were used for the structural design of the vessels. The first of these was the 'Mestral car ferry' concept design. Taking this initial design and varying its principal particulars, new vessel designs were developed. Five vessels were designed in a range from 50 to 150 metres, the length range of most of the new high speed marine vessels. This variation in length involved a new set of dimensions for beam, depth, etc., for each design.

The second data source for monohulls is an article from the fourth international conference on fast sea transportation, Hughes [12], where a strategy is presented for achieving a first principles optimum structural design of a ship using modern computer based tools.

The further part of the monohull structural design involved slight variations on the length and beam of the vessels. An investigation was performed to determine how the effect of keeping the load area of the decks constant would influence the final structural mass. Keeping the factors of length and beam constant make the load carrying ability of the vessels also constant. The investigation was performed on 50, 75, 100, 125, and 150 metre hulls and L/B variants of

4.5 to 7.0, to obtain an indication of the effect of these changes. These values can be seen in table 4.1. Total new designs were performed for these variations in length and beam. The parameters which are influenced directly by changes in length and beam were modified, although most dimensions were left intact. The work task developed for the monohull vessels is shown diagrammatically in Figure 4.2.

The structural design of catamarans also relied on Sainz [23] for it's final completion. It was assumed that the range in the case of catamarans would be up to 100 metres in length as the number of catamaran vessels above this value was very limited, with only a few prospective designs. The new dimensions for the newly developed designs were again derived from initial built vessel data acquired for the catamaran ships.

In the case of catamarans, three lengths, each with three hull separation ratios were investigated. The catamaran study used basic ship lengths of 50 m, 75 m and 100 m with S/L variants from 0.20 to 0.26. The technique used for estimating the hull mass of catamarans was similar to that of monohulls. The work task is shown diagrammatically in Figure 4.3 and the results are shown in Table 4.2.

4.2.2 Presentation of Hull Mass

A practical empirical approach involves developing formulae to represent the hull mass estimates. Many examples of empirical formulae exist to determine the mass of a hull. A commonly used formula for the estimation of hull mass for displacement vessels built in steel is that suggested by Watson et al [31]. The original formula used for the mass of structure estimation is;

$$W_{STRUCTURE} = W_{S7} \times [1 + 0.5 \times (C_B - 0.7)] \qquad \textbf{4-1}$$

The value of the block coefficient (C_B) for the new design is inserted here, and W_{S7} can be estimated from;

$$W_{S7} = K \times E^{1.36} \qquad \textbf{4-2}$$

with values of K for various ship types given in Figure 4.4, in the case of displacement monohull ferries, where E is the equipment numeral, the value of K for steel hulls is in the range $0.024 < K > 0.037$.

The value for equipment numeral (*E*) can be estimated from the following formula, which is commonly used for all varieties of displacement ships;

$$E = L \times (B+T) + 0.85 \times L \times (D-T) + 0.85 \times \sum l_1 h_1 + 0.75 \times \Sigma l_2 h_2 \qquad \textbf{4-3}$$

where l_1 and h_1 are the length and height of full width erections, and l_2 and h_2 are the length of houses. However, as fast ferries generally do not posses these separate types of erections, the last two terms of equation 4-3 would not be applicable.

Watson and Gilfillan [31] obtained values for the hull mass of typical vessels and plotted a graph showing the numeral value *E* against the net steel mass, showing a good relationship between these, and that the equipment numeral is appropriate in the determination of steel mass. This can be seen in Figure 4.4.

These empirical formulae are of great use in the first steps of design for traditional commercial displacement vessels. They provide a quick and immediate method of determining an approximate mass of the structural components of a hull. Next section explains the adaptation of these formulae to fast ferries.

4.2.3 Design Equations

The ship data created by employing Sainz's work [23] and that obtained from ship builders and written sources for high speed craft, are presented in terms of equipment numeral *E*. It is considered that although the method was originally developed for conventional vessels, a careful adaptation can make it suitable for high speed monohull and catamaran forms.

On this basis, the equipment numerals for monohulls and catamarans are obtained using equations 4-4 and 4-4. The different dimensions employed are described in Figure 4.5. In the equations, D_{OA} is taken as the depth overall including the superstructure.

$$E_M = L_{OA} \times (B+T) + 0.85 \times L_{OA} \times (D_{OA} - T) \qquad \textbf{4-4}$$

$$E_C = 2 \times L_{OA} \times (b+T) + 0.85 \times L_{OA} \times (D_{OA} - T) + 1.6 \times L_{OA} \times (B - 2b) \qquad \textbf{4-5}$$

In advocating the use of such an approach it can be noted that the numeral *E* is effectively a function of the total surface area of the ship, with a weighting for the portion above the waterline (D-T) (Figure 4.5). The weighting is currently left at the original value of 0.85 due to the lack of enough detailed data to suggest otherwise. In the case of catamarans, the third term in the equipment numeral is a function of the added area due to the cross structure. The weighting of 1.6 in this case was derived from the parametric study of the influence of hull spacing on mass described earlier.

Available hull mass data is plotted against numeral E for both monohulls and catamarans. Equipment numeral is calculated for each ship based on the equations 4-4 and 4-5. Plots of total hull mass (hull and superstructure) in aluminium alloy for monohulls and catamarans to a base of equipment numeral are shown in Figures 4.6 and 4.7. Suitable fits to the data are found to be as follows;

Hull Mass for Monohulls $$W_{HM} = 0.032 \cdot E_M^{1.2} \qquad \textbf{4-6}$$

Hull Mass for Catamarans $$W_{HC} = 0.00064 \cdot E_C^{1.7}, (E_C \leq 3025) \qquad \textbf{4-7}$$

$$W_{HC} = 0.39 \cdot E_C^{0.9}, (E_C > 3025) \qquad \textbf{4-8}$$

The regression line for monohulls is reasonably good, considering the lack of data and the difficulty to get real ship data. It can be thought that the lack of real ship data may not make the correlation reliable, but the data obtained from parametric design study is the only way to approach an estimation of preliminary hull mass of fast ferries. On this basis it is believed that the correlation is acceptable.

Of commercial confidentiality reasons the existing ship data for catamaran hull mass shown in Figure 4.7 cannot be referenced. These actual ship values made it clear that that the Lloyd's Register classification society rules based estimates for small catamarans (Figure 4.7) are very high. Reasons for this are not clear, although no effort was made in the rules based approach to adopt a low mass structure. Based on this, two individual relationships were created for large and small catamarans. For large catamarans, the parametric study results are found to be acceptable since they correlate well with the ship data. However, for small catamarans, as is mentioned above, the developed data did not show good correlation with the ship values. Thus, available ship values had to eased in the parametric design study results. These two curves fit the equations 4-7 and 4-8 with particular E numerals.

The data and its presentation provide a good starting point for the hull mass estimate. It is believed that as more data becomes available the method offers a good basis and opportunity for further development and refinement.

4.3 OUTFIT MASS

Outfit mass is divided into two parts in the current study. These are namely accommodation weight and remaining outfit weight. Accommodation weight is the most significant component of the outfit mass and is initially estimated by using a mass per unit area, which is explained in the following part of this section.

Accommodation weight includes lounges, dining rooms, self-service areas, air type seats, reception foyer, corridors, galley, toilets and cabins. These allow an initial estimation to be made based on total passenger and vehicle area. Average mass per unit area for components of accommodation is given as follows. Data has been derived from Karayannis [16].

Saloons, dining rooms, self service areas, Pullman seat areas, reception, foyers: 85 kg/m^2,
Refrigeration: 151 kg/m^2,
Toilet and shower rooms: 185 kg/m^2,
Cabins (crew): 176/176/202 kg/m^2 (1/2/4 beds),
Wheel house: 1300 kg/unit area,
Chart room: 350 kg/unit area,
Radio room: 450 kg/unit area.
Corridors: 60kg/m^2,
Galleys: 135 kg/m^2.

From all these detailed mass per unit area information, standard accommodation weight (W_{ACC}) can be found as;

$$W_{ACC} = x \times A_P \tag{4-9}$$

where passenger area is:

$$A_P = f(L_{OA} \times B) = y \times L_{OA} \times B \tag{4-10}$$

From these results, accomodation weight can be estimated as;

$$W_{ACC} = x \times f(L_{OA} \times B) = x \times y \times L_{OA} \times B \tag{4-11}$$

Remaining outfit mass including any equipment not included in the machinery mass may, as a first approximation, be assumed as a linear function of overall length and breadth. This linear function represents the area of the remaining outfit. Therefore remaining outfit mass can be derived from a formula such as;

$$W_{REM} = f(L_{OA} \times B) = z \times L_{OA} \times B \tag{4-12}$$

The above results led the outfit mass per deck to be estimated using equation 4-13. To find the outfit mass for the whole ship, the obtained outfit mass per deck should be multiplied by the number of decks (N_{DECK}) as seen in equation 4-14.

$$\begin{aligned} W_O &= W_{ACC} + W_{REM} \\ W_O &= (x \times y \times L_{OA} \times B) + (z \times L_{OA} \times B) \\ W_O &= [(x \times y) + z] \times L_{OA} \times B \\ n &= (x \times y) + z \\ W_O &= n \times L_{OA} \times B \end{aligned} \tag{4-13}$$

$$W_O = n \times L_{OA} \times B \times N_{DECK} \tag{4-14}$$

where n is derived from detailed lightship data. It is very hard to obtain detailed lightship data. Few data was found or could be estimated to obtain a suitable n value. All values and data can be seen in Table 4.3.

All the values derived from the available data are shown in Table 4.3. Typical values of n for an approximate preliminary estimate of total outfit mass per deck (for both monohulls and catamarans) were found to be around 0.027.

The above calculations lead to an approximate formula for outfit mass as follows;

$$W_O = 0.027 \times L_{OA} \times B_{OA} \times N_{DECK} \tag{4-15}$$

A more accurate outfit mass based on equations 4-13 could be developed once more data for fast ferries became available.

4.4 MACHINERY MASS

4.4.1 Background

The current study divides the overall machinery mass into two major components. These are the propulsion machinery and the auxiliary or remaining part of the machinery. The principal components of propulsion machinery are the main engines (diesel engine or gas turbine), gearboxes and propulsors (propeller or water jet), Guenther [11]. The remaining part of the machinery installation includes generators, pumps, piping and other auxiliary equipment. Figure 4.8 summarizes these components in a flowchart.

Machinery mass has been assembled into a set of data including the main machinery components suitable for high speed craft including medium and high speed diesels, gas turbines, water jets and gearboxes, Warren [30]. The data allows the overall mass of the propulsion system to be estimated with some confidence based on installed power. On the other hand, published data on the remaining part of the machinery mass is limited, hence it is currently calculated as a function of the overall propulsion mass.

In the initial stages of ship design, one of the important factors to choose is the suitable machinery. Especially, for fast craft the effect of propulsion is crucial. Some of these effects are listed below;

- Size (physical dimensions),
- Mass,
- Fuel consumption,
- Need for multiple installations and/or gearboxes.

Further factors, which can affect operating costs, are;

- Lubricating oil consumption,
- Reliability,
- Operational flexibility,
- Quick starting,
- Range of operation,
- Number of crew members,
- Maintenance costs.

All of the above effects are important, however some of them are crucial for fast craft. This is the case of the total machinery mass. An estimate is required at the initial stages of the design process. Big deviations from this initial assumption may result in future problems. Apart from changes in performance parameters and other engine properties, it might have an important effect on the final vessel's physical dimensions. For all these reasons, finding a method to estimate the initial machinery mass is considered to be vitally important. The current study deals with the preliminary estimation of main engine, propulsor, gearbox and remaining machinery weights. These are covered in the following sections.

4.4.2 Principal Components of Propulsion Machinery

The factors and parameters, generally used to characterize engine operation are;

- The engine's performance over its operating range and size,
- The engine's fuel consumption within this operating range and the cost of the required fuel type,
- Noise and air pollutant emissions within the operating range,
- The initial cost of the engine and its installation,
- The reliability and durability of the engine, its maintenance requirements, and how these affect engine availability and operating costs.

In addition to the above parameters engines specifically made for fast ferry applications are compared according to their load distribution Vrontorinakis [29]. Comparisons are performed considering that a fast ferry engine operates for up to 90% of the time at full load and only 10% of the time at less than 50% power.

Naturally in every application one of the primary requirements for an engine is to satisfy the power needs. This condition in fast ferries, not only has to be satisfied adequately, but it must also be achieved in confined spaces and by using the least mass. The main objective therefore is to achieve an increase in power to mass, and power to bulk volume ratios, in order to install more power in a given space, or to reduce the dimensions of the machinery room.

Another primary requirement for an engine is the fuel consumption. In engine tests, the fuel consumption is measured as a mass flow rate per unit time. A more useful parameter is the specific fuel consumption (sfc) which is fuel flow rate per unit power output. It measures how efficiently an engine is using the fuel supplied to produce work.

Low values of specific fuel consumption are obviously desirable. For diesel engines, typical best values are lower than 270 g/kWh, and in large engines this can go below 200 g/kWh, Vrontorinakis [29]. It is a measure of the engine's efficiency. This value is also used for the calculation of fuel mass in the current research.

Engine mass and bulk volume for a given rated power are important in many applications. This is especially important in the area of fast ferries, since the best engine could be impossible to use, if it simply cannot fit inside narrow catamaran demihulls. Two parameters useful for comparing these attributes from one engine to another are;

Specific Mass = Engine Mass / Rated Power
Specific Volume = Engine Volume / Rated Power

4.4.2.1 Total Mass Estimation for Diesel Engines

Dry engine mass (manufacturer's catalogues) excludes the necessary fluids, lubricating oil and cooling water. It also excludes other heavier and equally important accessories for a specific application, such as the gearbox, the water jet and other auxiliary machinery (pumps, coolers, etc.). Most engines in these high speed ranges discussed for fast ferry applications would need to utilize a gearbox to transmit the output power to the water jets or around bends etc. Although coolers, pumps, fluids and others are absolutely necessary in all applications, their mass is definable within the overall estimation. A detailed weight database of most available engines is presented in Vrontorinakis [29]. Based on this data, Figure 4.9 has been produced for diesel engine mass. The correlation between diesel engine weight and power/engine speed ratio can be summarized as follows;

$$W_D = 6.82 \times \left({}^{P_I}\!/_{n} \right)^{0.85} \text{ tonnes } (R^2=0.913) \qquad \textbf{4-16}$$

where P_I is the delivered power to per propulsion unit, and n is the engine speed (rpm).

It should be noted that since equation 4-16 is non linear, it has to be applied for each engine unit.

4.4.2.2 Total Mass Estimation for Gas Turbines

Apart from diesel engines as prime movers for fast ferries, gas turbines are the other alternative, either alone or combined with a diesel.

There are two main types of gas turbines namely the aero derivative and the heavy duty industrial. The former type usually comprises parts of a jet engine, somewhat down-rated with regard to temperature and power, acting as a hot gas generator supplying energy to a specially designed output turbine connected to the propulsion gearing.

As aircraft gas turbines are designed primarily for flying, the emphasis for fast ferry applications has to be on maintaining minimum size and mass, with restricted frontal area. However, these engines operate at higher-pressure cycles and burn expensive fuel, something not very desirable for marine applications in general.

The industrial gas turbine in turn, does not have so much emphasis on mass reduction, but has more emphasis on machine life and reduction on maintenance. The outcome is a more robust engine with inevitably higher mass, and bulk volume. For these reasons, the heavy-duty turbine is not offered for marine service, unless editions and developments in the cycle refine it.

Gas turbines consist of three parts:

1. Gas generator (produces hot gas), consists of compressor stages, combustion chambers and compressor turbine stages,
2. Power turbine,
3. Module.

For various reasons, marine gas turbines benefit from being in dedicated modules. When mass is considered, gas turbines have the ability to be able to include their auxiliaries in this contained platform, and offer advantages such as, structural support, ease of mounting, shock protection and others.

The mass of the turbine increases proportionally to the power output, just as diesel engines. Specific fuel consumption decreases along with the power increase. Based on Vrontorinakis [29] data was plotted in Figure 4.10. Gas turbines mass can be obtained using equation 4-17.

$$W_{GT} = 3.0 + 0.00056 \cdot P_I \text{ tonnes } (R^2=0.917) \qquad \textbf{4-17}$$

where P_I is the installed power per propulsion unit.

Again, the weight formula has to be applied for each gas turbine.

4.4.2.3 Total Mass Estimation for Propulsors

One of the most important differences between fast ferry propulsion and conventional ship propulsion is created by the prime mover itself. No matter if it is a high or medium speed diesel engine or gas turbine, they all operate at high rotational speeds for a propulsor to cope directly and deliver the expected power. The accepted solution, is to use a reduction gearbox, which will bridge the speed difference, but at the same time add more weight, lower the transmission efficiency, increase bulk volume and complexity, and ultimately increase costs.

The propulsion device in turn, is almost always a water jet for fast speed applications, since among other advantages they prove to be more efficient at speeds over 25-30 knots than conventional propellers. Another very important aspect of water jets, is that they weigh less than propeller installations. Water jet mass data correlated with installed power (P_I) is shown in Figure 4.10. The main trend is represented by equation 4-18.

$$W_{WJ} = 0.00018 \times P_I^{1.18} \text{ tonnes } (R^2=0.966) \qquad \textbf{4-18}$$

P_I represents the installed power per propulsion unit.

Again as in previous sections the obtained equation is non linear and has therefore to be applied for each propulsor independently.

4.4.2.4 Total Mass Estimation for Gearboxes

Large amounts of data were found for gearboxes suitable for fast ferries, Vrontorinakis [29]. The data was processed to find an initial mass estimate of the gearboxes for fast ferries. The relationship between maximum power and the total weight of the gearboxes has been correlated in figure 4.12 to estimate an initial weight. Regression from this correlation is summarized in equation 4-19 with a satisfactory reliability of $R^2=0.80$.

$$W_{GB} = 0.00348 \times P_I^{0.75} \text{ tonnes} \qquad \textbf{4-19}$$

P_I is the installed power per propulsion unit. The estimation must be multiplied by the number of propulsion units to obtain the total gearbox weight.

Since the weight formula of gearbox is non linear, it has to be applied for each propulsion unit.

4.4.3 Principal Components of Remaining Machinery

Research was carried out initially to find suitable data for each of the remaining machinery parts to make the estimation of the remaining part of the machinery mass (W_{RM}) as reliable as possible. Detailed search to obtain generator, pump, pipe and other auxiliary mass data was performed. It was only possible to attain some generator mass data. Pumps, piping and other auxiliary mass data was not available. An alternative solution was therefore required to estimate the remaining part of the machinery mass. It was decided that the remaining part of the machinery installation weight could be estimated as a function of the total propulsion mass (W_P) as shown in equation 4-20. It is clear that the amount of the remaining machinery installed on board is dependent on the sizes of the main engine, propulsor and the gearbox. Therefore, the idea of remaining machinery mass being a function of the total propulsion machinery mass was plausible.

$$\begin{aligned} W_P &= W_D(W_{GT}) + W_{WJ} + W_{GB} \\ W_{RM} &= f(W_P) \end{aligned} \qquad \textbf{4-20}$$

Propulsion mass data was gathered for high speed ferries from Joo et al [14] and Trincas et al [28]. These values can be seen in Table 4.4. It was very difficult to assess the type of function between the total propulsion mass and the remaining machinery mass since the available data was scarce. To keep the estimation simple, a linear relationship between these two masses was obtained. Thus, the remaining machinery mass found to be represented by equation 4-21.

$$W_{RM} = n \times W_P \qquad \textbf{4-21}$$

The value n is based on available data and a sequence of mass balances for high-speed craft. A number of calculations was carried out to find a suitable n value. An example from these calculations is shown below to better explain the process. The particular example's data is taken from Trincas et al [28]. The remaining calculations were undertaken in the same way. The average of the n values was then obtained. Values ranged from 0.64 to 0.45, with its final value being around 0.55. A suitable approximation of the remaining machinery mass was therefore that expressed in equation 4-22.

$$W_{RM} = 0.55 \times W_P \qquad \textbf{4-22}$$

4.4.4 Total Machinery Mass

Total machinery mass estimation was completed taking into account the different aspects and techniques detailed in the previous sections. The total machinery mass is then calculated as the sum of the main engine, propulsor, gearbox and the remaining machinery masses in equation 4-23.

$$\begin{aligned} W_{TM} &= W_P \times 1.55 \\ W_{TM} &= \left[W_D\left(or W_{GT}\right) + W_{GB} + W_{WJ}\right] \times 1.55 \end{aligned} \quad \textbf{4-23}$$

4.4.5 Summary

A method for the initial estimation of fast ferries total machinery weight has been generated. It is believed that the results can be accepted to be reliable with some degree of confidence.

Different engine modes and propulsors can be applied to the method in future to further expand its capabilities. Engine modes would account for the fact that some fast ferries contain diesel and gas turbines together as their main power suppliers. Also, a second propulsor such as a propeller could be added to the method.

It is clear that lack of data could cause some inaccuracy on the present results, but this does not invalidate the overall idea and methodology. Furthermore, the addition of more data in the future will enable a refinement of all the methods employed.

4.5 DEADWEIGHT

4.5.1 Background

Deadweight is defined as the difference between the load displacement and the lightweight. It is an important part of the whole vessel mass and can be estimated fairly accurately, since it is possible to obtain information for its components such as cargo, fuel, water, crew, effects, etc. In the context of the present research it is assumed to include the following:

- Passengers and luggage
- Vehicles
- Crew and effects
- Water and provisions

- Fuel and lubricating oil
- Ballast, cargo and others.

Deadweight estimation can only be carried out when the main operational requirements of the vessel are defined or assumed. These include speed, range and capacity. The mass per passenger, crew, luggage, effects and per vehicle is applied as typical standard values, as described in the next section.

4.5.2 Principal Components of Deadweight Mass

Standard values for components of deadweight mass are detailed in Table 4.5 from Karayannis [16]. The table shows the standard values for passenger, luggage, vehicle, crew, effects, water, provisions, fuel, lubricating oil and others weights.

Passenger and luggage weight is calculated by multiplying standard per person and luggage weight by number of passengers. The same method is applied to the vehicles and crew and effects.

The mass of water and provisions required are estimated by using typical daily consumption per person on board. This number then multiplied by the number of people on board.

Fuel and lubricating oil masses are calculated by using a relationship which is a function of service power, speed, consumption and range. The equations of principal components of deadweight are given in Table 4.6. The given equations show the basic relation between all these parameters. It is clear that the amount of fuel need to be stored on board is related to the effective power, specific fuel consumption, service speed and range of the vessel. A 9% for generator diesel and lubricating oil allowance is made together with a margin of 10%.

New deadweight values have been generated by using the equations in Table 4.7. These values have been compared against real ship data to measure the reliability of the current study's results. The comparisons are given in Table 4.7 and Figure 4.13. Figure 4.13 shows that the estimation is reliable for an initial set of calculations for deadweight. Only two parts of the real ship data and estimated value show reasonable correlation. For preliminary estimation purposes these two parts are acceptable.

4.5.3 Summary

Details of the estimation of masses which make up the total ship mass have been given in the previous sections. This allows the application of initial mass estimates to achieve a balance between masses and suitable dimensions. as described in chapter 2. They will then be employed for the building of cost estimates in chapter 5.

L_{OA} (m)	45	50	55	75	95	100	105	125	145	150	155
B (m)	9.83	8.85	8.04	12.6	15.86	15.07	14.35	19	23.06	22.3	21.58
D_{OA} (m)	9.18	9.18	9.18	11.14	13	13	13	15	16.7	16.7	16.7
T (m)	1.78	1.78	1.78	2.16	2.52	2.52	2.52	2.9	3.24	3.24	3.24
E	805.5	846	886.1	1680	2592	2650	2707	4023	5473	5547	5621
Wh (t)	121.5	125	129.1	249.3	384.8	399.3	409.6	654.6	981.7	984.7	1020

Table 4.1: Designed Monohulls for Hull Mass Estimation ($L_{OVERALL} \times B$ is constant).

L_{OA} (m)		50			75			100	
B (m)	13.8	15.2	16.9	22.72	24.26	25.88	28.9	30.2	31.8
B/2	6.9	7.6	8.45	11.36	12.13	12.94	14.45	15.4	15.9
S/L	0.209	0.222	0.238	0.218	0.239	0.26	0.196	0.224	0.258
D_{OA} (m)		9.68		15.42	15.34	15.44		19.36	
T (m)		1.88			2.83			3.8	
B (m)		4		6.37	6.34	6.38		8	
E	1384	1460	1587	3305	3476	3661	5618	5813	6053
W_h (t)	255	274	310	564	601	631	915	943	987

Table 4.2: Designed Catamarans for Hull Mass Estimation ($L_{OVERALL} \times B$ is constant).

N_{DECK}	L_{OA}	B_{OA}	W_{OUTFIT}	n	**Reference**
2	97.95	19.70	100.07	0.026	Joo et al [15]
2	109.50	29.50	180.00	0.028	Trincas et al [31]
2	80.24	20.18	87.59	0.027	Joo et al [15]
2	45	11.8	27.71	0.026	Wood et al [35]
2	50	11.8	33.95	0.029	Wood et al [35]
2.5	104.65	16.44	200.08	0.026	Trincas et al [30]

Table 4.3: Calculation of Outfit Mass.

$W_{PROPULSION}$ (t)	W_{REST} (t)	n	Reference
190.39	121.5	0.64	Joo et al [15]
177.82	98.25	0.55	Joo et al [15]
100	45	0.45	Trincas et al [32]

Table 4.4: Remaining Machinery Mass Estimation.

Passenger & Luggage	Passenger = 75 kg/person Luggage = 30 kg/person
Vehicles	1000 kg/car
Crew & Effects	Crew = 75 kg/person Effects = 60 kg/person
Water & Provisions	Drinking water = 20 kg/person.day Hygiene = 120 kg/person.day Provisions = 10 kg/person.day
Fuel & Lubricant	Fuel oil = $P_S \cdot SFC \cdot (R/V_S)$ Diesel oil = Fuel oil · 6% Lubricant oil = Fuel oil · 3% Margin = 10%

Table 4.5: Principal Components of Deadweight.

Passenger & Luggage	$W_{PAX} = 0.105 \times N_{PAX}$ tonnes
Crew & Effects	$W_{CREW} = 0.135 \times N_{CREW}$ tonnes
Cars	$W_{CAR} = 1.0 \times N_{CAR}$ tonnes
Fuel & Lubricant oil	$W_F = [P_S \times SFC \times (R/V_S) \times 1.09 \times 1.10]/1000$ tonnes
Fresh water&Provisions	$W_{FW} = 0.150 \times N_{PAX} \times (R/V_S) \times (1/24)$ tonnes

Table 4.6: Suitable Formulae for the Principal Components of Deadweight.

N_{PAX}	N_{CAR}	N_{CREW}	**R (nm)**	**P_I (kW)**	**V_S (kn)**	**DW_{real} (t)**	**Reference**
367	0	5	200	5740	27	64	FFI May'95
794	190	5	350	22000	36	373	FFI June'95
696	100	5	500	29830	40	314	FFI December'95
400	60	5	310	12000	35	155	FFI March&April'96
446	52	5	200	32200	52	142	FFI December'97
351	42	5	100	10840	39	77-102	FFI January&February'96
1200	219	5	300	33900	36.5	448-574	FFI April'97
700	140	5	500	28320	35	360-450	FFI April'97
500	148	5	500	24000	37	200-320	FFI July&August'96
1800	460	5	300	88000	40	800-1200	FFI March&April'96
1500	425	5	295	44000	35	709-1185	FFI June'95

Table 4.7: Deadweight Estimation Compared with Actual Ship Data (FFI stands for Fast Ferry International).

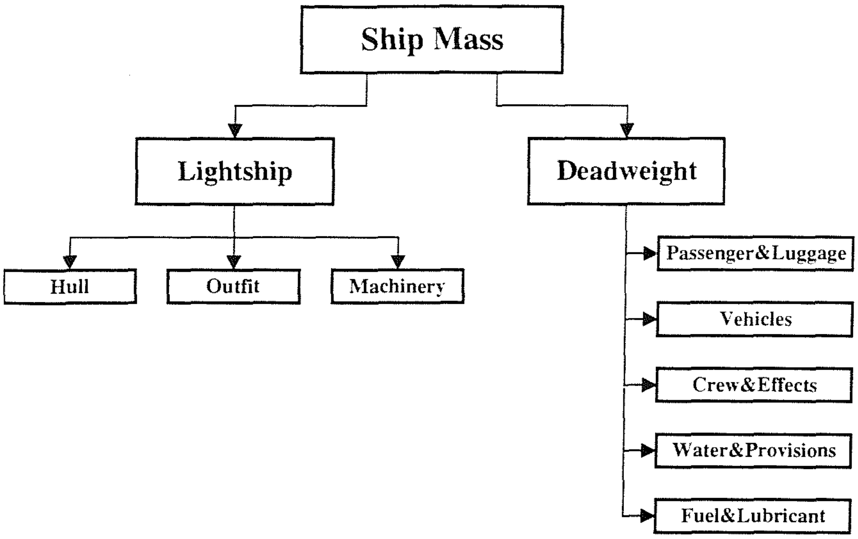


Figure 4.1: Breakdown of Ship Mass.

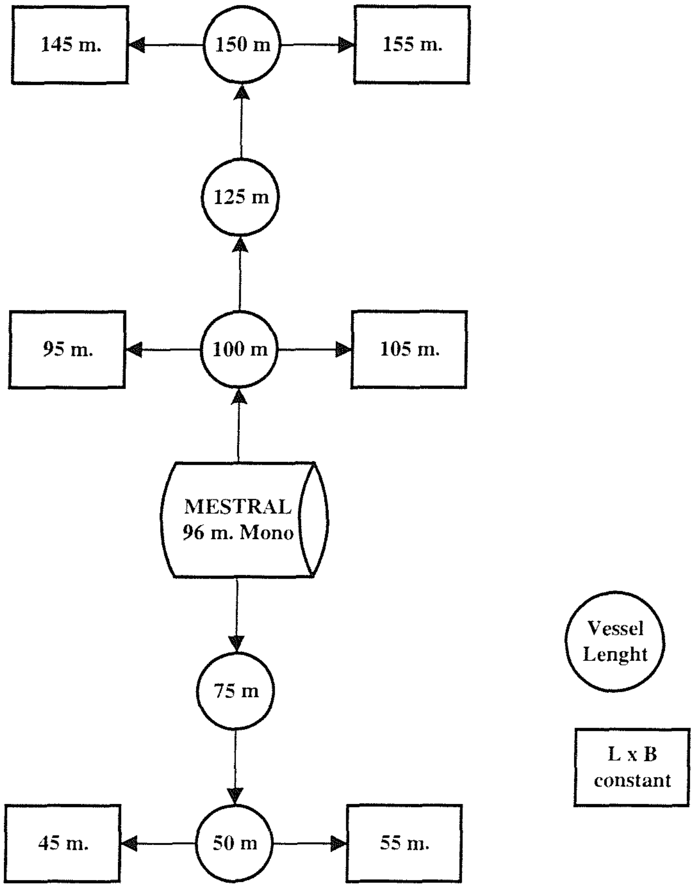


Figure 4.2: Work Task Developed for Monohull Hull Mass Estimation.

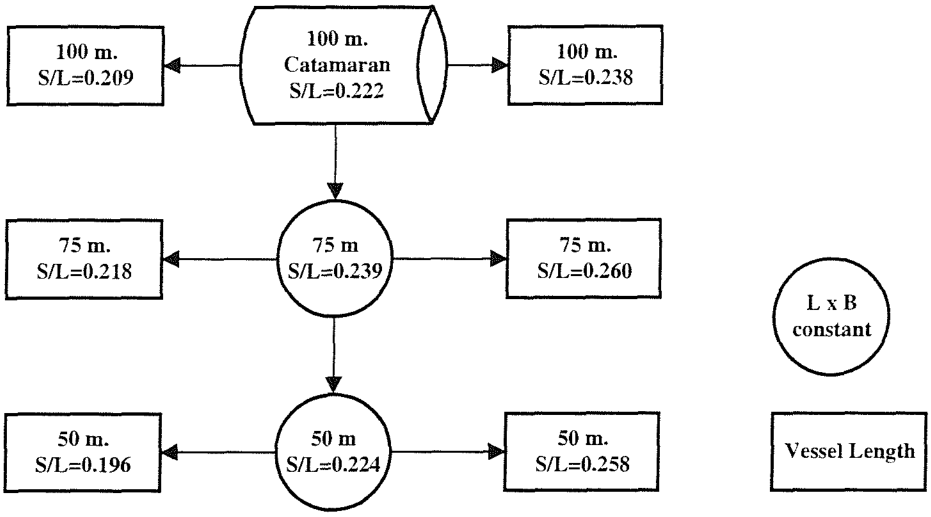


Figure 4.3: Work Task Developed for Catamaran Hull Mass.

Ship Type	K	E
Tankers	0.029-0.035	1500<E<40000
Chemical tanker	0.036-0.037	1900<E<2500
Bulk carrier	0.029-0.032	3000<E<15000
Open type bulk Container	0.033-0.040	6000<E<13000
Cargo	0.029-0.037	2000<E<7000
Refrig.	0.032-0.035	E≅5000
Coasters	0.027-0.032	1000<E<2000
Offshore supply	0.041-0.051	800<E<1300
Tugs	0.044	350<E<450
Trawler	0.041-0.042	250<E<1300
Research vessel	0.045-0.046	1350<E<1500
Ferries	0.024-0.037	2000<E<5000
Passenger	0.037-0.038	5000<E<15000

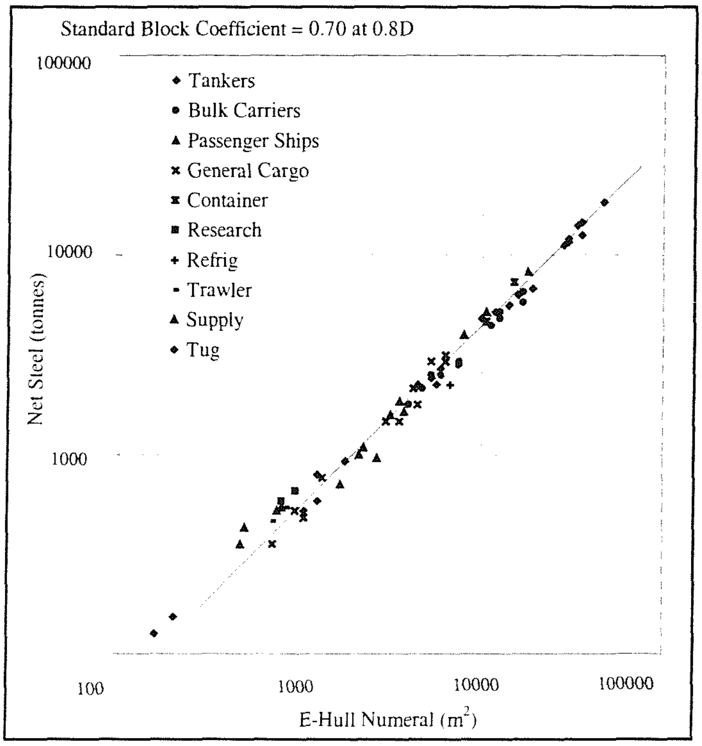


Figure 4.4: Relationship Between Equipment Numeral and Net Steel.

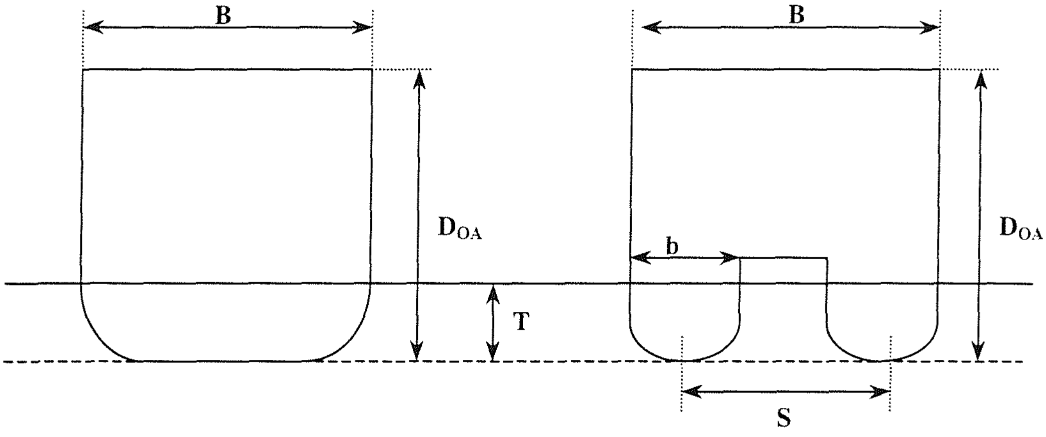


Figure 4.5: Midship Section of a Monohull and a Catamaran.

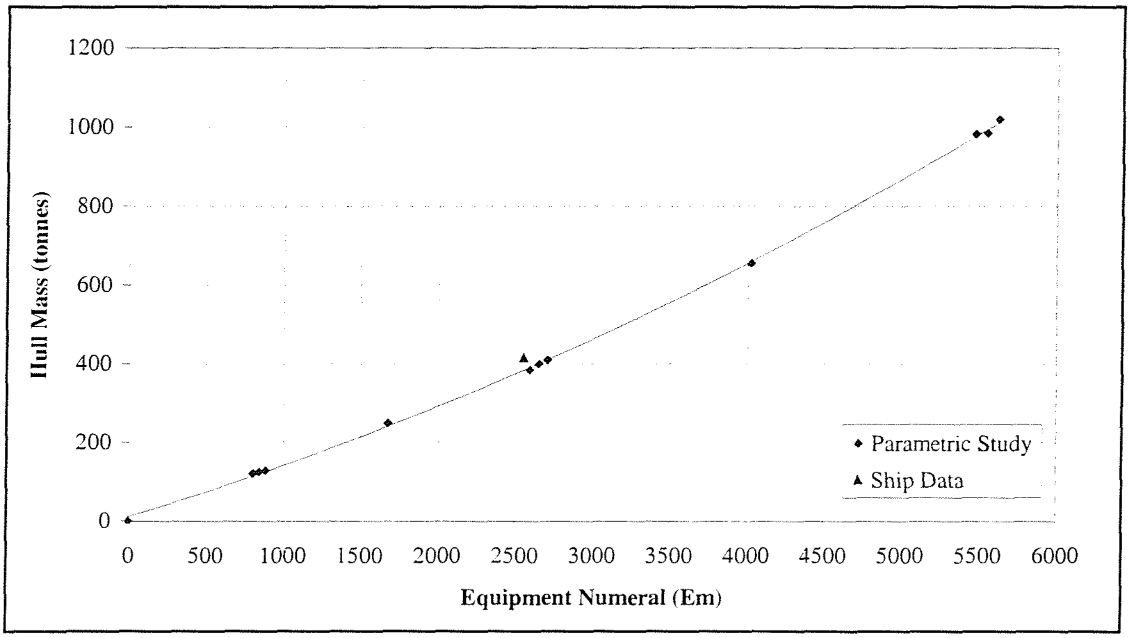


Figure 4.6: Monohull Hull Mass Data.

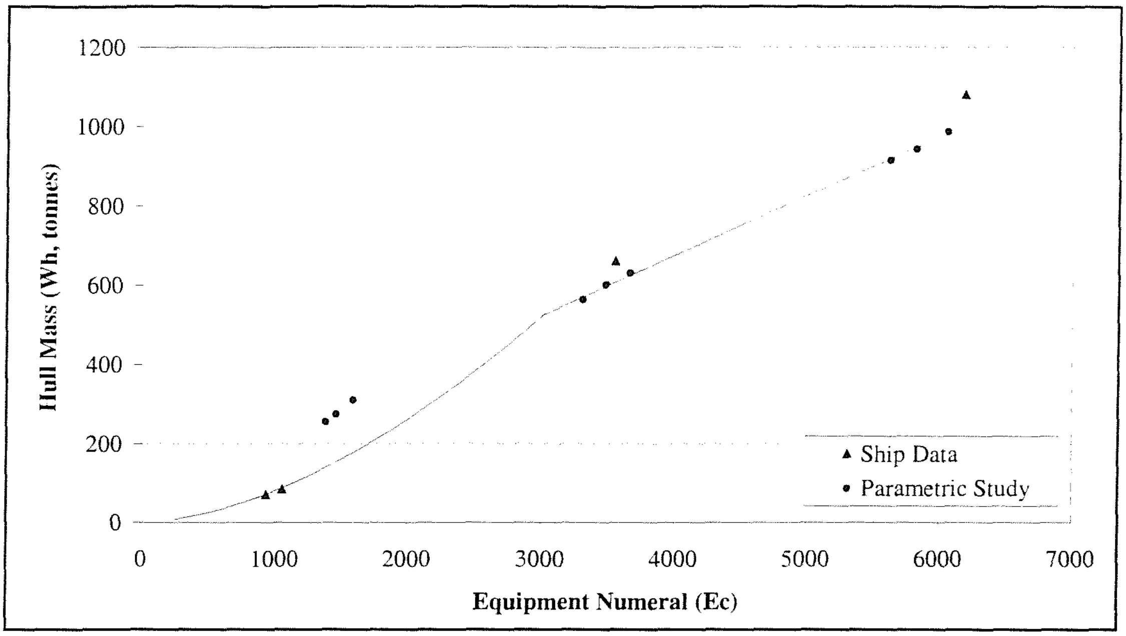


Figure 4.7: Catamaran Hull Mass Data.

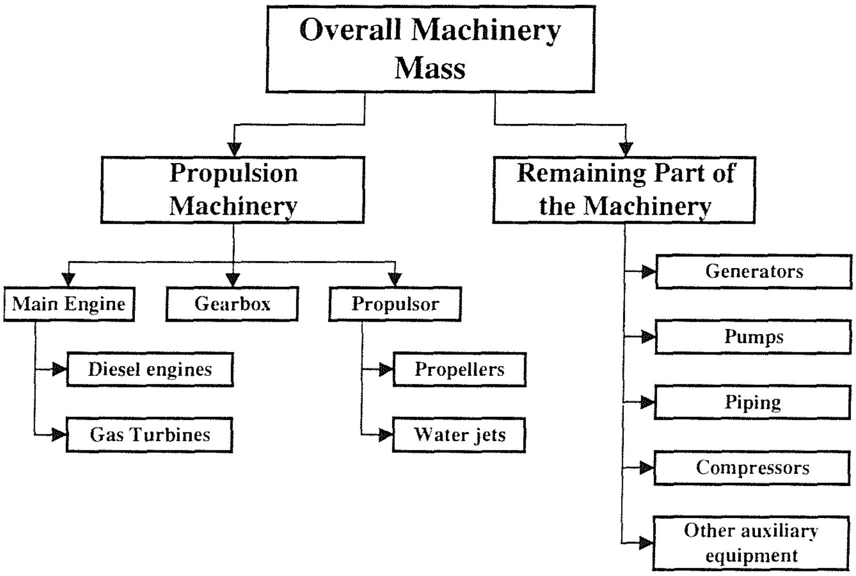


Figure 4.8: Principal Components of Overall Machinery Mass.

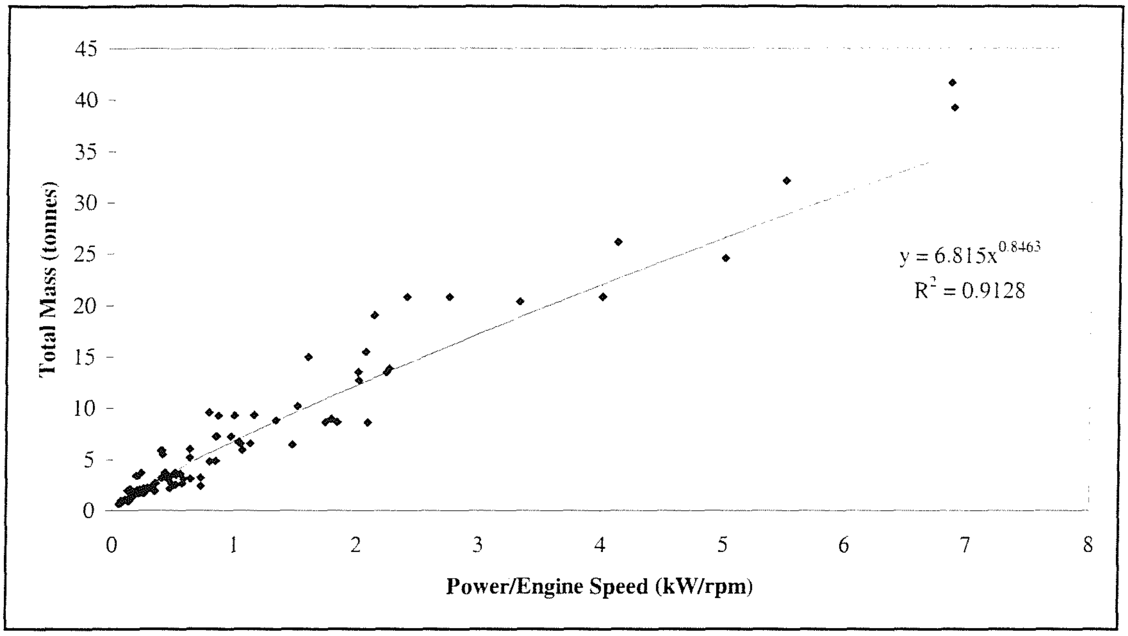


Figure 4.9: Diesel Engine Mass Data.

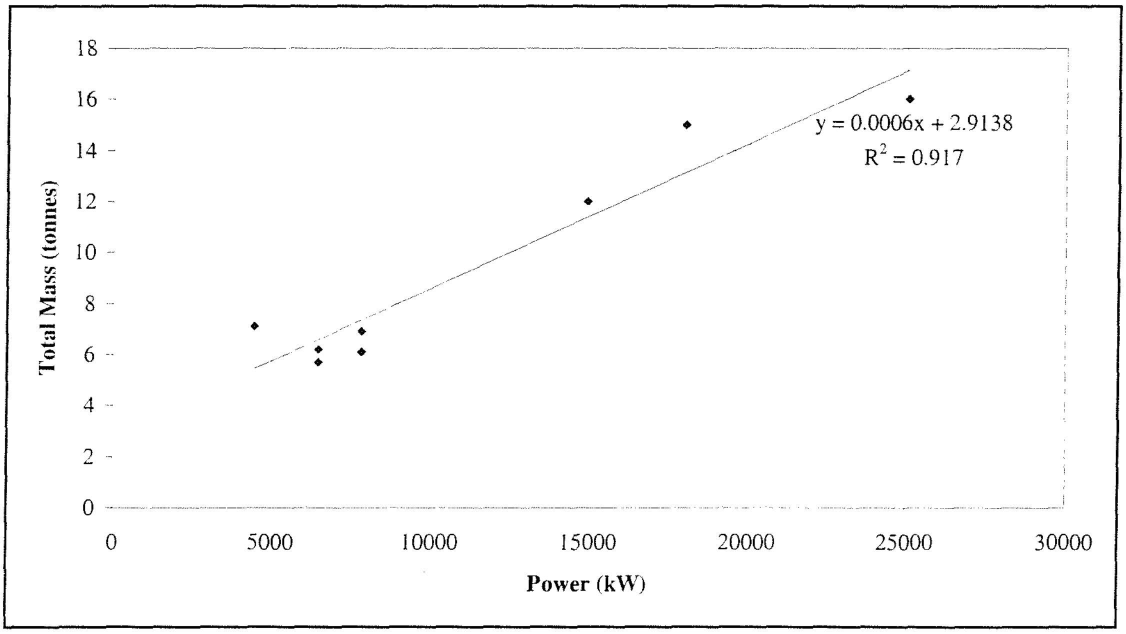


Figure 4.10: Gas Turbine Mass Data.

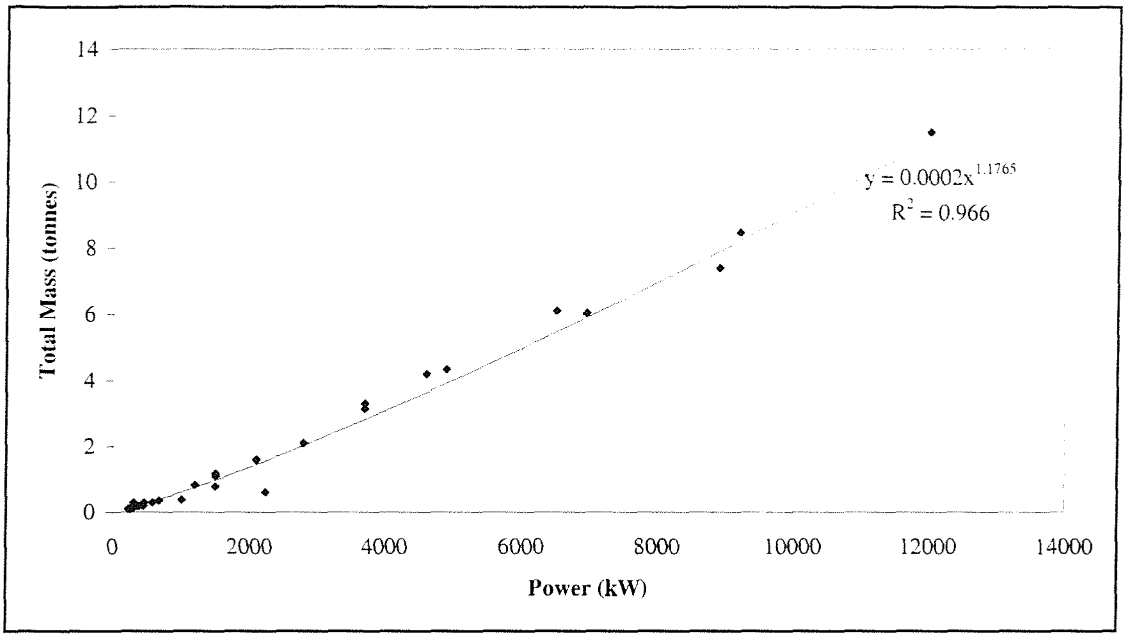


Figure 4.11: Water Jet Mass Data.

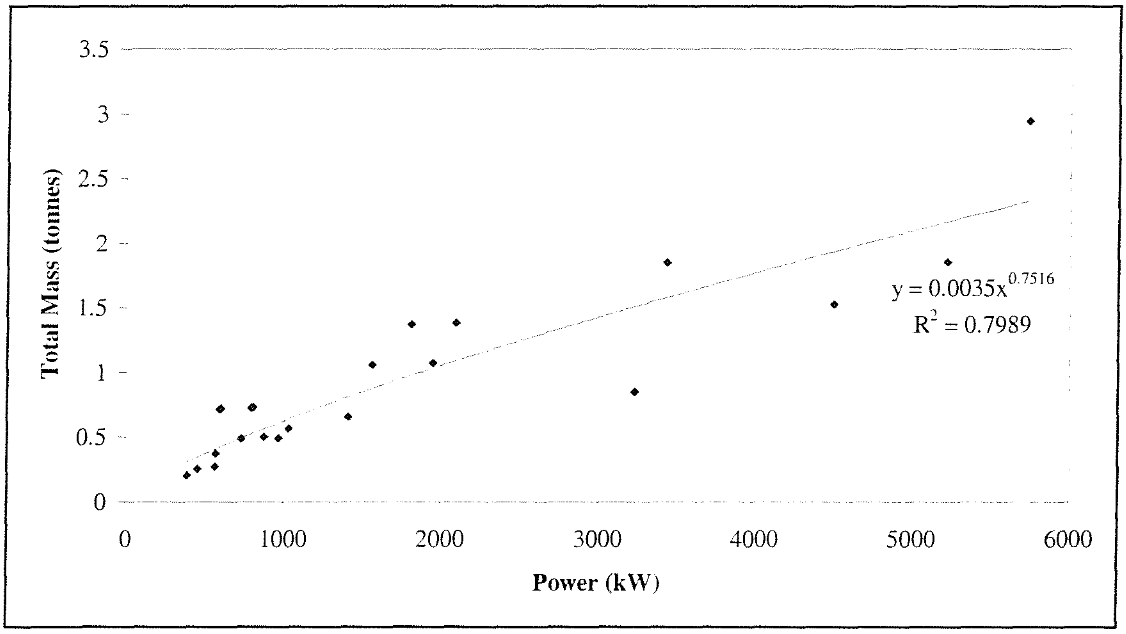


Figure 4.12: Gearbox Mass Data.

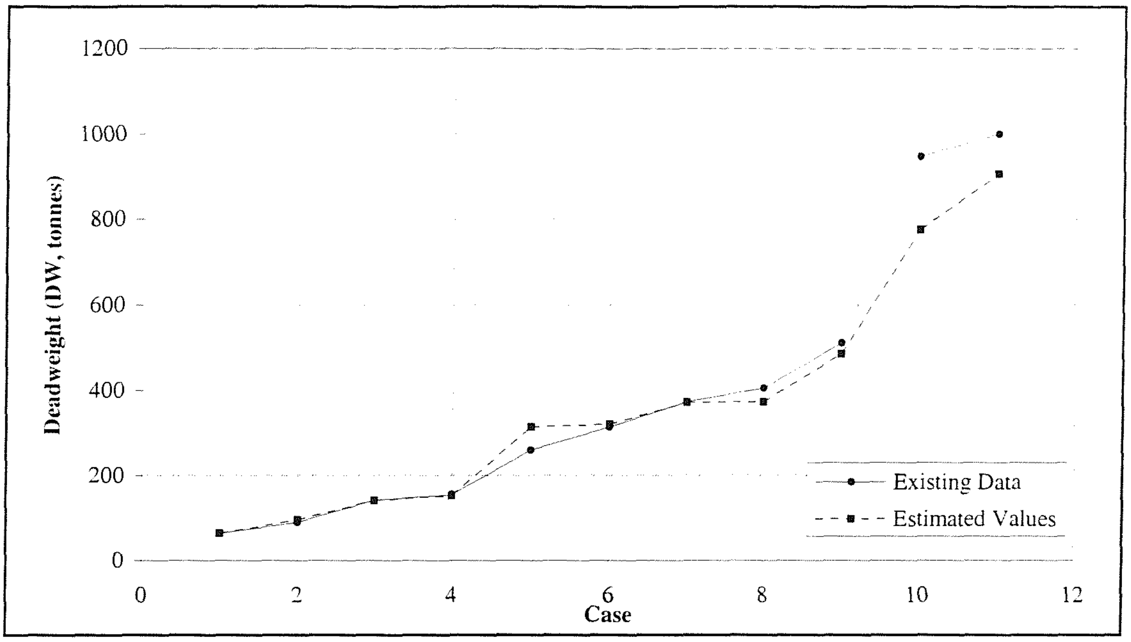


Figure 4.13: Deadweight Comparison.

5. COSTS

5.1 GENERAL

In order to assess the commercial viability of high speed ferries, it is important to be able to estimate the costs related to such vessels as accurately as possible at the very early design stages.

The analysis presented herewith focuses on building costs. Estimates of running costs should not normally present problems once the operational requirements are known. The design and construction of high speed vessels involves innovative techniques and technologies. As a result, traditional approaches commonly used for estimating building costs used in conceptual and preliminary design studies, such as that developed by Caryette [4], may not be directly applicable for such craft, at least quantitatively. The approaches presented in this section have therefore been specifically developed for high speed vessels.

5.2 APPROXIMATE OVERALL BUILDING COST

As it is stated in chapter 2, carrying capacity is the major initial requirement for a new high speed ferry design in the current research study. At the same time speed is likely to be the second major initial requirement for a new high speed ferry design. They both directly influence the size of the vessel and the machinery installation, which are significant factors affecting a vessel's building cost.

In an earlier work, Karayannis [16], in order to provide rapid initial estimates, developed relationships for building cost calculations based on these parameters. The analyses were based on actual acquisition costs found for existing high speed ferries in relevant literature such as Lloyd's List, Fast Ferry International and other professional journals. It revealed that adequate correlations could be obtained for these parameters. The resulting regression formulae are given as follows:

$$C_M = -37.6 + 0.0115 \cdot N_P + 0.121 \cdot N_V + 1.230 \cdot V_S \text{ MUS\$, } R^2=0.96 \qquad \textbf{5-1}$$

$$C_C = -18.4 + 0.0294 \cdot N_P + 0.111 \cdot N_V + 0.445 \cdot V_S \text{ MUS\$, } R^2=0.89 \qquad \textbf{5-2}$$

where C_M and C_C represent the building costs (million United States Dollars) for monohulls and catamarans respectively.

As discussed in Molland et al [19] the correlation are satisfactory, although some problems exist for small vessels, which suggests that the formulae should be used with caution at the lower end of the size range. Apart from this exception, agreement of calculated values with real prices is generally reliable. Therefore, data obtained from Karayannis [16] is adequate and is used in the present study cost estimation method with some updates and alterations, which are clarified in the following sections.

5.3 DETAILED COSTS

5.3.1 General

The development of detailed calculations entails breaking down the total building costs into the hull, outfit and machinery costs. Also, the further division of each of these components into materials/equipment and labour was also investigated in the current work. As it is understandable, such investigations are particularly important in concept design studies since every little item included in the whole estimation will provide more accurate final results. Detailed calculations of hull, machinery and outfit costs are described below.

5.3.2 Hull Cost

The estimate of hull cost is mostly based on the hull mass. It is also constructed as a function of the labour costs. Beside these two factors, a 10% material scrap value is assumed, and is added to the total hull cost. Some data have been obtained from shipbuilders on the basis of commercial confidentiality. These data are shown in Table 5.1, and provides suitable values for the material and labour rates to be used in equation 5-3. The data has been obtained from a fast ferry shipbuilding company and asked not to be referenced regarding their secrecy reasons.

$$C_H = (W_H \times M \times 1.10) + (W_H \times LT \times LC) \text{ US\$} \qquad \textbf{5-3}$$

where M is the material cost per tonne, LT is the labour hour per tonne and LC is the labour cost per hour. The first part of the equation calculates the material and scrap material values whilst the latter part determines the labour cost. The price of aluminium alloy is 5250US$ per tonne, whilst mild steel costs 900 US$ per tonne. Labouring time for simple structure is approximately 600 hours per ton and 900 hours per ton for complex structure. The definitions of simple and complex structures are explained in the following paragraph. Labour costs an average of 30 US$ an hour.

The labour hours have a range covering simple to complex structures. A monohull can be considered as a simple structured vessel. On the other hand a catamaran represents a complex structured ship, the simple reason being that a catamaran has got two thin demihulls and an extra structure between two hulls, which may be time consuming and difficult to manufacture.

From all above information, an estimation method of initial hull cost for high speed ferries has therefore been developed which is considered to be acceptable for preliminary estimates.

5.3.3 Outfit Cost

The estimate of outfit cost is based on a limited amount of available data. For the time being, an overall outfit cost (C_O) estimate, based on outfit mass (W_O), is proposed as follows. This value is derived from Karayannis [16] and has been updated according to the percentage of the inflation for each year.

$$C_O = 22{,}000 \times W_O \text{ US\$} \qquad \textbf{5-4}$$

5.3.3 Machinery Cost

The total machinery costs are made up from main engines (diesel engines and gas turbines), gearboxes and water jets together with the further costs. The further costs are a function of propulsion equipment costs, associated with the remaining equipment and the overall labour costs associated with the machinery installation.

It is assumed that the demand for passengers and cars to be transported always equals the full capacity of the vessel. For this reason the analysis had been carried out with the full displacement service speed and fuel consumption.

The overall factors that have been taken into account for a correct evaluation of the machinery costs are the following:

- Main engine capital cost as given by engine suppliers including installation, two days torsion vibrations tests, trials, and guarantee.
- Costs of gearboxes, water jets controls etc. according to prices obtained by manufacturers or suppliers.

All prices are quoted in United States Dollars (US$). It should be mentioned that prices given by manufacturers and suppliers can be subject to large changes, depending on the special circumstances on each occasion. Engine manufacturers for example are willing to significantly reduce their listed engine price in order to ensure a future spare parts customer. Other reasons for price reductions are greater qualities purchased, and/or services ensured. Therefore, the prices given are average list prices, depending on place, time and customer, as well as on successful negotiations.

Relevant initial cost data, Vrontorinakis [29] has been displayed versus installed power in Figures 5.1 to 5.4. Regressions from the relevant figures are presented in Table 5.2.

The cost of the remaining items of machinery such as generators, pumps together with the overall auxiliary costs was found to be of the order of 40% of the propulsion machinery cost. This number was been generated by a sequence of cost balances.

Initially, a number of ship data was obtained from the database, Then, their hull, outfit, main engine, water jet and gearbox costs were estimated according to the equations developed in the current study. Equations 5-1 and 5-2 were used to estimate the overall building cost of each vessel. The estimated hull, outfit and machinery costs were subtracted from the estimated building cost to obtain the remaining machinery cost. Mean value of the ratio remaining machinery cost/propulsion cost was found to be 0.40. The end products can be observed from Table 5.3.

Consequently, total machinery cost can be summarized by equation 5-5.

$$C_{TM} = \left[C_D\left(C_{GT}\right) + C_{GB} + C_{WJ}\right] \times 1.40 \qquad \textbf{5-5}$$

where C_D corresponds to diesel engine, C_{GT} to gas turbine, C_{GB} to gearbox and C_{WJ} to water jet costs.

5.4 OVERALL BUILDING COST

After obtaining all the detailed estimates, the total building cost for monohulls (C_M) and catamarans (C_C) may now be summarized. The resultant formula is that presented in equation 5-6.

$$C_M(C_C) = C_H + C_O + C_{TM} \qquad \mathbf{5\text{-}6}$$

It should be noted that when developing a database of costs and assessing its reliability, published ship acquisition costs will have been influenced by other effects such as assumed profit levels, multiple builds, commissioning and delivery charges and how badly a shipyard may need an order.

Data for detailed costing, particularly that relating to remaining machinery costs, is sparse. Broad assumptions and data generated by sequences of cost balances have therefore been used in places. However, it is considered that the proposed equations will provide a reasonable estimate of overall cost, together with a good indication of relative levels between components costs and changes in component costs as a result of design changes. This makes the equations particularly suitable for use in preliminary design and concept investigations.

Material (M)	Aluminium Alloy	5250 US$/tonne
	Mild Steel	900 US$/tonne
Labour Time(LT)	Simple Structure	600 hours/tonne
	Complex Structure	900 hours/tonne
Labour Cost (LC)		30 US$/hour

Table 5.1: Rates of Materials and Labour Costs dated March 1999.

Diesel Engines	$C_D = 0.0003 \times P_I - 0.0423$ million US$	$R^2=0.992$
Gas Turbines	$C_{GT} = (0.0004 \times P_I) - (4 \cdot 10^{-9} \times P_I^2)$ million US$	$R^2=0.999$
Gearboxes	$C_{GB} = (2 \cdot 10^{-5} \times P_I) - (3 \cdot 10^{-10} \times P_I^2)$ million US$	$R^2=0.982$
Water jets	$C_{WJ} = 0.0031 \times P_I^{0.61}$ million US$	$R^2=0.871$

Table 5.2: Costs of Propulsion Units.

Case	1	2	3	4	5	6	7	8	9	10
L_{OA}	54	31	24.55	54.46	95	95	96	102	124.7	82
B_{OA}	9	3.7	6.5	9.3	16	17.4	16.2	15	18.7	14
T	1.4	0.85	1.2	1.4	2.6	3.65	2.9	3.05	2.44	2.2
D_{OA}	5	2.5	2.5	4.45	4.6	6	10.5	5.2	6.2	9.25
V_S	35	33.5	26	38	36	35	35	37	38	40
N_{ENGINE}	2	3	3	3	2	2	2	2	3	2
N_{DECK}	2	1	1	2	2	2	2	2	2	2
P_I	3000	2370	1830	6960	24000	23200	26000	24000	24000	16000
N_{PAX}	100	190	135	410	600	626	600	500	1250	600
N_{CAR}	-	-	-	-	173	160	188	148	238	70
CH	2.07	0.40	0.48	2.06	6.66	7.76	8.89	7.07	11.48	6.21
CO	0.58	0.07	0.10	0.60	1.81	1.96	1.85	1.82	2.77	1.36
CP	2.65	3.21	2.54	8.57	17.84	17.29	19.21	17.84	26.76	12.28
BC	6.6	5.79	4.07	13.86	34.51	32.01	37.40	31.57	52.31	26.97
CRM	1.31	2.12	0.96	2.63	8.20	5.0	7.45	4.83	11.30	7.12
Ratio	0.47	0.58	0.38	0.31	0.44	0.29	0.39	0.27	0.40	0.54
Reference	PM12b	PM31	PM35	PM38	VM6a	VM10a	VM16c	VM28	VM7c	VM15c

Table 5.3: Costs of Remaining Machinery (please see nomenclature for the abbreviations).

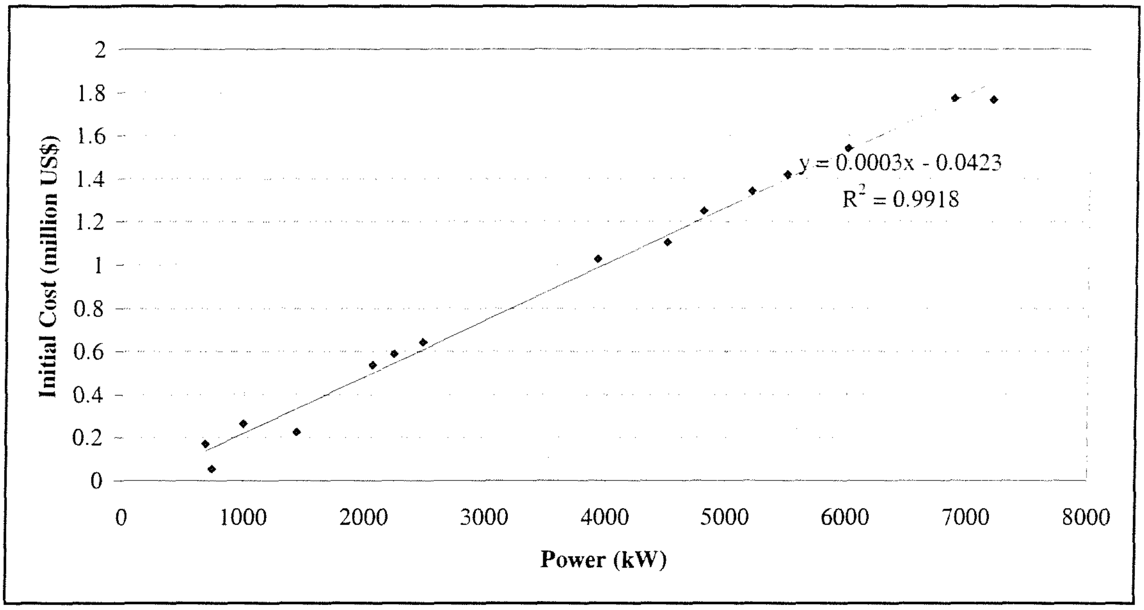


Figure 5.1: Diesel Engine Initial Cost Calculations.

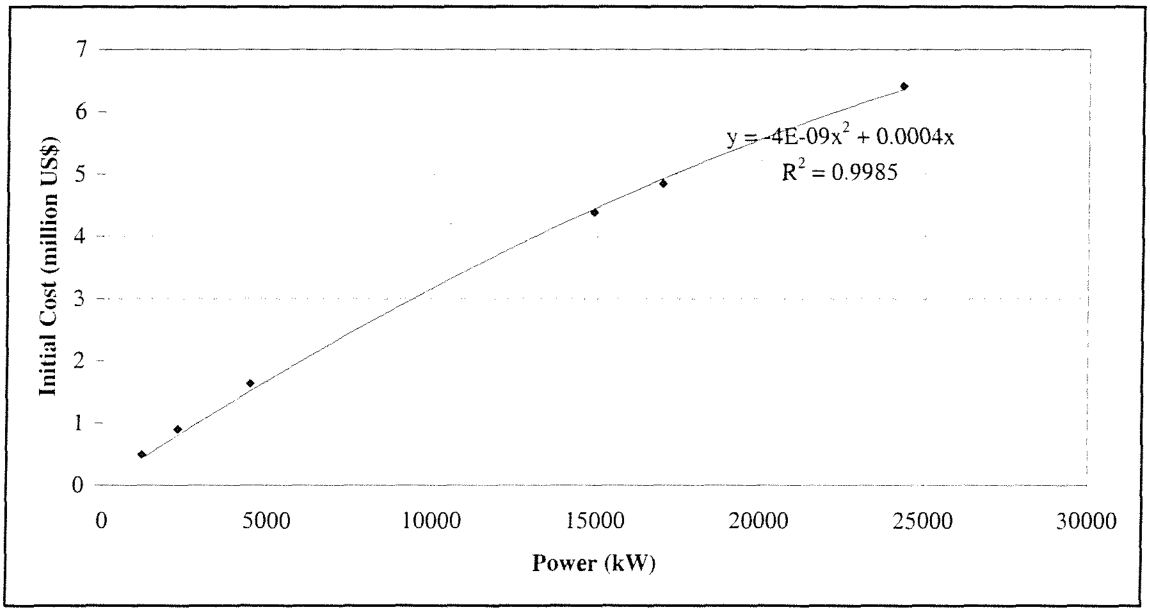


Figure 5.2: Gas Turbine Initial Cost Calculations.

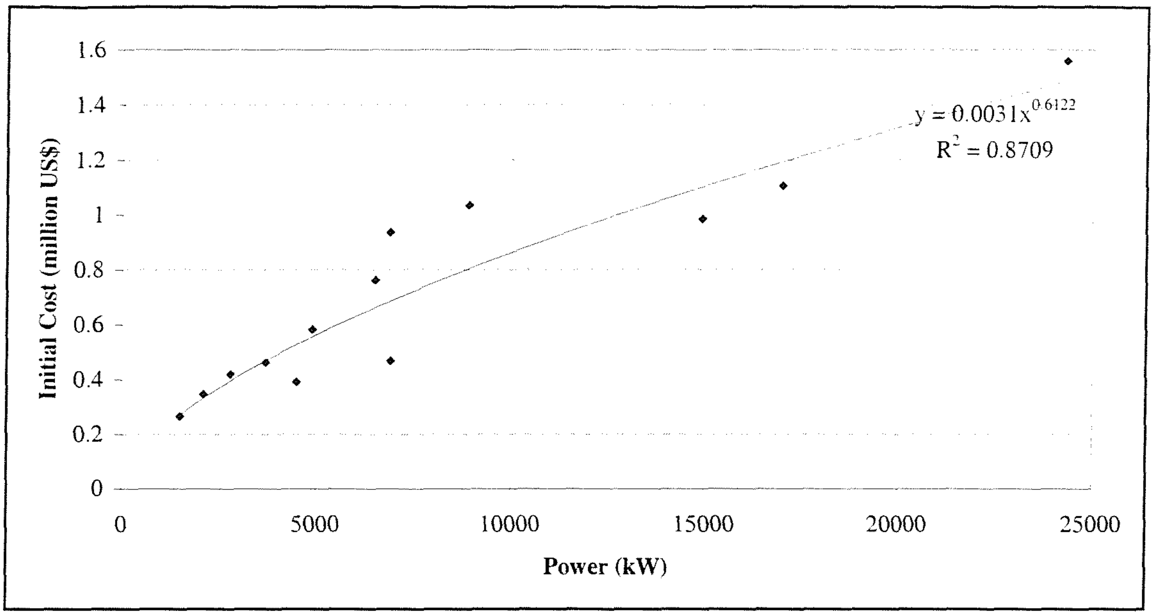


Figure 5.3: Water Jet Initial Cost Calculations.

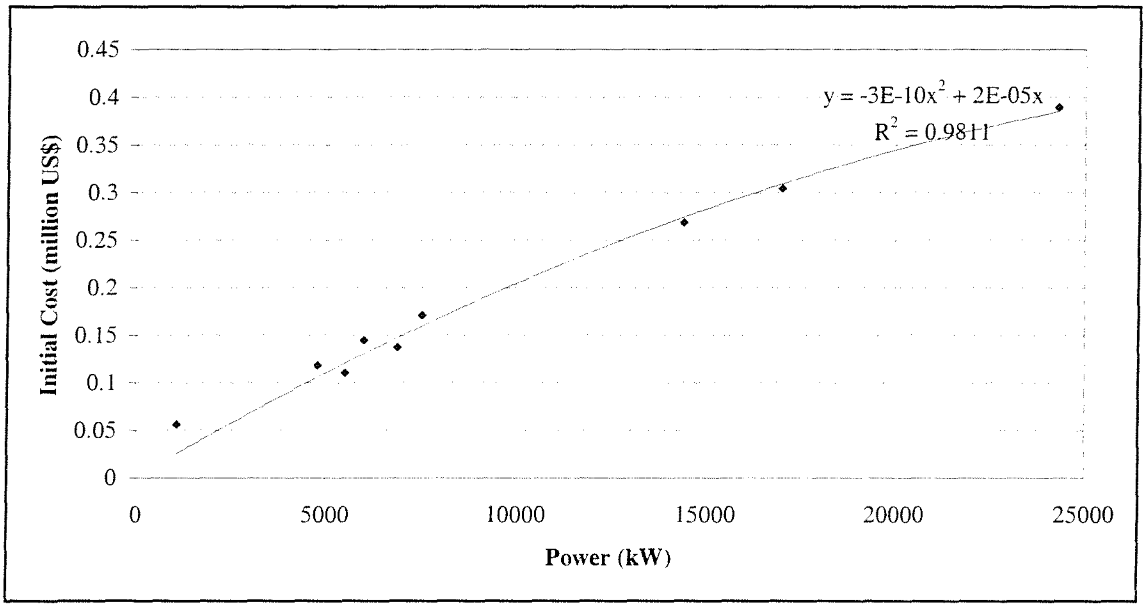


Figure 5.4: Gearbox Initial Cost Calculations.

6. EXAMPLES OF THE METHODOLOGY

6.1 GENERAL

Example designs, which have been generated by applying the methodologies explained in this thesis, are presented in order to demonstrate their feasibility. Two major cases are discussed separately, namely passenger-only and vehicle-passenger vessels. This allows the generation of both small and large vessel designs to be performed. For each of these two categories monohull and catamaran designs are generated, illustrating the use of the methodologies for these two major vessel categories. Two engine and one propulsor type have been used namely diesel, gas turbine and water jet. Each case is estimated for three different service speeds in order to demonstrate the mass balance study as discussed in section 2.2. Hence five examples are carried out resulting in fifteen designs, and these are designated as follows:

Example A: Passenger-only monohull vessel, Diesel main engine, Water jet propulsor.
Example B: Passenger-only catamaran vessel, Diesel main engine, Water jet propulsor.
Example C: Vehicle-passenger monohull vessel, Diesel main engine, Water jet propulsor.
Example D: Vehicle-passenger catamaran vessel, Diesel main engine, Water jet propulsor.
Example E: Vehicle-passenger catamaran vessel, Gas Turbine main engine, Water jet propulsor.

Products of these examples are presented and commented in section 6.2 while an overall view discussed in section 6.3.

Another important issue investigated in this part of the study are the three different methods of changing hull parameters to achieve a mass balance, described earlier in this thesis (chapter 2). These methods are listed as:

Method 1	Constant $L/\nabla^{1/3}$ and modified C_B and B/T.
Method 2	Constant B/T and modified C_B and $L/\nabla^{1/3}$.
Method 3	Constant C_B and modified B/T and $L/\nabla^{1/3}$.

The outcome of this investigation can be seen in Example F. More detailed explanation can be found in section 6.2.6.

Lastly, Example G illustrates the application of different passenger comfort levels for two designs. This is also outlined in chapter 2.

6.2 RESULTS

6.2.1 Example A

Example A results, Table 6.1, show good correlation with the ship data, which is taken from Appendix I coded as PM4. The particular ship data provides good agreement with the study, and this can be clearly seen in the Figures 6.1.

First figure shows the similarity of some of the main dimensions against the ship data. As it is clear that there is a significant similarity between cases and the actual data.

Later figure presents the installed power changes with the gradually increased service speed. The power increases with speed as would be expected. The ship data is slightly higher then the example, this can be caused by the fact that the ship A is finer, so it would require less power to do the same speed, but this is only an assumption.

Fuel mass is little higher in the ship data. This should be a reason of the bigger installed power. On the other hand the fresh water mass is very low in the actual ship data. This might be caused by a watermaker. Most fast ferries have watermakers on board. There is no need for big tanks of water if the fresh water supplier is a watermaker. This stops the extra weight on board which is a very important issue for any ship, but especially for fast ships.

6.2.2 Example B

Example B demonstrates a good relationship with the ship data, Table 6.2, which is originally taken from Appendix I, PC10c.

Overall main dimensions display a good closeness. It is easy to see this with the Figures 6.2.

Installed power does not exhibit a good correspondence like the rest of data, and the reasons for this are unclear.

It appears to be the fuel mass is very much like the example. On the other hand fresh water mass seemed to be giving the same indication as previous example that. there is likely to be a watermaker installed on board.

6.2.3 Example C

Example C presents an acceptable agreement with the ship data, Table 6.3, which is gained from Appendix I, VM33.

Overall main dimensions exhibit satisfactory results. Figure 6.3 displays the results in a bar chart, which makes it easy to visualise the outcomes.

Installed power does not show a particularly good match. It is possible that the ship data engine is not as efficient as the engine Example C. That is why to produce 34 knots service speed actual ship needs more installed power than Example C ship. This is only one reason from many.

Unfortunately, no detailed deadweight data were available, but the given total deadweight demonstrates a satisfactory similarity with the example.

6.2.4 Example D

Example D represents a complete match with the existing ship data, see Table 6.4. The data adopted from Appendix I, VC3.

Main dimensions correlates very well with the VC3. It is possible to see the good correlation in Figure 6.4. The slight difference between the lengths might have been caused by the fact that the existing data has less cargo on board.

Existing ship's installed power is moderately less than the example. Considering that the existing ship is a smaller vessel a decrease in the power can be predicted.

Fuel mass and the total deadweight shows a good comparison. On the other hand fresh water mass seems to have some miscorrelation which is likely to be due to an installed watermaker.

Overall the examples demonstrates very satisfactory results, noting that these are preliminary values.

6.2.5 Example E

This study offers the best comparison of all the other examples. Table 6.5. The existing ship data is from Appendix I, VC11.

All the dimensions display reasonable correspondence, except the draught. It appears to be the existing ship's draught is very small. The fact is that with this draught and given displacement the ship's block coefficient can approximately be estimated as 0.76. This value is too large for a catamaran hull form as it is appreciated. As it is stated early in this thesis (chapter 2, Table 2.2) that the block coefficient for this type of vessel varies between 0.40 to 0.55. Therefore, 0.76 cannot be considered as a correct block coefficient.

This means that whether the given draught or displacement is not accurate. It should also be mentioned that considering the size of the ship draught seems very low, which means it might well be no-load draught. This size vessel should draw (full load) around 3.8 to 4.5 metres. This also shows that the estimated value presents approximately a true value.

The power displays good similarity with the available ship data. The concern is the deadweight of the existing vessel. It is heavier than the estimated value. Also, the displacement of the existing vessel is higher about 300 kg. It seems to be the estimated deadweight somehow is low, and this causes the total displacement to be low too. Considering that this estimation is a preliminary design few not very close results should not cause a problem.

All comparison of the results can be seen in Figures 6.5.

6.2.6 Example F : Investigation of Mass Balance

Example F illustrates the application of alternative mass balance methodologies, using either constant $L/\nabla^{1/3}$, B/T or C_B. Choice of these options may depend on limitations on length, breadth or draught or acceptable C_B for powering purposes.

A generated ship has been mass balanced with three different methods individually, and shown in Table 6.6. For each method, the altered parameters' fonts have been formatted in bold and underlined to be recognised. It is clear that only the method 2 kept all the initial estimated dimensions as it is, and the rest of the derivatives changed little comparing with the other two methods' results. For illustrative purposes, for the rest of the generative designs only method 2 is used.

In Examples A to D, for convenience, C_B was varied and the other two variables held constant, which results in the main dimensions of the ship remaining unaltered. This method has been imported into the software, therefore the mass balance can be created easily, and efficiently.

6.2.7 Example G : Investigation of Passenger Comfort Levels

It is apparent that when applied to parametric concept exploration exercises, other parameters can also be varied such as levels of passenger comfort using different seating areas as shown in Example G, see Table 6.7.

Two vessels have been included in the particular example. These are one passenger-only monohull and one vehicle-passenger monohull. Each vessel has two versions with different As/Np and Ap/As ratios. As explained earlier in this thesis, these are the parameters which alter passenger comfort. Case1 for passenger-only monohull uses less seating and passenger area per passenger, whilst Case2 has more area to improve passenger comfort. Improvement in the passenger comfort affects the dimensions of the vessel since bigger vessels require bigger engines and most importantly costs increase. A more clear picture can be drawn in Figures 6.6.a and 6.6.b.

This study makes it clear that passenger comfort should be controlled with care.

6.3 DISCUSSION OF RESULTS

In each of Examples A to D, three cases have been created. Cases1 are the original designs, Cases2 and Cases3 are speed-varied versions of the first design. These last two cases have been created to demonstrate the mass balance with speed change. Speed change causes differences on the machinery, fuel, fresh water weight, building cost and power. These differences from the original ship sometimes cause an imbalance between the first and the second displacements. The problem is solved employing the mass balance procedure outlined in section 2.

As stated earlier, the influence of speed on building costs can be clearly seen. It was, however, found that the approximate building costs for smaller vessels were unreliable, and hence have been omitted. This is believed to be a question of lack of data, and can therefore be improved in the future as soon as more data become available.

Overall, comparisons of these vessels with existing high speed ferries indicate that the methodologies presented in this research programme generate realistic and feasible designs. It is clear that it is difficult to find complete ship data. Comparisons, therefore, should be approached taking this into account and thus allow for certain leeway in the results. Considering this, it is believed that the examples are reliable and feasible.

Some examples and existing ship data might have apparent differences. This may be due to variation in passenger comfort. Therefore, the deviation between the true and created ship might be quite larger than expected. This should also be approached with taking the passenger comfort level into account.

As noted elsewhere, for reliable results, input data should be used with caution, and input parameters within the limits of the database shown in Tables 2.1 and 2.2.

	Case I	Case II	Case III	Ship Data
Vessel Type	PM	PM	PM	PM
Engine Type	Diesel	Diesel	Diesel	Diesel
Propulsor	Water Jet	Water Jet	Water Jet	-
A_S/N_{PAX}	0.60	0.60	0.60	-
A_P/A_S	1.15	1.15	1.15	-
NPAX	400	400	400	450
VS	33	35	37	36
LOA	45.4	45.4	45.4	48.0
LWL	39.9	39.9	39.9	39.5
B	7.2	7.2	7.2	7.9
T	1.6	1.6	1.6	1.3
D	8.3	8.3	8.3	-
CB	0.40	0.41	0.42	-
AS	240	240	240	-
AP	276	276	276	-
LOD	7.00	6.95	6.90	7.20
BOT	4.5	4.5	4.5	6.1
NE	2	2	2	3
RPM	1800	1800	1800	-
PD	3850	4262	4746	-
PE	2551	2880	3264	-
PI	4427	4902	5458	6000
R	300	300	300	-
NCREW	20	20	20	-
NDECK	2	2	2	2
WH	77.5	77.5	77.5	-
WO	17.7	17.7	17.7	-
WM	33.6	36.8	40.5	-
WPAX	42	42	42	-
WFUEL	8.3	8.9	9.5	10.9
WFWPROV	4.6	4.3	4.1	1.5
WCREW	2.7	2.7	2.7	-
BC (milUS$)	5.5	5.7	6.1	-
ABC (milUS$)	-	-	-	-
LS	129	132	136	-
DW	61	61	62	-
DISP1	189	193	198	-
DISP2	190	193	198	-

Table 6.1: Example A.

	Case I	**Case II**	**Case III**	**Ship Data**
Vessel Type	PC	PC	PC	PC
Engine Type	Diesel	Diesel	Diesel	Diesel
Propulsor	Water Jet	Water Jet	Water Jet	-
A_S/N_{PAX}	0.65	0.65	0.65	0.59
A_P/A_S	1.20	1.20	1.20	1.18
NPAX	400	400	400	420
VS	33	35	37	37.5
LOA	42.2	42.2	42.2	40.0
LWL	37.0	37.0	37.0	35.6
B	11.4	11.4	11.4	10.1
BH	3.3	3.3	3.3	-
T	1.6	1.6	1.6	1.5
D	9.0	9.0	9.0	-
S	8.1	8.1	8.1	-
CB	0.51	0.52	0.54	-
AS	260	260	260	247
AP	312	312	312	291
LOD	7.96	7.89	7.80	-
BHOT	2	2	2	-
SOL	0.22	0.22	0.22	-
NE	2	2	2	2
RPM	1800	1800	1800	-
PD	4582	5212	6102	-
PE	3036	3521	4196	-
PI	5269	5993	7017	4000
R	250	250	250	-
NCREW	10	10	10	-
NDECK	2	2	2	2
WH	81.5	81.5	81.5	-
WO	26.0	26.0	26.0	-
WM	39.3	44.0	50.7	-
WPAX	42	42	42	-
WFUEL	8.3	9.1	10.2	10.1
WFWPROV	3.8	3.6	3.4	1.5
WCREW	1.4	1.4	1.4	-
BC (milUS$)	7.1	7.5	8.1	-
ABC (milUS$)	-	-	-	-
LS	147	152	158	-
DW	59	59	60	-
DISP1	204	208	216	-
DISP2	206	211	218	-

Table 6.2: Example B.

	Case I	Case II	Case III	Ship Data
Vessel Type	VM	VM	VM	VM
Engine Type	Diesel	Diesel	Diesel	Diesel
Propulsor	Water Jet	Water Jet	Water Jet	-
A_S/N_{PAX}	0.95	0.95	0.95	-
A_P/A_S	1.20	1.20	1.20	-
NPAX	650	650	650	600
NCAR	150	150	150	160
VS	36	38	40	34
LOA	100.9	100.9	100.9	100.0
LWL	88.5	88.5	88.5	89.4
B	15.1	15.1	15.1	16.0
T	2.0	2.0	2.0	3.0
D	13.0	13.0	13.0	-
CB	0.35	0.36	0.36	-
AS	618	618	618	-
AP	741	741	741	-
LOD	9.00	8.95	8.91	7.77
BOT	7.4	7.4	7.4	5.3
NE	4	4	4	4
RPM	2000	2000	2000	-
PD	13142	14543	16028	-
PE	8961	10085	11288	-
PI	15114	16724	18433	26000
R	500	500	500	-
NCREW	50	50	50	-
NDECK	4	4	4	-
WH	414	414	414	-
WO	164	164	164	-
WM	102	111	122	-
WPAX	68	68	68	-
WCAR	150	150	150	-
WFUEL	45	48	51	-
WFWPROV	11	11	10	-
WCREW	6.8	6.8	6.8	-
BC (milUS$)	24.6	26	27	-
ABC (milUS$)	32.3	34.8	37.2	-
LS	679	689	699	-
DW	298	300	303	310
DISP1	973	989	1002	-
DISP2	976	986	1004	-

Table 6.3: Example C.

	Case I	Case II	Case III	Ship Data
Vessel Type	VC	VC	VC	VC
Engine Type	Diesel	Diesel	Diesel	Diesel
Propulsor	Water Jet	Water Jet	Water Jet	-
A_S/N_{PAX}	1.10	1.10	1.10	1.17
A_P/A_S	1.40	1.40	1.40	1.36
NPAX	650	650	650	620
NCAR	150	150	150	152
VS	36	38	40	36
LOA	82.7	82.7	82.5	76.6
LWL	72.5	72.5	72.4	68.0
B	21.3	21.3	21.3	22.2
BH	6.8	6.8	6.8	6.3
T	2.8	2.8	2.8	3.0
D	13.4	13.4	13.4	-
S	14.5	14.5	14.5	15.9
CB	0.45	0.46	0.46	-
AS	715	715	715	726
AP	1001	1001	1001	987
LOD	8.50	8.47	8.43	8.50
BHOT	2.40	2.40	2.40	2.10
SOL	0.20	0.20	0.20	0.23
NE	4	4	4	4
RPM	1250	1250	1250	-
PD	23724	25454	27319	-
PE	16176	17651	19239	-
PI	27283	29272	31417	22800
R	400	400	400	300
NCREW	50	50	50	-
NDECK	3	3	3	-
WH	580	580	580	-
WO	142	142	142	-
WM	232	248	264	-
WPAX	68	68	68	-
WCAR	150	150	150	-
WFUEL	65	67	69	77
WFWPROV	9	8.6	8.1	4
WCREW	6.8	6.8	6.8	-
BC (milUS$)	32.6	33.6	34.7	-
ABC (milUS$)	33.4	34.3	35.2	-
LS	955	970	986	-
DW	317	318	321	360
DISP1	1273	1302	1302	-
DISP2	1272	1288	1307	-

Table 6.4: Example D.

	Case I	Case II	Case III	Ship Data
Vessel Type	VC	VC	VC	VC
Engine Type	Gas Turbine	Gas Turbine	Gas Turbine	Gas Turbine
Propulsor	Water Jet	Water Jet	Water Jet	-
A_S/N_{PAX}	1.10	1.10	1.10	-
A_P/A_S	1.40	1.40	1.40	-
NPAX	1500	1500	1500	1500
NCAR	440	440	440	440
VS	35	37	39	37
LOA	119.4	119.4	119.4	120.0
LWL	104.7	104.7	104.7	105.5
B	31.2	31.2	31.2	36.0
BH	8.2	8.2	8.2	-
T	4.1	4.1	4.1	2.6
D	17.7	17.7	17.7	-
S	23.0	23.0	23.0	-
CB	0.44	0.45	0.45	-
AS	1650	1650	1650	-
AP	2310	2310	2310	-
LOD	9.05	9.0	9.0	-
BHOT	2.0	2.0	2	-
SOL	0.22	0.22	0.22	-
NE	4	4	4	4
PD	47645	51927	56283	-
PE	32193	35712	39338	-
PI	54792	59716	64726	60000
R	700	700	700	700
NCREW	150	150	150	-
NDECK	8	8	8	-
WH	1148	1148	1148	-
WO	805	805	805	-
WM	288	312	337	-
WPAX	157.5	157.5	157.5	-
WCAR	440	440	440	-
WFUEL	232	243	254	-
WFWPROV	37.5	35.5	33.7	-
WCREW	20.3	20.3	20.3	-
BC (milUS$)	71.1	71.7	72.4	-
ABC (milUS$)	89.7	90.7	91.5	-
LS	2241	2266	2291	-
DW	940	950	960	1433
DISP1	3181	3230	3230	3500
DISP2	3181	3216	3250	3500

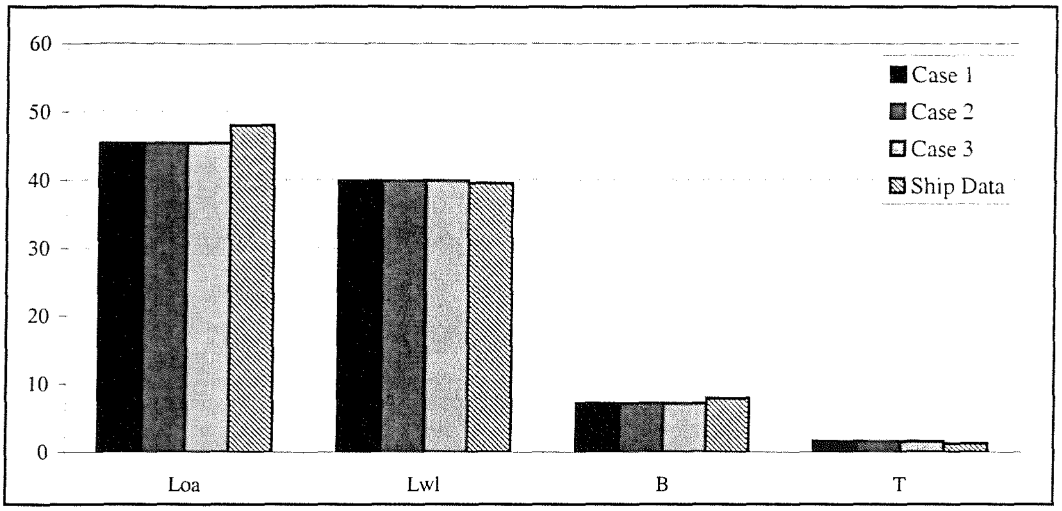
Table 6.5: Example E.

	Generated Ship	**Method 1**	**Method 2**	**Method 3**
Vessel Type	PM	PM	PM	PM
Engine Type	Diesel	Diesel	Diesel	Diesel
Propulsor	Water Jet	Water Jet	Water Jet	-
A_S/N_{PAX}	0.60	0.60	0.60	0.60
A_P/A_S	1.15	1.15	1.15	1.15
NPAX	500	500	500	500
VS	36	40	40	40
LOA	46.4	46.4	46.4	46.4
LWL	40.7	40.7	40.7	40.7
B	9.0	9.0	9.0	9.0
T	1.8	1.5	1.8	2.0
D	9.4	9.4	9.4	9.4
CB	0.37	**0.45**	**0.39**	0.37
AS	300	300	300	300
AP	345	345	345	345
LOD	6.5	6.5	**6.39**	**6.30**
BOT	5	**6.08**	5	**4.55**
NE	2	2	2	2
RPM	1800	1800	1800	1800
PD	5905	7464	7264	7926
PE	4026	5257	5115	5582
PI	6791	8584	8353	9115
R	500	500	500	500
NCREW	20	20	20	20
NDECK	2	2	2	2
WH	98	98	98	98
WO	23	23	23	23
WM	49	61	59	64
WPAX	53	53	53	53
WFUEL	15	17	17	18
WFWPROV	8.7	7.8	7.8	7.8
WCREW	2.7	2.7	2.7	2.7
BC (milUS$)	7.0	8.0	7.8	8.3
ABC (milUS$)	-	-	-	-
LS	170	181	180	185
DW	83	85	85	86
DISP1	252	252	265	276
DISP2	253	266	265	271

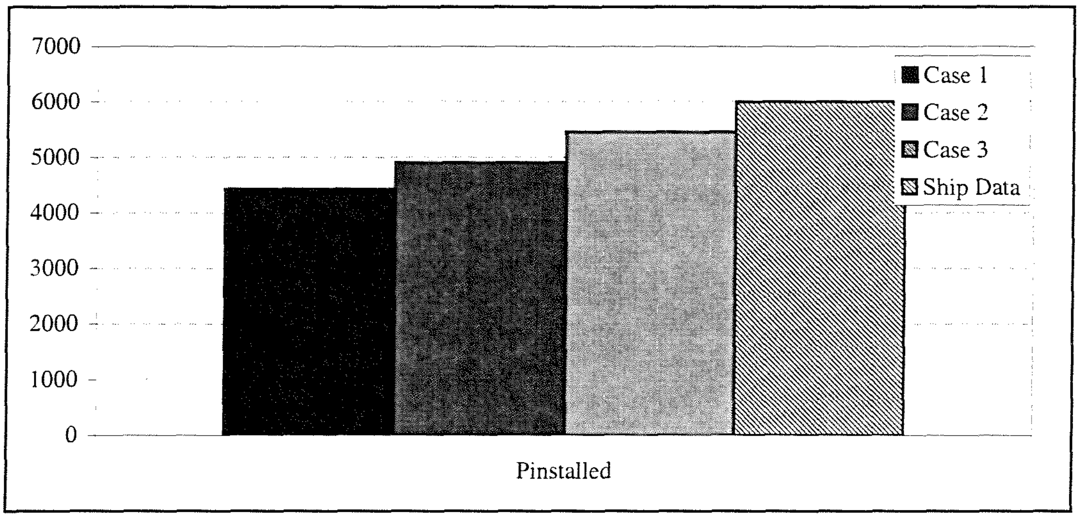
Table 6.6: Example F.

	PM	PM	VM	VM
A_S/N_{PAX}	0.55	0.75	0.85	1.25
A_P/A_S	1.10	1.30	1.15	1.45
NPAX	400	400	650	650
NCAR	-	-	150	150
VS	35	35	38	38
LOA	42.8	55.5	98.7	104.1
LWL	37.5	48.7	86.6	91.3
B	6.8	8.8	15.1	15.9
T	1.5	2.0	2.3	2.4
D	8.1	9.3	13.0	13.5
CB	0.44	0.31	0.35	0.33
AS	220	300	553	813
AP	242	390	635	1178
LOD	6.77	7.64	8.50	8.69
BOT	4.50	4.50	6.50	6.50
NE	2	2	4	4
RPM	1800	1800	1250	1250
PD	3706	6906	16665	18903
PE	2504	4666	11556	13108
PI	4262	7942	19165	21738
R	300	300	1000	1000
NCREW	20	20	100	100
NDECK	2	2	4	4
WH	68	119	404	455
WO	16	26	161	179
WM	33	57	170	190
WPAX	42	42	68	68
WCAR	-	-	150	150
WFUEL	5.7	10.6	80.2	91.0
WFWPROV	4.3	4.3	21.4	21.4
WCREW	2.7	2.7	13.5	13.5
BC (milUS$)	4.7	8.2	28.1	31.6
ABC (milUS$)	-	-	34.8	34.8
LS	116	202	734	823
DW	58	63	353	365
DISP1	174	265	1084	1188
DISP2	174	265	1087	1188

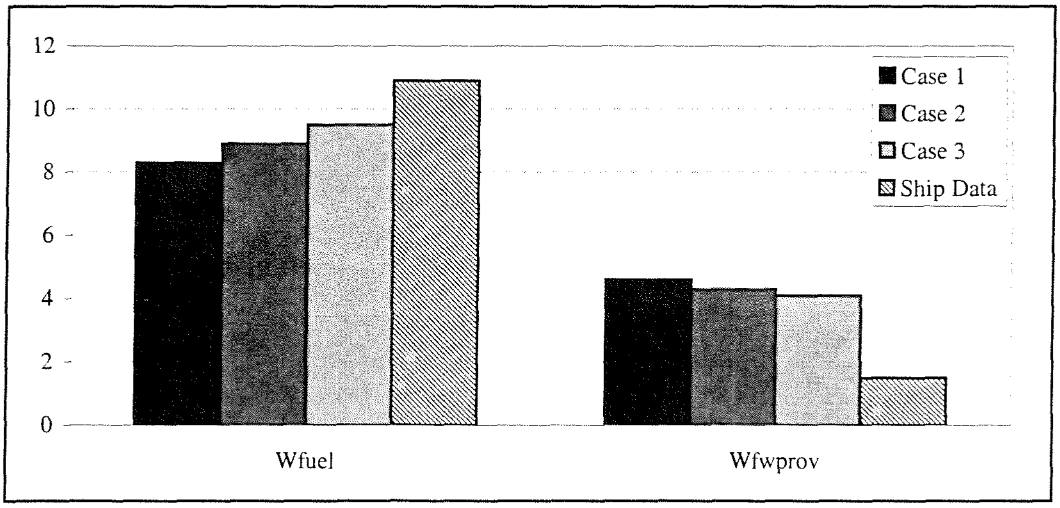
Table 6.7: Example G.



Dimensions (L_{OA}, L_{WL}, B, T)

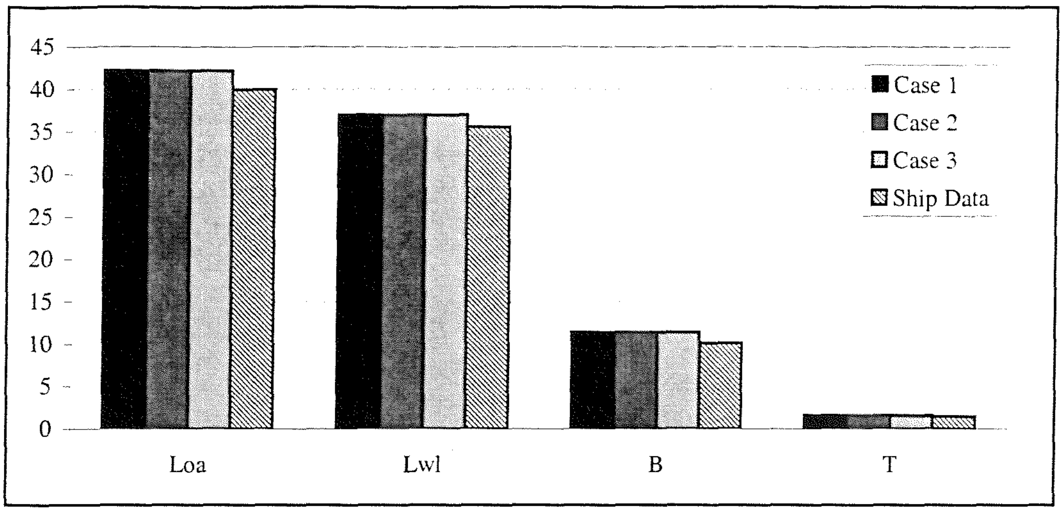


Installed Power (P_I)

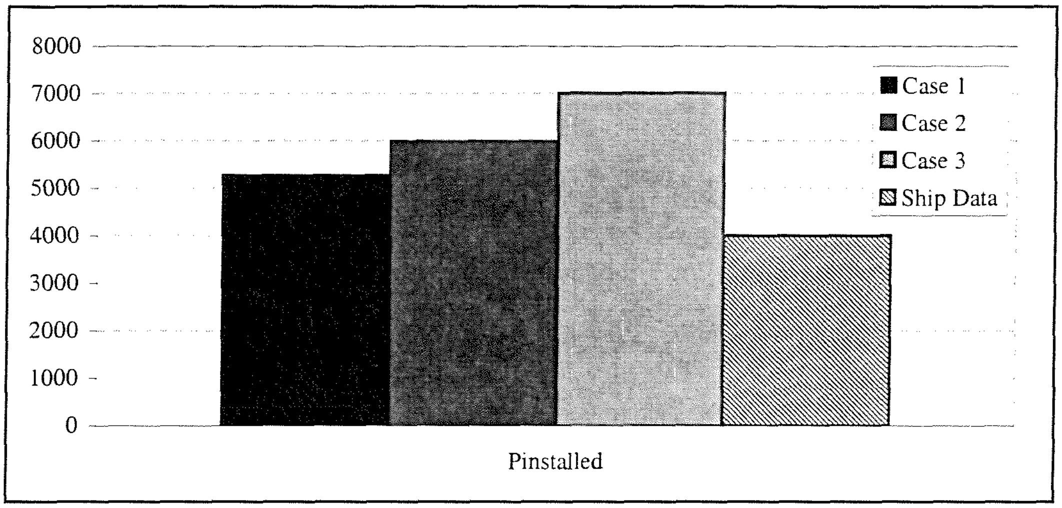


Masses (W_{FUEL}, W_{FWPROV})

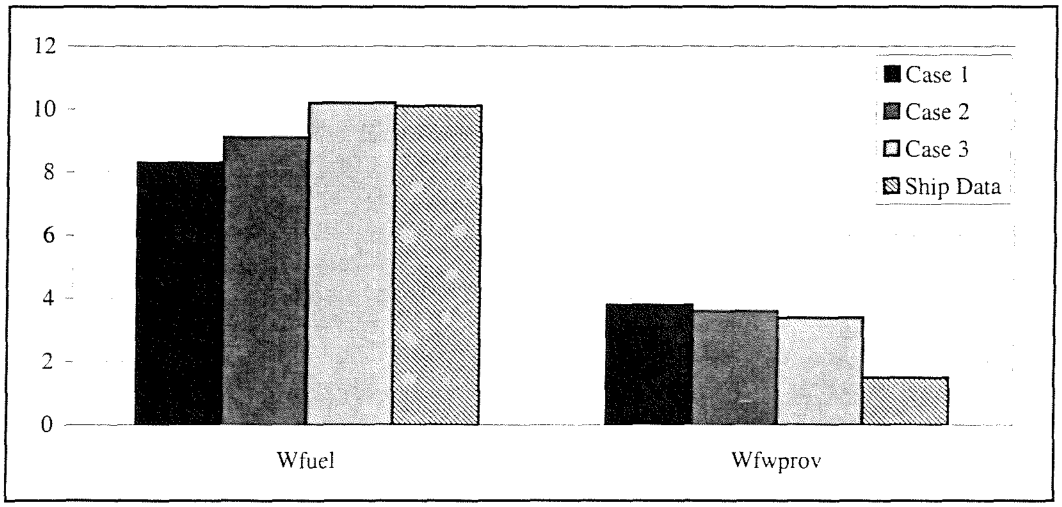
Figures 6.1: Comparison of Design Study A against Ship Data



Dimensions (L_{OA}, L_{WL}, B, T)

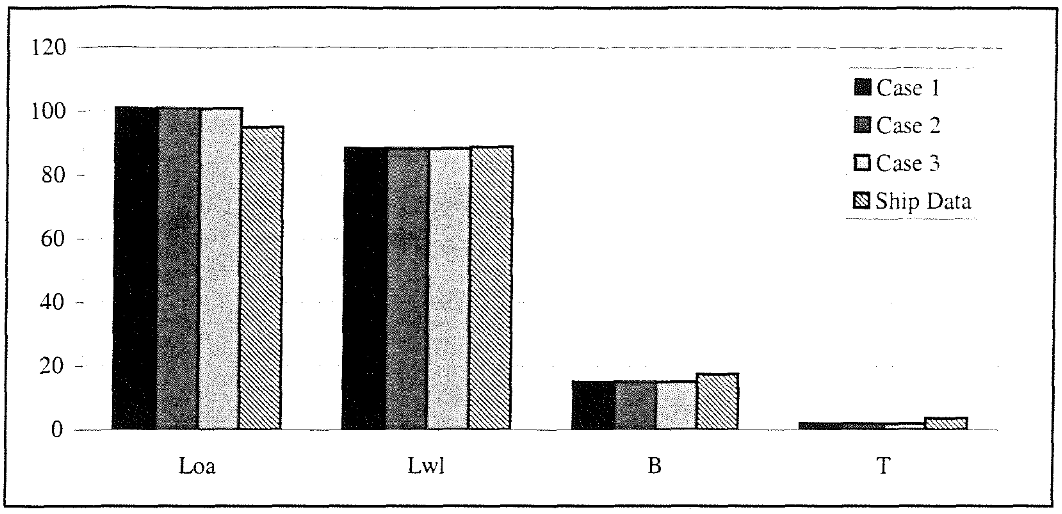


Installed Power (P_I)

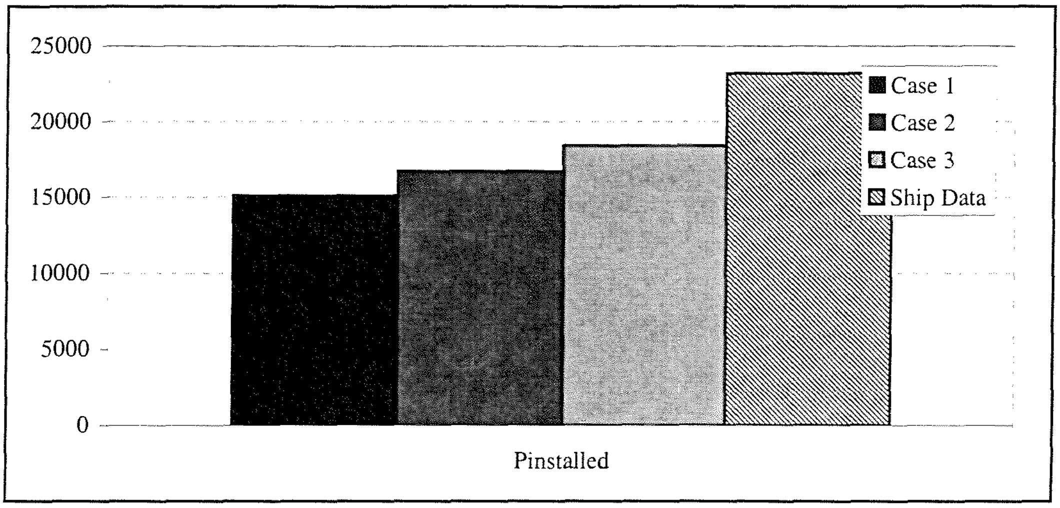


Masses (W_{FUEL}, W_{FWPROV})

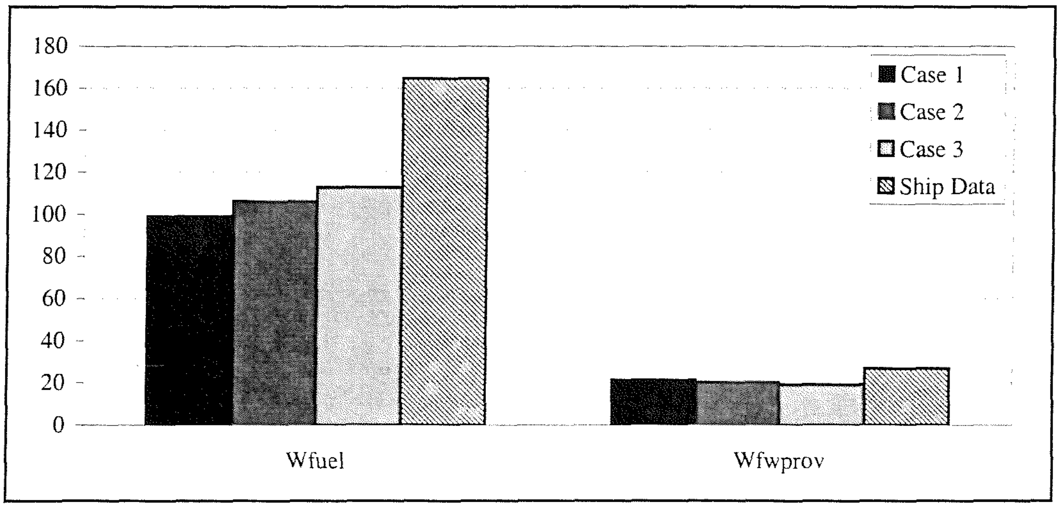
Figures 6.2: Comparison of Design Study B against Ship Data.



Dimensions (L_{OA}, L_{WL}, B, T)

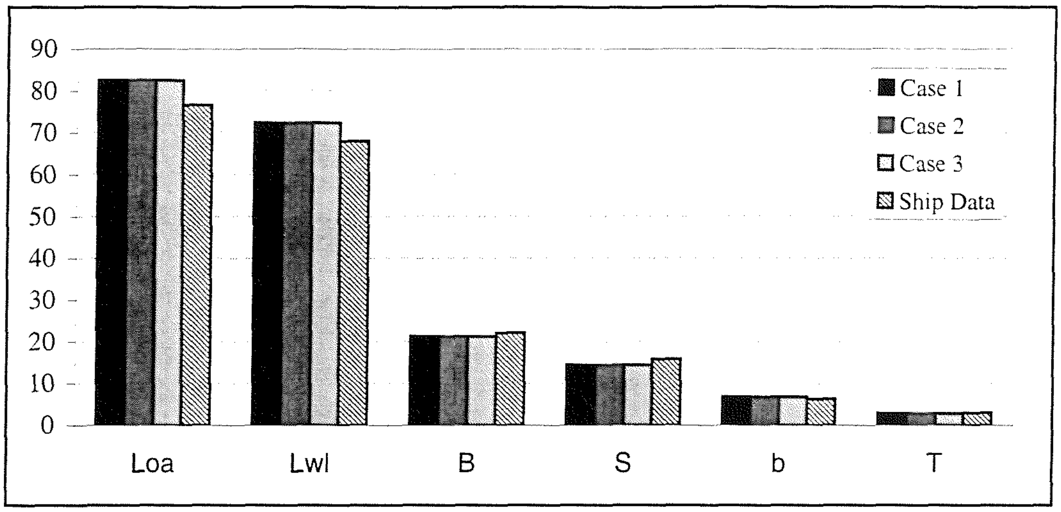


Installed Power (P_I)

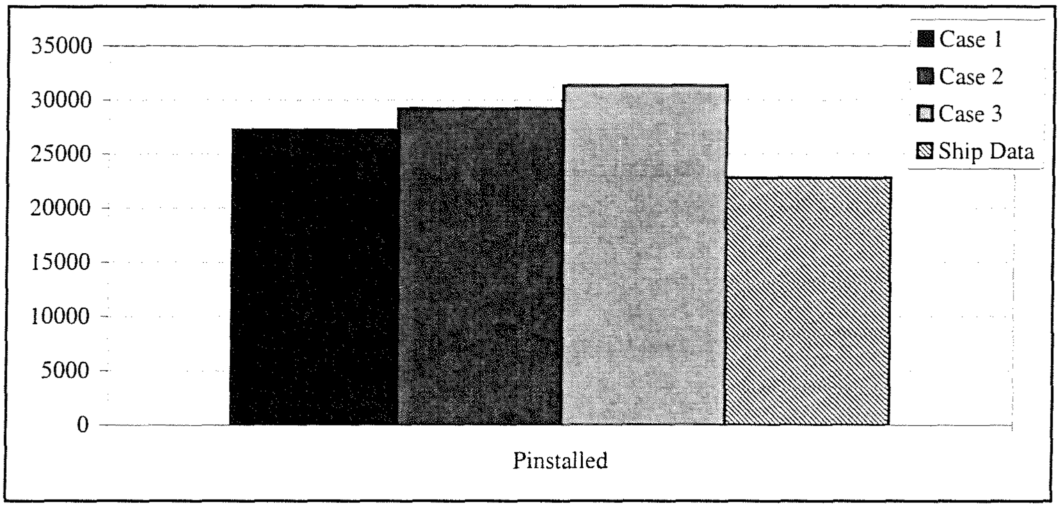


Masses (W_{FUEL}, W_{FWPROV})

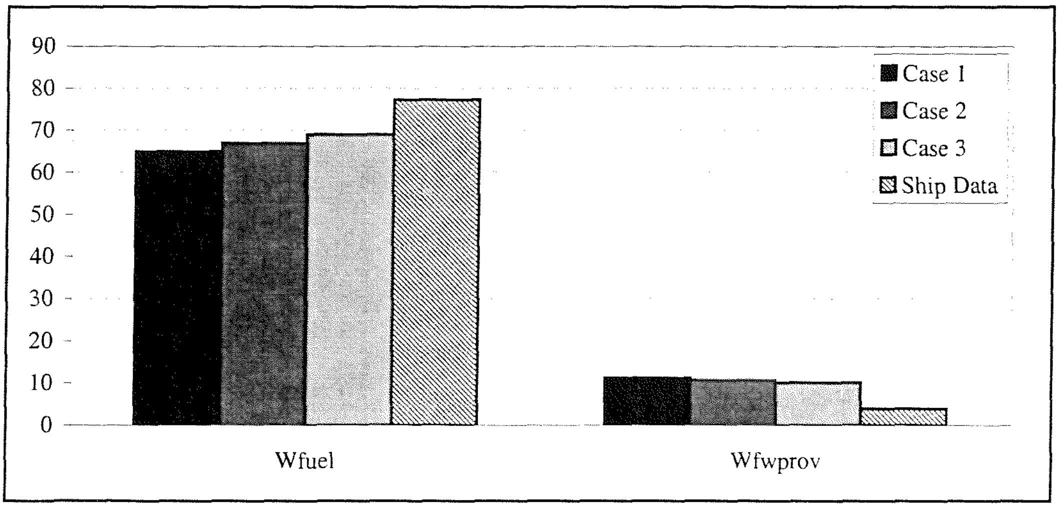
Figures 6.3: Comparison of Design Study C against Ship Data.



Dimensions (L_{OA}, L_{WL}, B, S, b, T)

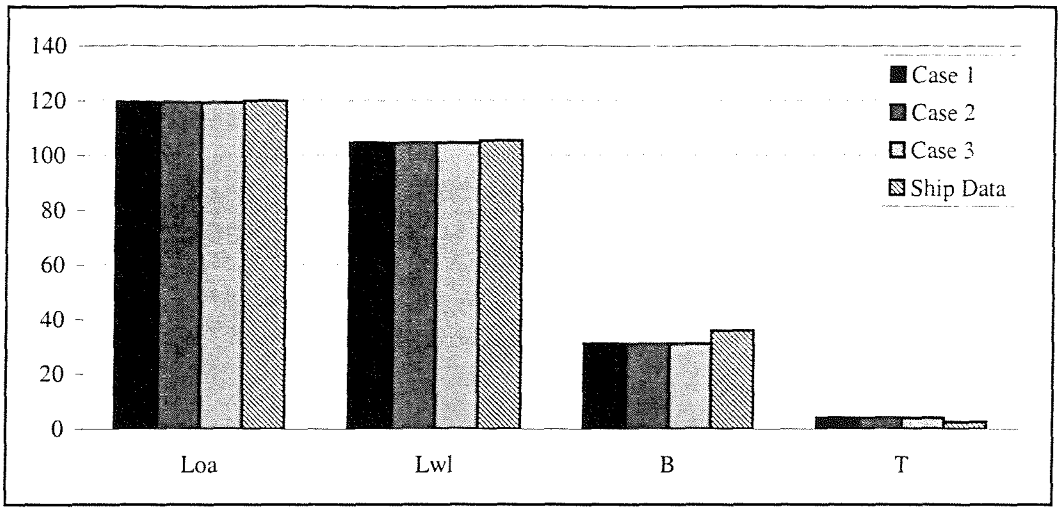


Installed Power (P_I)

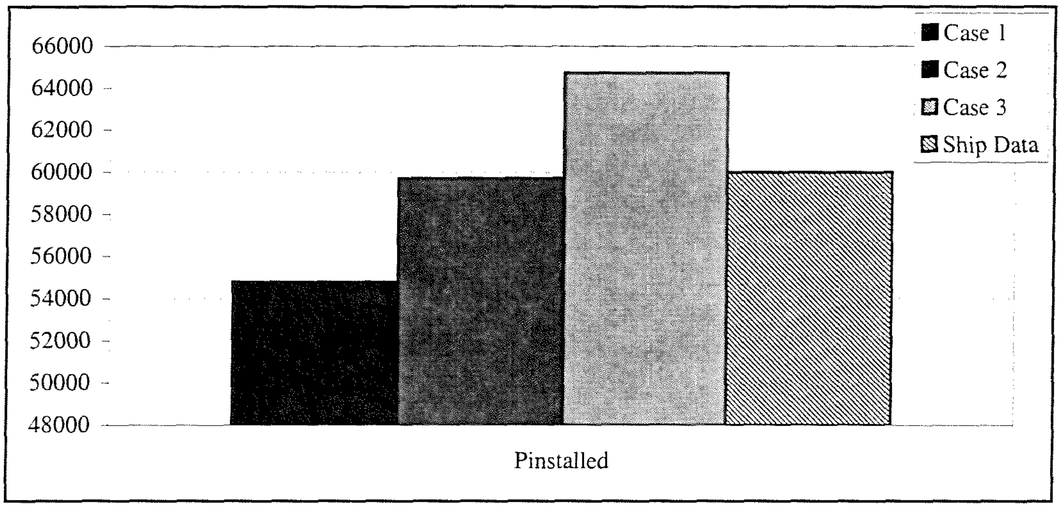


Masses (W_{FUEL}, W_{FWPROV})

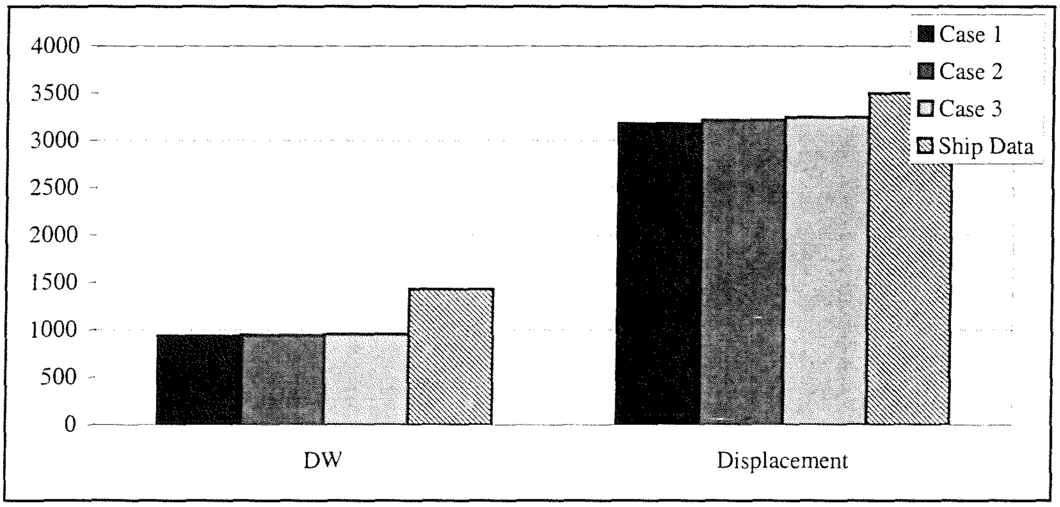
Figures 6.4: Comparison of Design Study D against Ship Data.



Dimensions (L_{OA}, L_{WL}, B, T)

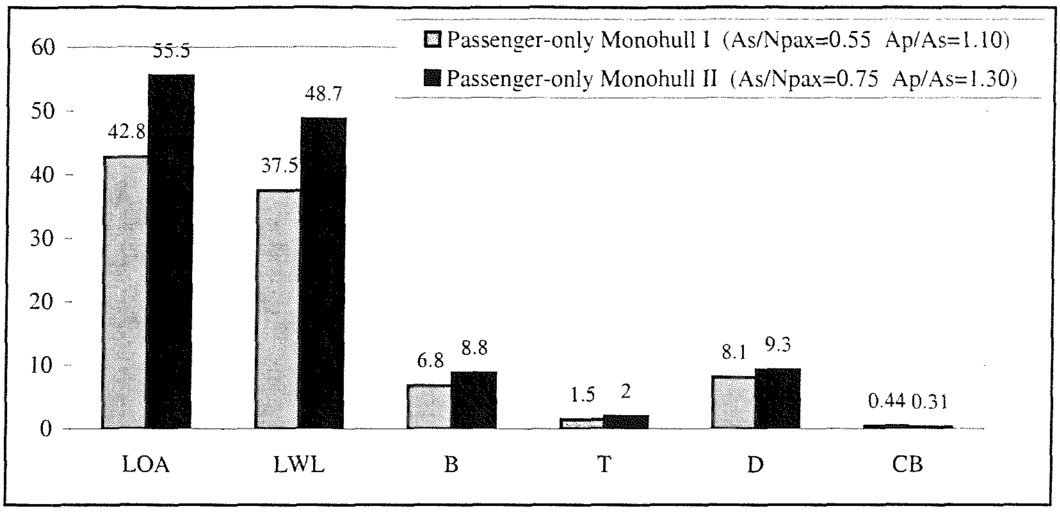


Installed Power (P_I)

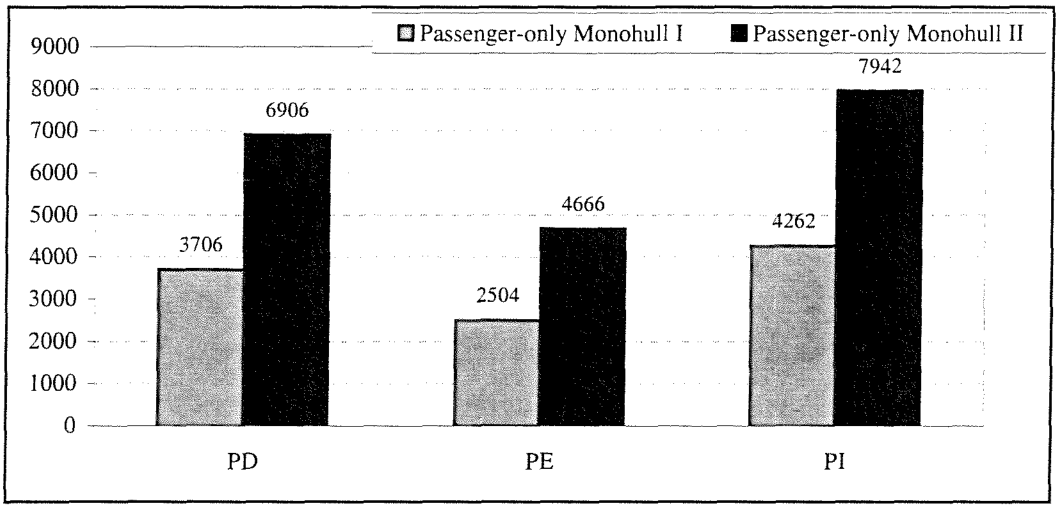


Masses (DW, Displacement)

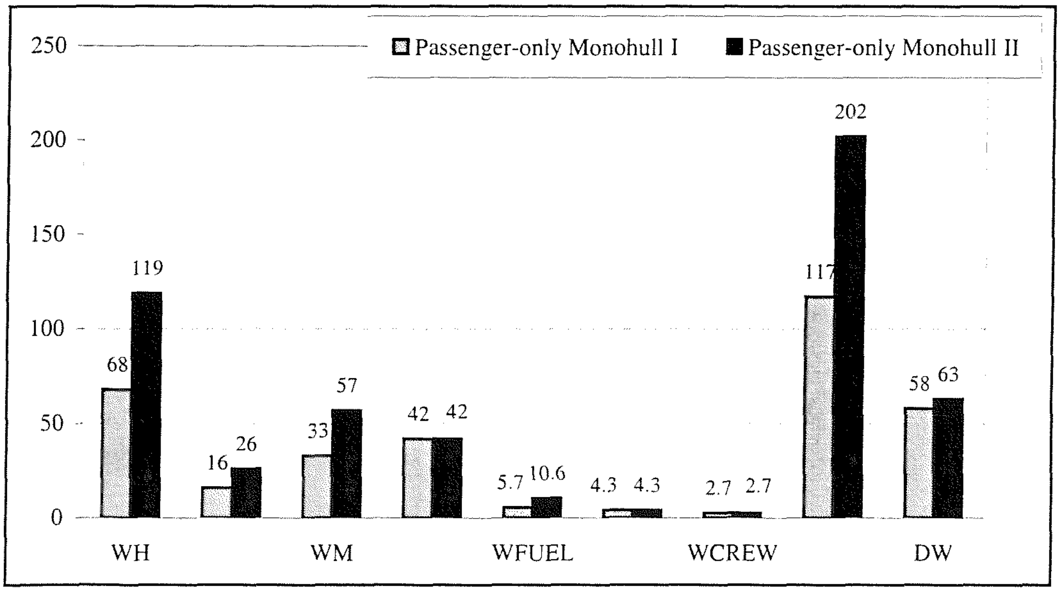
Figures 6.5: Comparison of Design Study E against Ship Data.



$N_{PAX} = 400$, $V_S = 35$ knots

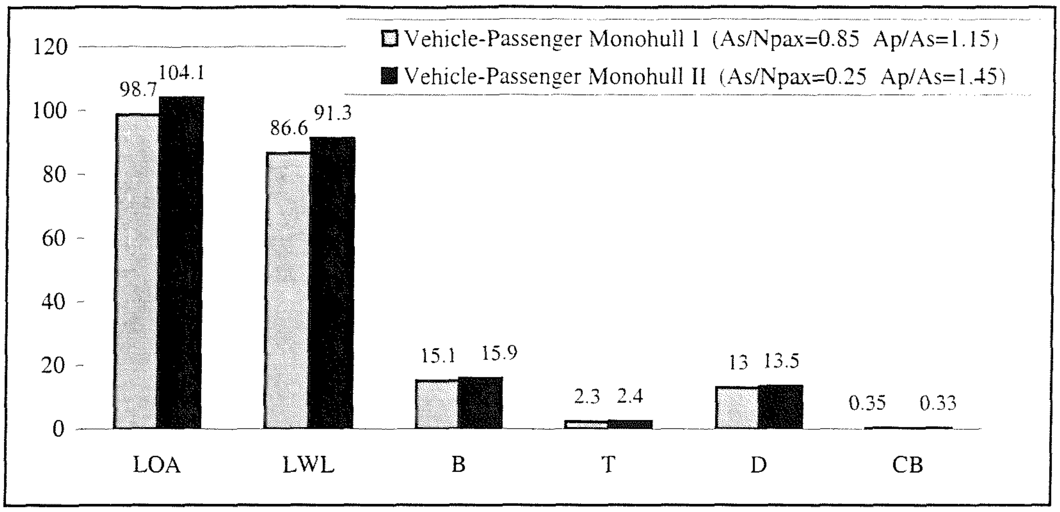


$N_E = 2$, RPM = 1800

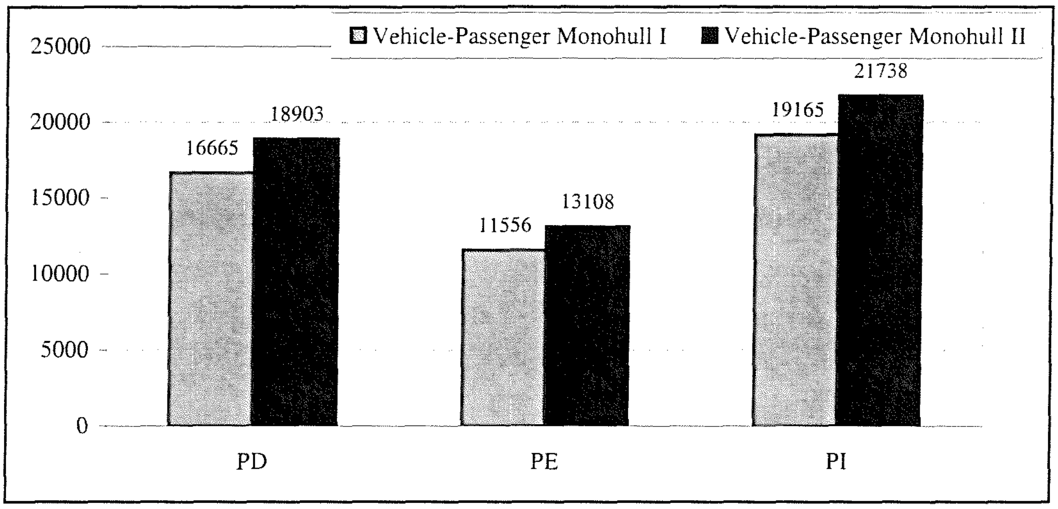


Masses

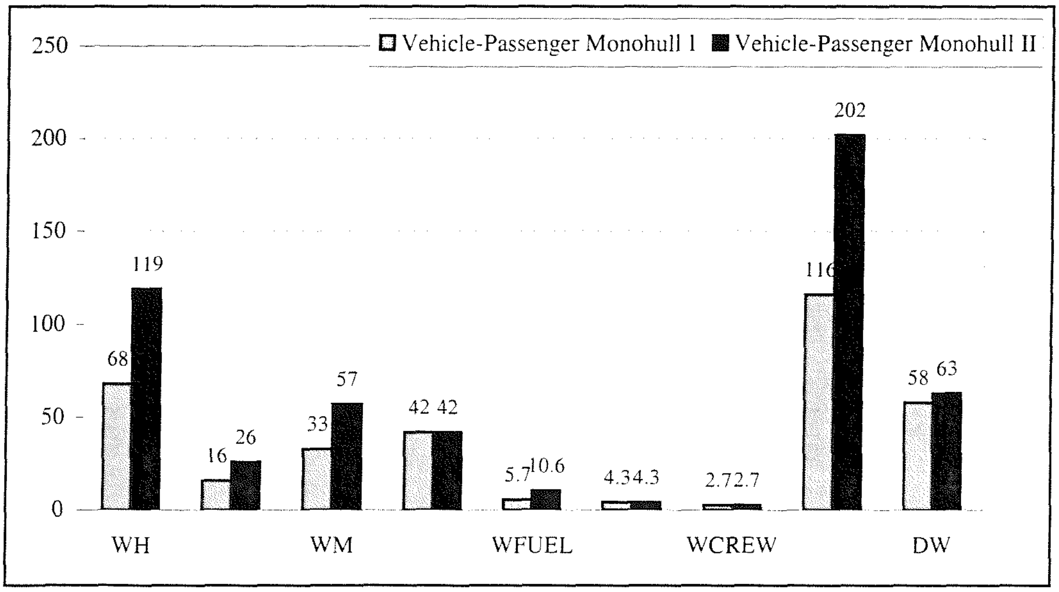
Figures 6.6.a: Effect of Comfort Levels, Design Study G.



$N_{PAX} = 650$, $N_{CAR} = 150$, $V_S = 35$ knots



$N_E = 4$, RPM = 1250



Masses

Figures 6.6.b: Effect of Comfort Levels, Design Study G.

7 CONCLUSIONS

7.1 INTRODUCTION

This final section reassesses the thesis main results and conclusions. Firstly, the significance of the present work is examined. Secondly, the concept of a further work process is then detailed in section 7.3. Finally, the main contributions and achievements are briefly outlined.

7.2 GENERAL DISCUSSION

- A technical design methodology has been developed and described which can be satisfactorily applied to the generation of principal particulars of fast ferries at the concept design stage. The methodology has been included in a computer based design program. Data and equations are presented in the thesis which facilitate the estimation of dimensions, powering, masses and building costs at the preliminary design stage. The procedure is suitable for high speed monohulls and catamarans which currently make up the majority of fast ferries. The scope of the current model would be enhanced with the inclusion of other multihulls, such as SES, SWATH and hybrid vessels, which offer the potential for further research.

- Background work associated with collecting and establishing the data and equations presented in the thesis indicates that it can be difficult to obtain, process and/or establish design data of adequate quality, particularly in the cases of masses and building costs. For this reason, caution should be exercised when using the data and equations, which should be only applied within the data range and for the correct vessel type.

- Complete calculations of a set of reliable, realistic and feasible main dimensions can be performed for high speed monohull and catamaran ferries. The methodology offers flexibility in the hull ratios and passenger comfort (such as seating and overall area per passenger).

- Approximate powering calculations offer reasonably reliable results for monohull and catamaran round bilge hulls. It would be desirable to enhance the scope of the powering module by including other hull types and more detailed calculations. At present, an approximation to water jet efficiency is used. Future work should focus on including the efficiencies of propellers and other propulsors.

- It is considered that the presented mass estimations offer reliable results. However, there is a general lack of reliable data for high speed vessels, which can restrict the quality of the estimations.

- Detailed calculations of building costs indicate that relatively reliable estimates of total cost can be obtained. The approximate estimates of building costs were not so reliable, particularly for small vessels. The overall costing procedures would benefit from improvements in the estimates of outfitting cost.

- Examples of the methodology have been used to demonstrate the scope of the technical design procedures. The resulting designs are found to be feasible and realistic, and suitable for further use in concept exploration and decision making methodologies.

- It is considered that, based on the data currently available, the methodology and design equations presented provide adequately reliable first estimates at the preliminary design stage. They should prove particularly useful for parametric concept exploration studies. It is also considered that the methodology developed and presented offers a good basis on which to build and develop further estimating techniques.

7.3 FURTHER WORK

The need for further work is important in order to improve some areas of the current methodologies and hence improve the overall accuracy of estimation of the design. These can be noted as follows;

- Enlargement of the database for the existing type of the vessels and calculations.
- Include different hull forms in the database.
- Include different types of propulsors along with engine configurations.
- Investigate the mass balance methods.
- Stability check on the overall design process.

7.4 SUMMARY

The work in this thesis can be summarised as follows;

- A robust method for estimation of initial set of main dimensions of fast ferries.

- A rigorous approach to calculate the installed power of fast ferries.
- A set of equations to estimate preliminary masses and costs of fast ferries.
- A computer program to create new designs efficiently.
- A comparison between results and existing ship data.
- Overall, creating a set of initial dimensions, power, masses and costs of four types of fast ferries with only few input variables.

8. REFERENCES

[1] Bailey D., "The NPL High Speed Round Bilge Displacement Hull Series," *Marine Technology,* **4**, 1976.

[2] Bertram V., "Estimating Main Dimensions and Coefficients in Preliminary Ship Design," *Ship Technology Research,* **45**, 96-103, 1998.

[3] Buckland D.M., "Calm Water Resistance Estimation for High Speed Catamarans," M.Sc. Thesis, University of Southampton, Department of Ship Science, 1999.

[4] Carreyette J., "Preliminary Ship Cost Estimation," *Transactions of the Royal Institution of Naval Architects,* **120**, 235-258, 1977.

[5] Cordano A. and De Martini L. "SES 500-Fincantieri-Design Criteria," *The 1st International Conference on Fast Sea Transportation,* Trondheim, Norway, 179-198, 1991.

[6] Czimmek D.W. and Schaub B.H., "Concept of a Large Surface Effect Ship for Fast Ocean Transport," *The 1st International Conference on Fast Sea Transportation,* Trondheim, Norway, 91-106, 1991.

[7] Daidola J.C. and Reyling C.J., "Weight Definition and Control for Fast Craft," *Marine Technology,* **28**(6), 329-339, 1991.

[8] Doctors L.J., Renilson M.R., Parker G. and Hornsby N., "Waves and Wave Resistance of a High Speed River Catamaran," *The 1st International Conference on Fast Sea Transportation,* Trondheim, Norway, 35-52, 1991.

[9] Etter D.M., "Fortran 77 with Numerical Methods for Engineers and Scientists," *The Benjamin Cummings Publishing Company Inc*, California, USA, 1992.

[10] Fan M. and Pinchin M., "Structural Design of High Speed Craft-A Comparative Study of Classification Requirements," *The 4th International Conference on Fast Sea Transportation,* Sydney, Australia, 27-33, 1997.

[11] Guenther C., "Prime Movers for High Speed Vehicles," *The 1st International Conference on Fast Sea Transportation,* Trondheim, Norway, 893-914, 1991.

[12] Hughes O., "Two First Principles Structural Designs of a Fast Ferry-All-Aluminium and All-Composite," *The 4th International Conference on Fast Sea Transportation,* Sydney, Australia, 91-98, 1997.

[13] Insel M. and Molland A.F., "An Investigation Into the Resistance Components of High Speed Displacement Catamarans," *Transactions of the Royal Institution of Naval Architects,* **134**(11), 1992.

[14] Joo Y.R., Nho K.Y., Jang H.S., Choi Y.K., Lavis D.R. and Forstell B.G., "Parametric Design Trade-Off Study and Preliminary Design of an SES Passenger Car Ferry," *The*

2^{nd} *International Conference on Fast Sea Transportation,* Yokohama, Japan, 1531-1541, 1993.

[15] Karayannis T., Molland A.F. and Sarac Williams Y., "Design Data for High-Speed Vessels," *The* 5^{th} *International Conference on Fast Sea Transportation,* Seattle, USA, 605-615, 1999.

[16] Karayannis T., "A Concept Design and Decision Making Model for Alternative High Speed Ferries," Ph.D. Thesis, University of Southampton, Department of Ship Science, 1999.

[17] Kraus A. and Naujeck A., "Comparison of a Cargo Catamaran with Conventional Seaborne and Airborne Transportation," *The* 1^{st} *International Conference on Fast Sea Transportation,* Trondheim, Norway, 293-308, 1991.

[18] Litau H., "Design, Trial and Operation of 'Hong Xiang' SES Ferry," *The* 1^{st} *International Conference on Fast Sea Transportation,* Trondheim, Norway, 529-539, 1991.

[19] Molland A.F., Karayannis T. and Couser P.R., "Concept Exploration and Assessment of Alternative High-Speed Ferry Types," *The* 4^{th} *International Conference on Fast Sea Transportation,* Sydney, Australia, 77-84, 1997.

[20] Molland A.F. and Karayannis T., "Development of a Concept Exploration and Assessment Model for Advanced Fast Marine Vehicles," *The* 6^{th} *International Marine Design Conference*, Newcastle upon Tyne, UK, 249-265, 1997.

[21] Wellicome J.F., Molland A.F., Cic J. and Taunton D.J., "Resistance Experiments on a High Speed Displacement Catamaran of Series 64 Form," Report **106**, University of Southampton, Department of Ship Science, 1999.

[22] Molland A.F., Wellicome J.F. and Couser P.R., "Resistance Experiments on a Systematic Series of High Speed Displacement Catamaran Forms: Variation of Length-Displacement Ratio and Breadth-Draught Ratio," *Transactions of the Royal Institution of Naval Architects,* **138**, 55-71, 1995.

[23] Sainz M., "High Speed Marine Vehicles Parametric Hull Mass Estimation," M.Sc. Thesis, University of Southampton, Department of Ship Science, 1997.

[24] Svensson R., "A Description of the Water Jets Selected for DESTRIERO," *The* 1^{st} *International Conference on Fast Sea Transportation*, Trondheim, Norway, 1169-1184, 1991.

[25] Svensson R., "Water Jet for Naval Applications," *The Royal Institution of Naval Architects International Conference on New Developments in Warship Propulsion*, London, UK, 1989.

[26] Taggart R., "Ship Design and Construction," *Society of Naval Architects and Marine Engineers*, New York, USA, 1980.

[27] Trincas G., Zotti I., Kahu O. and Totolici S., "Multi-Criterial Design Of Fast Monohulls For The Adriatic Shortsea Shipping Network," *The 4th International Conference On Fast sea Transportation*, Sydney, Australia, 191-200, 1997.

[28] Trincas G., Biriaco A., Grubisic I. and Ponomarev A., "Feasibility Study on a High-Speed Catamaran: Comparison with Aquastrada," *The 3rd International Conference on Fast Sea Transportation*, Lubeck-Travemunde, Germany, 319-330, 1995.

[29] Vrontorinakis I., "The Technical and Economic Assessment of Alternative Propulsion Engines for Fast Ferries", M.Sc. Thesis, University of Southampton, Department of Ship Science, 1997.

[30] Warren N.F., Kecsmar J. and Sims N., "Water Jet Propulsion–A Shipbuilder's View", *The Royal Institution of Naval Architects International Symposium on Water Jet Propulsion Latest Developments*, London, UK, **4**, 1994.

[31] Watson D.G.M. and Gilfillan A.W., "Some Ship Design Methods", *Transactions of the Royal Institution of Naval Architects*, **119**, 279-289, 1976.

[32] Wood W.A. and Hunter J.A., "TRICAT High Speed Ferry-Redesign for the US Market", *Marine Technology*, **36**(1), 45-54, 1999.

[33] Wright C., "Operation and Cost of High-Speed Craft," *Marine Technology*, **27**(2), 104-113, 1990.

[34] Yeh H.Y.H., "Series 64 Resistance Experiments on High Speed Displacement Forms," *Marine Technology*, **2**(3), 248-272, 1965.

APPENDIX I

A1. DATABASE

A1.1. BACKGROUND

Appendix I contains information about the assembled database. An initial simpler database was first designed during earlier research, Karayannis [17]. This has been updated, expanded and modified during the current research programme until April 2000.

A1.2. GENERAL DESCRIPTION

The database includes over three hundred different vessels which have been recorded on four main spreadsheets representing the four major vessel categories, namely passenger-only monohulls (PM), passenger-only catamarans (PC), vehicle-passenger monohulls (VM) and vehicle-passenger catamarans (VC). The two catamaran databases also include all the different hull forms (SWATHs, SESs, wavepiercers and foil-assisted catamarans). For these hull types, relevant data are too few to analyse, and for this reason full analysis has been performed only for monohulls and conventional catamarans as it is mentioned earlier on this thesis.

In the spreadsheets, each row represents one vessel and each column represents different relevant information. Each column is often named as an abbreviation in order to accommodate as much information as possible. These abbreviations are described in Table A1.

The database has been focused on technical aspects such as main dimensions, seating and cargo areas, capacities, machinery installations, masses, some operational aspects and costs. Some of these values have been estimated from the general arrangement drawings, these are also described in Table A1.

The database has been developed in order to assist the generation of feasible and realistic technical designs for previous, current and future research studies. It is believed that it is an excellent tool great use for its purposes and can be easily updated and developed.

The relevant spreadsheets are presented as hardcopies at the end of this appendix. It should be mentioned that apparent lack of formatting is due to the fact that they were not designed to be used as printed spreadsheets. Therefore, they are also affixed at the end of the thesis in electronic format so as to be observed easily.

COLUMN	DESCRIPTION
Ship Code	Each vessel has been given a code to be recognised. There are mainly four different types of codes for four types of vessels, namely passenger-only monohull (PM), passenger-only catamaran (PC), vehicle-passenger monohull (VM) and vehicle-passenger catamaran (VC). Also, there are other vessel types for future studies, these are; passenger-only foil (PF), passenger-only SES (PS), passenger-only wavepiercer (PW), passenger-only SWATH (PSW), vehicle-passenger SES (VS) and vehicle-passenger wavepiercer (VW). Each vessel has a number immediately after the vessel type code. In some cases, different variants of the same design have been found often with slightly different characteristics from one operator to another. These are logged separately with the same number and with a lower case letter, such as PM1a and PM1b.
Des./Cons./ Yard	Designer, constructor or shipyard of the vessel whichever have been found.
L_{OA}	Overall length (m).
L_{BP}	Length between perpendiculars (m).
L_{WL}	Length on waterline (m).
B	Moulded and/or overall breadth (m). 'Mld' stands for moulded and 'oa' for overall.
D	Moulded and/or overall depth (m). 'Mld' stands for moulded and 'oa' for overall.
T	Draught (m).
b	Breadth of demihulls (m). This is given only for multihulls.
S	Separation of centrelines demihulls (m). This is given only for multihulls.
DWT	Deadweight (tonne).
DW Distribution	Detailed deadweights can be found in this column. These are represented as abbreviations and given as follows; Passenger (pax), fuel (f), fresh water (fw), luggage (lug), crew (cr), lubricating oil (lo), provisions (pro), bicycles (bike), store (str).
LS	Lightship (tonne).
Δ	Displacement (tonne).
GRT	Gross tonnage (tonne).
NT	Net tonnage (tonne).
Fuel	Fuel capacity on board (lt).
Fresh Water	Fresh water capacity on board (lt).
Other	Any other capacities (lt) and weights (t) have been found. Cargo and store are

Capacities, Weights	taken as weights and always united as tonne. The rest of the capacities units are all given as litre. These are represented as abbreviations and given as follows; Diesel oil (do), fuel oil (fo), lubricating oil (lo), hydraulic oil (ho), sewage (sew), sewage treatment (sew trt), bilge (bil), oily bilge (obil), sullage (sul), cargo (crg), store (str), black water (bw), grey water (gw), dirty oil (doil), reserve osmosis (rosm), container (con), bicycle (bike).
Pax	Number of passengers.
Pax Distribution	It gives information on the passenger distribution. Abbreviations used in this column are as follows; Upper deck (ud), main deck (md), upper deck bow (udb), upper deck lounge (udl), upper deck saloon (uds), main deck saloon (mds), upper saloon (us), main saloon (ms), aft saloon (as), bow saloon (bs), forward saloon (fs), forward lounge (fl), upper external (ue), very important person (VIP), upper saloon (us), lower saloon (ls), main bow saloon (mbs), main aft saloon (mas), bow saloon (bs), upper deck external (ude), forward deck external (fde), internal (in), top deck (top) external (ex).
Crew	Number of crew.
Cars	Number of cars.
V_S	Service speed (knots).
V_M	Maximum speed (knots).
SFC	Specific fuel consumption (units are given for each data individually).
RPM	Revolutions per minute for main engine (rpm).
Range	Range of the vessel (nautical miles).
Propulsion Plant	Column supplies information about the main propulsion plant. These are as follows; Main engine type, number of engines and installed power (kW). Main engine type is presented as abbreviations, namely diesel engine (D) and gas turbine (G).
Auxiliary Power	It provides data on auxiliary plant of the vessel. They can be summarised as follows; Number of engines, installed power (kW else it is noted next to the value) and revolutions per minute (rpm).
Propulsor	This column includes propulsor type and number. For example; 2wj stands for two water jets and 2prop two propellers.
GA	It indicates the availability of the vessel's general arrangement. '*' means that general arrangement is obtainable from the given reference.
Page	This is the page number of the relevant reference which has the data been taken from.

Source	It is the source of the data. There are several magazines and publications which most of the data have been gathered from. These are Fast Ferry International (FF), Ship and Boat (SB), Naval Architect (NA), and International conference on fast sea transportation (FAST'Year). Roman numbers present the month of the year. Example; FF/III'96 represents Fast Ferry International magazine's March 1996 edition.
BC million	Available building cost values. The units are noted next to the value.
ESTIMATED VALUES	
$Fn_{M/WL}$	Froude Number (based on waterline length and service speed).
L_{OA}/B	Overall length and breadth ratio.
L_{WL}/B	Waterline length and breadth ratio.
A_S (m^2)	Seating area.
A_S/p (m^2)	Seating area and number of passengers ratio.
A_P (m^2)	Passenger area.
A_P/p (m^2)	Passenger area and number of passengers ratio.
A_P/A_S	Passenger area and Seating area ratio.
B/T	Breadth and Draught ratio.
$L_{WL}*B$	Waterline length and breadth product.
∇	Underwater volume of the vessel.
$L_{WL}/\nabla^{1/3}$	Waterline length and underwater volume ratio.

Table A1.1: Database description.

A1.3. CONTRIBUTIONS

The major contributions of this thesis to the database can be summarised as follows;

- There has been an increase of 39% in the number of vessels and extra information columns have been included. These are as follows; Demihull breadth for multihulls, Deadweight distribution, Net tonnage, Lightship, Crew number, Specific fuel consumption, RPM of main engine, Auxiliary power details (number of engines, power, and rpm), Propulsor details (number and type), Building cost, Page of the source.

- All the vessel data after September 1998 have been included to the database during the current research programme.

- Database format has been altered to make it easy to understand, and use. All the abbreviations are made to a uniform standard, which makes it easier to use. Where it is necessary columns have been expanded. The font has been uniformed.

- A detailed table has been created to give all the details of the database and meanings of the abbreviations.

- Passenger distribution, Other capacities data columns have been edited in more detail.

- Some calculations have been undertaken to find out separation between demihulls, Froude number, Displacement volume, L/B, S/L, B/T, L×B, b/T, L/b products.

Approximate vessel data have been entered to the database during the current work can be summarised as following table.

Vessel Type	**Contributions**		**Total**	**Percentage of the Current Contributions**
	Current Research	**Previous Research**		
PM	33	108	141	33 %
VM	15	28	43	54 %
PC	10	60	70	17 %
VC	63	120	183	53 %
Total	121	316	437	39 %

Table A1.2: Contributions to the database from the current study.

Ship Code	Des./Cons./Yard	L_{OA} (m)	L_{BP} (m)	L_{WL} (m)	B (m)		D (m)		T (m)	DWT (t)	LS (t)	Δ (t)	GRT	Fuel (lt)	Fresh Water (lt)	Other Capacities (lt) / Weights (t)	Pax	Pax Distribution	Crew	V_S (kn)	V_M (kn)
PM1	Westport	28.90		24.55	6.90				1.65					11350	1 x 1130		149			28.0	
PM2	WaveMaster	33.00		28.40	6.50		1.80		1.80					10000	1000		200			32.5	
PM3	Pelmatic	31.00	26.50	26.50	6.50	mld			1.20					3000	450		149			34.0	
PM4	Pelmatic	48.00	39.50	39.50	7.90	mld			1.30					13000	1500		450			36.0	
PM5	Oceanfast	31.90		27.70	6.50		1.90	mld	1.00					6000	1000		228			28.0	30.0
PM6	Oceanfast	40.00		34.60	9.50		3.50	mld	1.10					10000	1500		340			34.0	36.0
PM7	WaveMaster	35.40		31.60	7.00	mld	2.85	mld	2.10			85		5800	600	sul 600	260			27.0	
PM8	WaveMaster	31.50		26.60	6.50	mld	2.50	mld	0.90					6000	1000		196			28.0	
PM9	Aluminium Craft	35.00		30.12	7.40		2.90										250			27.0	
PM10	Aluminium Craft	37.00		31.84	8.00		3.70										350			30.0	
PM11	Aluminium Craft	32.00		28.50	7.40		2.75		1.25				229	2 x 2000	1 x 1000		275			25.0	26.0
PM12a	Almaz/Agat/Sukhoi	54.00			9.00		5.00							15000	1500		400			50.0	
PM12b	Almaz/Agat/Sukhoi	54.00			9.00		5.00							22000	1500		400			55.0	
PM12c	Almaz/Agat/Sukhoi	54.00			9.00		5.00							23000	1500		400			60.0	
PM13	Marinteknik	35.00			7.50				1.20								200	178 + 22 up		32.0	
PM14	Penguin	34.00			7.40		3.00		1.35								230	200 + 30 up		32.0	
PM15	FBM	70.00		65.00	13.50				2.00								650-800			33.0	35.0
PM16	FBM	45.00		42.00	8.80				1.50								500				35.0
PM17	FBM	35.00		32.65	7.00				1.1-1.8								170-210				33.0
PM18	Semo	28.00	25.50		7.20	oa	2.53		1.22					4500	1000		194	92 + 42 as + 60 up		32.0	37.0
PM19a	Rodriquez	50.46		43.00	9.20	oa	4.20		1.35	57		183.6		32000			511	106 + 290 mid + 115 up			29.0
PM19b	Rodriquez	50.46		43.00	7.7;8.8		4.20		1.35	56	127.6	183.6		28000	15000		500	134ls + 158mbs + 106mas + 102us	6		28.5
PM20	Lürssen-Werft	69.80	62.00		10.40		4.80		2.00								925	158 dn + 428 + 339 up		38.0	
PM21	Derecktor / NGA	32.50			8.50				1.20								100			35.0	
PM22a	Derecktor / NGA	36.40			8.50				1.60								150			30.0	
PM22b	Derecktor / NGA	36.40			8.50				1.60								150			40.0	
PM23	Covestar	33.50		28.42	6.85	oa			1.32								260	172 + (76+12) up		28.0	
PM24	WaveMaster	30.30		25.20	6.50	mld	3.80	mld	0.95					5600	1000	sul 750	191	116 + (13+62) up			30.0
PM25a	Westport	30.50			6.90	mld									1135		150	102 + 48 up			
PM25b	Westport	29.00			6.90									11350	1125		149			28.0	
PM26	Marinteknik	45.00		39.20	8.90	mld			1.30					30000	2000	lo 1000	550	112bs + 212as + 111us +115ud			
PM27	Allen Marine	19.50			3.90				0.45				27	1 x 1900	1 x 152		49		3	32	
PM28	Tenix Fast Ferry Designs	45.00		39.70	8.50		4.00		1.60	45				4000	1000		450			30.0	
PM29	Tenix Fast Ferry Designs	67.00		58.40	10.00				1.75								900				
PM30	SBF Shipbuilders	31.00		26.60	6.50	mld			1.50					5000	1000		238	167 ms + 25 us + 16 md + 30 ud		30.0	
PM31	SBF Shipbuilders	31.00		27.00	3.70	mld			0.85					8000	1000		190	146 ms + 42 us + 2 md		33.5	
PM32	WaveMaster	37.40		31.30	8.00	oa	3.00	mld	2.45					10000	1000	sul 750	272	100 mbs + 72 mas + 82 us + 18 ud		24.0	
PM33	WaveMaster	50.00		42.50	9.00	mld			2.00	30				8000	1000	lo 500 + sew 1000	324			30.0	
PM34	SBF Shipbuilders	35.00		31.70	7.00	mld			1.90					10000	1000		312	207 ms + 105 us			32
PM35	OCEA Fast Ferry	24.55	23.50	20.00	6.50	mld	2.50		1.20	15.8			100	5000	1000	lo 250	135	80 md + 55 ude	3_4		
PM36	OCEA Fast Ferry	27.60	27.30	23.70	7.00	mld	2.65		1.40	18.8				4400	1000	lo 250	180	108 md + 72 ude	3_4		
PM37	OCEA Fast Ferry	30.00		27.20	5.50	mld	2.50		2.10	11.8			100	4400	1000	lo 250	90	30 md + 60 ude	2		30
PM38	Rodriquez Cantieri Naval	54.46		46.70	9.30		4.45		1.40								410	230 md + 180 ud		38	

Ship Code	SFC	RPM	Range (nm)	Propulsion Plant (kW)	Auxilary Power (kW)	Propulsor	GA	Page	Source	Fn_{MWL}	L_{OA} / B	L_{WL} / B	A_S (m^2)	A_S/p (m^2)	A_P (m^2)	A_P/p (m^2)	A_P / A_S	B / T	L_{WL} * B	∇	$L_{WL}/\nabla^{1/3}$
PM1				D 2 x 1287			*		FF / I-II '95		3.980	3.558	95.000	0.638	117.000	0.785	1.232	4.182	169.395	111.801	5.096
PM2			450	D 2 x 1240			*		FF / III '95		3.851	4.369	114.000	0.570	131.000	0.655	1.149	3.611	184.600	132.912	5.565
PM3				2 x 1500					FF / IV '95		4.769	4.077						5.417	172.250	82.680	6.083
PM4				3 x 2000					FF / IV '95		6.076	5.000						6.077	312.050	162.266	7.242
PM5			150	D 3			*		FF / VII-VIII '95	0.936	4.908	4.262	130.000	0.570	141.000	0.618	1.085	6.500	180.050	72.020	6.658
PM6			300	D 2			*		FF / VII-VIII '95	1.005	4.211	3.642	254.000	0.747	314.000	0.924	1.236	8.636	328.700	144.628	6.592
PM7			420	D 2 x 970			*		FF / XII '95		5.057	4.514	184.000	0.708	205.000	0.788	1.114	3.333	221.200	185.808	5.538
PM8			360	D 3 x 660			*		FF / XII '95		4.846	4.092	106.000	0.541	136.000	0.694	1.283	7.222	172.900	62.244	6.712
PM9				D 3					FF / I-II '96		4.730	4.070							222.888	0.000	
PM10				D 2 x 1940					FF / I-II '96		4.625	3.980							254.720	0.000	
PM11			180	D 3 x 620			*		FF / I-II '96	0.800	4.324	3.851	159.000	0.578	172.000	0.625	1.082	5.920	210.900	105.450	6.032
PM12a			400	D 4 x 2000					FF / III,IV '96		6.000										
PM12b			400	D 2 x 5000					FF / III,IV '96		6.000										
PM12c			400	D 2 x 5600					FF / III,IV '96		6.000										
PM13				D 3 x 735			*		FF / XII '96		4.667							6.250			
PM14				D 4 x 610			*		FF / XII '96		4.595							5.481			
PM15							*		SB / V '96	0.713	5.185	4.815						6.750	877.500		
PM16				D 2					F	0.887	5.114	4.773						5.867	369.600		
PM17				D 2/3					F	0.949	5.000	4.664							228.550		
PM18				D 2 x 1470			*		FF / IV '97		3.889							5.902			
PM19a				D 2 x 2000					FF / VI '97	0.726	5.485	4.674						6.815	395.600	179.122	7.628
PM19b	232 g/kWh	1975	280	D 2 x 2000	2 x 100		*		FF / V'99	0.714										179.122	7.628
PM20			550	D 4 x 3805			*		FF / V '97		6.712							5.200			
PM21				D 2 x 1500					FF / V '97		3.824							7.083			
PM22a				D 2 x 610					FF / V '97		4.282							5.313			
PM22b				D 4 x 610					FF / V '97		4.282							5.313			
PM23				D 2 x 735			*		FF / IX '97		4.891	4.149						5.189	194.677		
PM24			250	D 3 x 660			*		FF / IX '97	0.981	4.662	3.877						6.842	163.800		
PM25a				D 2 x 1950					FF / V '98		4.420										
PM25b		1835		D 2 x 1460					FF / VII-VIII'99		4.203										
PM26							*		FF / XII'98		5.056	4.404						6.846	348.880		
PM27	225 lt/h			D 2 x 412					FF / I-II'98		5.000							8.667			
PM28		1835	250	D 2 x 2300			*	6	FF / X'99		5.294	4.671						5.313	337.450		
PM29								6	FF / X'99		6.700	5.840						5.714	584.000		
PM30		2100		D 3 x 610		prop	*	21	FF / X'99		4.769	4.092						4.333	172.900		
PM31		2100		D 3 x 790		3 wj	*	21	FF / X'99		8.378	7.297						4.353	99.900		
PM32		2300	350	D 3 x 783		3 prop	*	14	FF / XI'99		4.675	3.913						3.265	250.400		
PM33	200 g/kWh	1850	200	D 2 x 2000			*	8	FF / XII'99		5.556	4.722						4.500	382.500		
PM34	598 lt/h (75% mcr)	2100		D 3 x 790			*	36	FF / III'00	0.933	5.000	4.529						3.684	221.900		
PM35	470 lt/h	2100	290	D 3 x 610	42 kVA at 1500 rpm	3 wj		22	FF / III'00		3.777	3.077						5.417	130.000		
PM36	590 lt/h	2100	210	D 3 x 788	60 kVA at 1500 rpm	3 wj		22	FF / III'00		3.943	3.386						5.000	165.900		
PM37	455 lt/h	1950	290	D 2 x 883		2 prop		22	FF / III'00	0.945	5.455	4.945						2.619	149.600		
PM38				D 3 x 2320		3 wj	*	23	FF / III'00		5.856	5.022						6.643	434.310		

Ship Code	Des./Cons./Yard	L_{OA} (m)	L_{BP} (m)	L_{WL} (m)	B (m)		D (m)		T (m)	h (m)	S (m)	DWT (t)	DW Distribution (t)	Δ (t)	GRT	NT	Fuel (lt)	Fresh Water (lt)	Other Capacities (lt) / Weights (t)	Pax	Pax Distribution	Crew	V_S (kn)	V_M (kn)
PC1a	Rosendal Werft	29.00	27.40	27.20	8.00		3.10		1.50		5.50								erg 7	100			32.0	
PC1b	Rosendal Werft	29.00	26.10	27.20	8.10		3.10		1.50		5.55								erg 7	100			32.0	
PC2a	Rosendal Werft	36.00	32.70	31.60	9.60		3.70		1.70		6.20									308			35.0	
PC2b	Rosendal Werft	36.00	32.77	31.60	9.90				1.74		6.45						6500	1500	sew 1500	312			35.0	
PC3	Incat / Nichols	32.40		28.70	9.10	oa			1.40								2 x 8525	3 x 2460	sew 3140 + str 1.13	49			25.0	
PC4a	Austal	40.10		35.00	11.50	mld			1.40								17000	1500		355	266 + 81 up + 8 VIP		40.5	
PC4b	Austal	40.10		35.00	11.50	mld			1.40								10000	1500		338	262 + 60 up + 16 VIP		33.5	
PC4c	Austal	40.10		35.00	11.50	mld			1.40								20000	1500		332	256 + 64 up + 12 VIP		40.2	
PC5	Lock Crowther	35.00		32.15	11.60				1.60		8.60									310			29.0	30.0
PC6a	Marinteknik	42.10		36.80	11.00	mld			1.20	3.55	6.95									395			40.0	42.0
PC6b	Marinteknik	42.00		37.95	11.50	mld	3.70	mld	1.30	3.35	7.65	46.80					2 x 5000	1 x 1000		506			33.0	
PC6c	Marinteknik	42.10		36.00	11.00	mld				3.70	7.05									381			50.0	
PC7	Austal	43.40		37.70	11.20	mld	3.90	mld	1.30	3.90	7.45				543		14000	1500		331			42.5	
PC8a	Båtservice	38.00		33.95	11.20		3.90		1.60								8000	1000	sew 800	336			35.0	
PC9	Incat Designs	47.40		46.40	12.20	oa			1.60	3.20	9.00									550				
PC10a	Kvaerner Fjellstrand	40.00		35.55	10.10		3.97	mld	1.50								2 x 6000	1 x 1500	bil 1 x 1500 + sew 1 x 1500	306			37.5	
PC10b	Kvaerner Fjellstrand	40.00		35.55	10.10		3.97	mld	1.50								2 x 6000	1 x 1500	bil 1 x 1500 + sew 1 x 1500	333			37.5	
PC10c	Kvaerner Fjellstrand	40.00		35.55	10.10		3.97	mld	1.50								2 x 6000	1 x 1500	bil 1 x 1500 + sew 1 x 1500	420			37.5	
PC11	Oceanfast	35.60		29.10	10.60		3.70	mld	1.40								10000	1000		250	222 + 28 up		35.0	37.0
PC12a	Oceanfast	40.00		33.20	12.00		3.70	mld	1.40								12000	1500		366	282 + 84 up		31.0	33.0
PC12b	Oceanfast	40.00		33.20	12.00		3.70	mld	1.40											300	252 + 48 up		34.0	36.0
PC13a	Oceanfast	42.00		35.20	12.00		3.70	mld	1.50								14000	1500		380	274 + 106 up		42.0	44.0
PC13b	Oceanfast	42.00		35.70	12.00		3.70	mld	2.20											415	334 + 81 up		41.0	43.0
PC13c	Oceanfast	42.00		35.70	12.00		3.70	mld	2.20								30000	2000		532	406 + 126 up		38.0	40.0
PC14	Oceanfast	55.00		48.30	15.00		3.70	mld	1.50								22000	1500		572	418 (+30 VIP) + 124 up		38.0	40.0
PC15	Marinette Marine	30.00		27.00	9.10				0.90								2 x 3800			400			35.0	38.0
PC16a	FBM	45.00		43.00	11.80	oa			1.40		8.60						23000	1000	lo 100	496			20.0	
PC16b	FBM	45.00		43.00	11.80	oa			1.38		8.60									496			23.0	25.0
PC17	Nigel Gee Associates	40.10		33.00	10.60	mld			1.60								12000			350			35.0	
PC18	WaveMaster	42.00		36.00	12.00	mld	3.70	mld	2.00	2.75	8.30						19000 / 39000	2000	sul 1000	380			42.0	
PC19	Incat Designs	49.92		49.68	12.40				1.80	3.00	9.40									550			40+	
PC20	Aluminium Craft	38.00		34.45	12.00		4.45			3.20	8.30				567		12000	1800		360			32.0	34.0
PC21	Lloyd's Ships	38.00		33.66	12.20				1.80	3.00		40.00		161			10500	4000	lo 11.5 + fw 3.8	400			30.0	
PC22a	Advanced Multihull Designs	41.27		36.23	12.00				1.50											301			32.0	
PC23a	Iris	39.92		38.00	10.24	oa			1.50			35.00						760	fo 4.2	160			26.6	32.0
PC23b	Iris	39.92		38.00	12.74	oa			1.56			51.00						1100	fo 6.6	240			29.8	33.3
PC23c	Iris	39.92		38.00	12.74	oa			1.62			72.00						1800	fo 8.8	384			31.6	36.1
PC24	Famille Dufour	38.60		34.20	10.40				1.40					122						300			30.0	
PC25	SBF	31.70		28.08	9.60				1.00											250	218 + 32 up (1st calss)		32.0	35.0
PC26a	Westamarin	42.00		37.37	10.00	mld			2.13											400	314 + 86 up		38.0	42.0
PC26b	Westamarin	42.00		37.37	10.00	mld			2.18	2.75	6.85				499		2 x 3200 + 2 x 4200	2 x 1000	lo 1x250 + sew 1x2000	400			38.0	42.0
PC27	Ulstein	38.00		30.55	10.00				1.00	3.60	6.05									225				
PC28	Oceanfast	44.80		38.30	12.00	oa	3.70	mld	2.20	3.15										450	342 + 108 up		43.0	46.0
PC29	Daewoo	40.25		35.65	9.30	mld			1.50								14000	1500		350			38.0	40.0
PC30a	Semo	40.00	36.50	36.50	11.50		3.95		1.50					155						351			35.0	
PC31a	FBM	45.00		40.00	11.80		4.76		1.45		8.50			188						312			44.0	
PC31b	FBM	45.00		40.00	11.80		4.76		1.37		8.50			188						332			45.0	
PF1a	Hyundai	45.50		37.98	11.40	oa	5.10		1.60											300	208 + 92 up		35.0	
PF1b	Hyundai	45.00		37.56	11.40	oa	5.10		1.60											300	208 + 92 up		40.0	
PF2a	Marinteknik	45.00	37.00	37.00	11.00	mld	4.10	mld	1.90											400			50.0	54.0
PF2b	Marinteknik	45.00	37.00	37.00	11.00	mld	4.10	mld	1.85	3.75	7.25	180.00					2 x 7000	1 x 2500		445			41.5	
PF3a	Kvaerner Fjellstrand	35.00		29.65	12.00		4.20	mld	3.63						450		2 x 10000	1 x 250	lo 1x400 + bil 1x1000 + sew 1x1500	407			45.0	
PF3b	Kvaerner Fjellstrand	35.00		29.65	12.00		4.20	mld				50.00								403				
PF4	Almaz/Agat/Sukhoi	44.90			11.70				1.75								12400	2300		350			46.0	
PF5a	Hitachi	39.00			11.40	mld			1.90					300						200				45.0
PF5b	Hitachi	39.50			11.40	mld	3.70	mld	1.90						284					200	170 + 30 up			45.0
PF6	Rodriquez	31.20		26.40	6.78	mld	3.90	hull	1.45					121	210	80				240	132ls + 108us		40.0	41.5
PF7	Rodriquez	28.60			5.86	mld			3.50						144	98				125			32.0	34.0
PF8	Rodriquez	30.95		26.31	6.20	mld			3.70						174	115				161			32.0	34.0
PF9	Air Ride Seacoaster	19.80			5.80				1.60					60						162	102 ms + 60 ud		32.0	
PS1a	International Shipyards / Ulstein	39.60		33.30	11.90		4.00	mld	1.80								14000	1500		350			45.0	48.0
PS1b	International Shipyards / Ulstein	38.30		33.30	11.90		4.00	mld	3.00								14000	1500		350			45.0	48.0
PS2	Semo	40.00		35.20	11.60				1.25											400				50.0
PS3	Samsung	36.70		32.25	12.00	oa	4.00		1.40					160						352			45.0	
PS4	International Shipyards	38.70		33.19	11.60				2.84											350			45.0	48.0
PS5	Oceanfast / Ulstein	35.60		29.30	10.60		3.70	mld									10000	1000		250			35.0	37.0
PS6	Oceanfast / Ulstein	39.60		33.30	11.90		3.70	mld									12000	1500		350			31.0	33.0
PS7	Oceanfast / Ulstein	42.00		35.80	11.90		3.90	mld									14000	1500		380			42.0	44.0
PS8	Oceanfast / Ulstein	55.00		48.15	15.00		4.30	mld									22000	1500		548			38.0	40.0
PW1	NQEA	45.45		39.56	16.24				1.90	3.00	13.15	53.00					2 x 6000 / 2 x 36000	2 x 3000	sul 1x4500	450				36.0
PW2	Advanced Multihull Designs	42.50		36.95	12.20	oa			1.95		8.95	38.00					14000	1000		350			33.0	36.0
PW3	AMD 183	30.00			9.60	oa	4.50		1.80			20.00					10000	1000	lo 200 + sul 1000 + obil 180	158		8		27.5
PSW1	Almaz/Agat/Sukhoi	32.30			10.50	oa			2.30			275.00					9700	2000		186			28.0	
PSW2	FBM	39.70			14.20				2.00											400			29.0	30.0
PSW3	SWATH Int'l / Nichols	37.52		32.40	18.07	oa			3.44			63.74			1025		14000			367			27.0	
PSW4	SWATH International	33.60			16.20	oa			2.90											449			26-34	
PSW5	SWATH International	37.20			18.00	oa			3.50											550			26-34	
PSW6	Samsung	34.00			13.00	oa			2.70			41.00		200						350			30.0	31.5
PC4d	Austal	40.10		35.00	11.50	mld	3.80	mld	1.35								2 x 5000	1 x 1500		318	198 + 108 up + 12 VIP		34.0	
PC4e	Austal	40.10		35.00	11.50	mld	3.80	mld	1.35								2 x 5000	1 x 1500		338	222 + 90 up + 26 VIP		34.0	
PC4f	Austal	40.10		35.00	10.80	mld			1.40								10000	1500		304	250 + 54 up	7	35.0	
PC8b	Båtservice	38.00			11.46	oa	3.90	mld	1.65											354	248 + (100+6) up		35.0	
PC8c	Båtservice	38.00			11.46	oa	3.90		1.84			37.43		144	531		2 x 3000	1 x 1500	lo 2x130 + sew 1x1500 + sul 1x100	357	250md + 100ud + 7VIP		33.0	35.0
PC10d	Kvaerner Fjellstrand	40.00			10.10		3.97		1.70						478		2 x 6000	1500	sew 1500 + bil 1500	376	253ms + 123us		36.0	
PC10e	Kvaerner Fjellstrand	40.00			10.10							52.00							erg 10	300	276 ms + 24 us	8	30.0	
PC19b	Incat / South Australian Ships	49.92		46.68	12.40		4.13	mld	2.08	3.00		47.95					19800	2800	sew 1000	430				41.0
PC22b	A.M.D. / Dakota Creek	41.27			11.50	oa			1.50			40.00					14000	3800		325			32.0	36.0
PC22c	AMD	41.27		36.23	11.50	mld			1.50	3.00		40.00					14000	3800		301	182 + (94+25) up			32.0
PC22d	AMD / Dakota Creek	41.30			11.50	oa			1.50			40.00					13600	3000		325	212 + (92+21) up			36.0
PC26e	Båtservice / Westamarin	42.00		37.40	10.00	mld	4.10	mld	2.20								1800			392	306 + 86 up		39.0	
PC30b	Semo	40.00	36.50		10.40	oa	4.10		1.35						290		2 x 4000	2000		372	244 + 128 up		34.0	39.5

Ship Code	SFC	RPM	Range (nm)	Propulsion Plant (kW)	Auxliary Power (kW)	Propulsor	GA	BC million	Page	Source	Fn_{SWL}	Fn_{MWL}	L_{OA} / B	L_{WL} / B	S / L_{WL}	A_S (m^2)	A_S/p (m^2)	A_P (m^2)	A_P/p (m^2)	A_P / A_S	B/T	L_{WL} * B	B_H / T	L_{WL} / B_H	$L_{WL}/\nabla^{1/3}$	∇
PC1a				D 2 x 1040			*			FF / I-II '95	1.008		3.625	3.400	0.202	78.000	0.780	97.000	0.970	1.244	5.333	217.600				
PC1b				D 4 x 550			*			FF / VII-VIII '95	1.008		3.580	3.358	0.204	81.000	0.810	104.000	1.040	1.284	5.400	220.320				
PC2a				D 4 x 735			*			FF / I-II '95	1.023		3.750	3.292	0.196	271.000	0.880	333.000	1.081	1.229	5.647	303.360				
PC2b				D 4 x 735			*			FF / VII-VIII '95	1.023		3.636	3.192	0.204	271.000	0.869	333.000	1.067	1.229	5.690	312.840				
PC3				D 2 x 772						FF / I-II '95	0.767		3.560	3.154							6.500	261.170				
PC4a				G 2 x 2600						FF / I-II '95	1.125		3.487	3.043							8.214	402.500				
PC4b				D 2 x 2000						FF / X '95	0.930		3.487	3.043							8.214	402.500				
PC4c				G 2 x 2600						FF / X '95	1.116		3.487	3.043							8.214	402.500				
PC5				D 2 x 1440			*			FF / III '95	0.840	0.869	3.017	2.772	0.267	221.000	0.713	256.000	0.826	1.158	7.250	372.940				
PC6a			275	D 4 x 1415			*			FF / IV '95	1.083	1.137	3.827	3.345	0.189	263.000	0.666	311.000	0.787	1.183	9.167	404.800	2.958	10.366	9.263	125.414
PC6b			300	D 2 x 1935			*			FF / IV '95	0.880		3.652	3.300	0.202	395.000	0.781	412.000	0.814	1.043	8.846	436.425	2.577	11.328	9.386	132.218
PC6c				D 4			*			SB / I-II '95	1.369		3.827	3.273	0.196	263.000	0.690	311.000	0.816	1.183		396.000		9.730		
PC7				D 4 x 1960			*			FF / V '95	1.137		3.875	3.366	0.198	266.000	0.804	321.000	0.970	1.207	8.615	422.240	3.000	9.667	8.883	152.911
PC8a				D 4 x 735			*			FF / VI '95	0.987		3.393	3.031		249.000	0.741	287.000	0.854	1.153	7.000	380.240				
PC9				D 2 x 2000			*			FF / VI '95			3.885	3.803	0.194	367.000	0.667	455.000	0.827	1.240	7.625	566.080	2.000	14.500	10.168	190.054
PC10a				D 2 x 2000			*			FF / VII-VIII '95	1.033		3.960	3.520		179.000	0.585	210.000	0.686	1.173	6.733	359.055				
PC10b				D 2 x 2000			*			FF / I-II '96	1.033		3.960	3.520		200.000	0.601	227.000	0.682	1.135	6.733	359.055				
PC10c				D 2 x 2000			*			FF / I-II '96	1.033		3.960	3.520		247.000	0.588	291.000	0.693	1.178	6.733	359.055				
PC11			200	D 2						FF / VII-VIII '95	1.066	1.126	3.358	2.745							7.571	308.460				
PC12a			250	D 2						FF / VII-VIII '95	0.884	0.941	3.333	2.767							8.571	398.400				
PC12b				D 2						FF / VII-VIII '95	0.969	1.026	3.333	2.767							8.571	398.400				
PC13a				D 2						FF / VII-VIII '95	1.163	1.218	3.500	2.933		274.000	0.721	320.000	0.842	1.168	8.000	422.400				
PC13b				D 2						FF / VII-VIII '95	1.127	1.182	3.500	2.975							5.455	428.400				
PC13c			225	D 2						FF / VII-VIII '95	1.045	1.099	3.500	2.975							5.455	428.400				
PC14			390	D 4						FF / VII-VIII '95	0.898	0.945	3.667	3.220							10.000	724.500				
PC15				G 2 x 1125			*			FF / IX '95	1.106	1.201	3.297	2.967		307.000	0.768	319.000	0.798	1.039	10.111	245.700				
PC16a			1000+	D 2 x 948			*			FF / X '95	0.501		3.814	3.644	0.200	275.000	0.554	314.000	0.633	1.142	8.429	507.400				
PC16b			184	D 2 x 960			*			SB / XI '95	0.576	0.626	3.814	3.644	0.200	275.000	0.554	314.000	0.633	1.142	8.551	507.400				
PC17			400	D 2 x 2000			*			FF / X '95	1.001		3.783	3.113		232.000	0.663	255.000	0.729	1.099	6.625	349.800				
PC18			340	D 4 x 1941			*			FF / XII '95	1.150		3.500	3.000	0.231	249.000	0.655	290.000	0.763	1.165	6.000	432.000	1.375	13.091	9.227	118.800
PC19				D 4 x 1932			*			FF / XII '95	0.932		4.026	4.006	0.189	370.000	0.673	447.000	0.813	1.208	6.889	616.032	1.667	16.560	10.454	214.618
PC20			400	D 2 x 1940						FF / I-II '96	0.896	0.951	3.167	2.871	0.241	296.000	0.822	330.000	0.917	1.115		413.400		10.766		
PC21				D 2 x 2000			*			FF / I-II '96	0.849		3.115	2.759							6.778	410.652	1.667	11.220	8.065	145.411
PC22a				D 2 x 2000						FF / I-II '96	0.873		3.439	3.019		355.000	1.179	386.000	1.282	1.087	8.000	434.760				
PC23a				D 2 x 960						FF / I-II '96	0.709	0.853	3.898	3.711							6.827	389.120				
PC23b				D 2 x 1524						FF / I-II '96	0.794	0.887	3.133	2.983							8.167	484.120				
PC23c				D 2 x 2032						FF / I-II '96	0.842	0.962	3.133	2.983							7.864	484.120				
PC24				D 2 x 1618						FF / I-II '96	0.843		3.712	3.288							7.429	355.680			8.760	119.024
PC25				D 2 x 1435						SB / V '94	0.992	1.085	3.302	2.925							9.600	269.568				
PC26a				D 4 x 1485						FF / III '95	1.021	1.128	4.200	3.737							4.695	373.700				
PC26b				D 4 x 1485			*			FF / VII-VIII '95	1.021	1.128	4.200	3.737	0.183	275.000	0.688	334.000	0.835	1.215	4.587	373.700	1.261	13.589	8.901	147.985
PC27							*			SB / VI-VIII '94			3.800	3.055	0.198	180.000	0.800	223.000	0.991	1.239	10.000	305.500	3.600	8.486	8.654	87.984
PC28				D 4 x 2000						FF / XII '95	1.141	1.221	3.733	3.192		297.000	0.660	389.000	0.864	1.310	5.455	459.600	1.432	12.159	8.089	212.335
PC29			200	D 2 x 2000			*			SB / I-II '95	1.045	1.100	4.328	3.833							6.200	331.545				
PC30a				D 2 x 1940			*			FF / IV '95	0.952		3.478	3.174		237.000	0.675	291.000	0.829	1.228	7.667	419.750			8.632	151.220
PC31a				G 2 x 4200			*			SB / I-II '95	1.143		3.814	3.390	0.213	264.000	0.846	298.000	0.955	1.129	8.138	472.000			7.040	183.415
PC31b				G 2			*			SB / XI '93	1.169		3.814	3.390	0.213	256.000	0.771	322.000	0.970	1.258	8.613	472.000			7.040	183.415
PF1a			500	D 2 x 4105						SB / XI '95	0.933		3.991	3.332							7.125	432.972				
PF1b				D 2 x 4105						SB / I-II '95	1.072		3.947	3.295							7.125	428.184				
PF2a			200	D 4						FF / IV '95	1.350	1.458	4.091	3.364							5.789	407.000				
PF2b				D 4 x 1470			*			FF / I-II '96	1.121		4.091	3.364	0.196	317.000	0.712	388.000	0.872	1.224	5.946	407.000	2.027	9.867		
PF3a			300	G 2 x 4474			*			FF / VII-VIII '95	1.357		2.917	2.471		304.000	0.747	352.000	0.865	1.158	3.306	355.800				
PF3b							*			SB / V '94			2.917	2.471		304.000	0.754	352.000	0.873	1.158		355.800				
PF4			400	D 2 x 2945			*			FF / III,IV '96			3.838								6.686					
PF5a				D 4 – 2022						FF / XI '97			3.421								6.000					292.683
PF5b				D 4 – 2023			*			FF / V '98			3.465								6.000					
PF6		2000	120	D 2 x 2000	2 x 57,5 kVA		*			FF / V'99	1.279	1.327	4.602	3.894							4.676	178.992			5.382	118.049
PF7				D 2 x 932						FF / V'99			4.881								1.674					
PF8				D 2 x 1320						FF / V'99	1.025	1.089	4.992	4.244							1.676	163.122				
PF9				D 2 x 932		2 prop	*		15	FF XII'99			3.414								3.625					58.537
PS1a			400 / 300	D			*			FF / III '95	1.281	1.366	3.328	2.798		217.000	0.620	263.000	0.751	1.212	6.611	396.270				
PS1b			400 / 300	D			*			FF / III '95	1.281	1.366	3.218	2.798		217.000	0.620	263.000	0.751	1.212	3.967	396.270				
PS2				D 2 x 1970			*			SB / I-II '95	0.000	1.384	3.448	3.034		258.000	0.645	335.000	0.838	1.298	9.280	408.320				
PS3			250	D 2 x 2000			*			FF / V '95	1.301		3.058	2.688		294.000	0.835	373.000	1.060	1.269	8.571	387.000			7.546	156.098
PS4				D 2						SB / I-II '95	1.283	1.368	3.336	2.861							4.085	385.004				
PS5			200	D 2						FF / III '95	1.062	1.123	3.358	2.764								310.580				
PS6			250	D 2						FF / III '95	0.882	0.939	3.328	2.798								396.270				
PS7			185	D 4						FF / III '95	1.153	1.208	3.529	3.008								426.020				
PS8			390	D 4						FF / III '95	0.899	0.947	3.667	3.210								722.250				
PW1			220	D 4 x 1343			*			FF / VII-VIII '95		0.940	2.799	2.436	0.332	380.000	0.844	480.000	1.067	1.263	8.547	642.454	1.579	13.187		
PW2				D 2 x 1960			*			FF / XII '95	0.892	0.973	3.484	3.029	0.242	280.000	0.800	299.000	0.854	1.068	6.256	450.790				
PW3		2165	220	D 2 x 1135	2 x 65		*			FF / V'99			3.125								5.333					
PSW1			250	D 2 x 1500			*			FF / III,IV '96			3.076								4.565					
PSW2				D 2 x 2000			*			SB / V '95			2.796								7.100					
PSW3			200	G 2 x 2870			*			FAST '95	0.779		2.076	1.793							5.253	585.468				
PSW4							*			F			2.074								5.586					
PSW5							*			F			2.067								5.143					
PSW6			200	D 2 x 2000						F97			2.615								4.815					195.122
PC4d				D 2 x 1980			*			FF / IX '97	0.944		3.487	3.043							8.519	402.500				
PC4e				D 2 x 1980			*			FF / IX '97	0.944		3.487	3.043							8.519	402.500				
PC4f	0.82 t/h			D 2 x 1980			*			FF / XII'98	0.972		3.713	3.241							7.714	378.000				
PC8b				D 2 x 2040			*			FF / XII '97			3.316								6.945					
PC8c				D 4 x 788	2 x 97		*			FF / IV'99			3.316								6.228					140.488
PC10d				D 2 x 2000			*			FF / XII'98			3.960								5.941					
PC10e		2000	750	D 2 x 2000		2 wj	*		9	FF XI'99			3.960													
PC19b			280	D 4 x 1940			*			FF / III '97		0.986	4.026	3.765							5.962	578.832	1.442	15.560		
PC22b				D 2 x 1960			*			F			3.589								7.667					
PC22c				D 2 x 1960			*			FF / V '97		0.873	3.589	3.150							7.667	416.645	2.000	12.077		
PC22d				D 4 x 1194			*			FF / V '98			3.591								7.667					
PC26c				D 2 x 1260 + D 2 x 1680			*			FF / XII '97	1.047		4.200	3.740							4.545	374.000				
PC30b			230	D 2 x 1100						BWPV '97			3.846								7.704					

Ship Code	Des./Cons./Yard	L_{OA} (m)	L_{BP} (m)	L_{WL} (m)	B (m)		D (m)		T (m)	b (m)	S (m)	DWT (t)	DW Distribution (t)	Δ (t)	GRT	NT	Fuel (lt)	Fresh Water (lt)	Other Capacities (lt) / Weights (t)	Pax	Pax Distribution	Crew	V_S (kn)	V_M (kn)
PC30c	Semo	40.00	36.50		10.40	oa	4.10		1.35						290		2 x 4000	2000		379			34.0	39.0
PC32	Sabre	32.00			9.30				1.70								20000	2000		300	230 + 70 up			28.0
PC33	Incat Designs	33.98			9.45		2.74		1.22								10600	950	sew 760	365			31.5	
PC34a	Marinteknik	32.80							1.85			21.00								200				50.0
PC34b	Marinteknik	32.00			8.10	oa			1.85								2 x 3000	1 x 1000		180			35 / 45	
PC35	FBM	50.00		45.11	11.80				1.35			44.35					10000	1000	lo 350 + sew 1500 + ho 150 + obil 1000	403	307md + 96ud	9	36.0	
PC36	Advanced Multihull Designs	42.50			11.20															344			32.0	
PC37	FBM	31.50		27.50	8.40				1.10											120				38.0
PC38	FBM	39.20		35.30	10.00				1.35											306				38.0
PC39	WaveMaster	41.00		37.00	12.00		3.70		2.20								16000	2000	sew 1500 + sul 1000	639	in 264 + 148 up / out 20 + 64 + 143		26.0	29.0
PC40	Kvaerner Fjellstrand	34.00			10.10				1.50						400		2 x 4000	1000	sew 1000	250				32.0
PC41	New Tech	42.00		36.00	12.00	mld	3.70	mld	1.50					128			12000	1250		380	315 + 33 up + 16 VIP + 16 off.			44.0
PC42	Kvaerner Fjellstrand	46.00			12.00	oa						57.00					2 x 10000	1 x 1500	sew 1x1500 + sul 500	440	278 + 162 up			38.0
PC43a	Kvaerner Fjellstrand	35.00			10.10	oa			1.60			32.00			395		2 x 3000	1 x 800	sew 1x1000 + sul 1000	350	270 + 80 up			32.0
PC43b	Kvaerner Fjellstrand	35.00			10.10				1.60						395		2 x 3000	1 x 800	sew 1x1500 + sul 1x800	400	300md + 100ud		32.0	
PC44a	Derecktor / NGA	32.00			8.50				1.50											220-300			28.0	
PC44b	Derecktor / NGA	32.00			8.50				1.50											220-300			38.0	
PC45	Derecktor / NGA	36.70			10.00				1.80											400			32.0	
PC46	Derecktor / NGA	37.70		32.90	10.00	mld			1.80			39.00		143			12000			345	267 + 78 up		35.0	36.5
PC47	Buro J. de Haas	32.20		30.00	9.50	mld	2.75		1.00										20 bike	150			27.0	
PC48	WaveMaster	49.00		42.70	12.00				1.60			60.00					40000	3000		372				40.0
PC49	Austal	30.00		26.25	8.70		3.26	mld	1.11			16.00		65			2 x 3000	1 x 400	sul 1x400	140	133 + 7 up		32.0	
PC50a	Austal	44.00			11.80	mld			2.50											500	272 + (50+84) up + 94 top		28.0	
PC50b	Austal Ships	44.00		40.70	11.80	mld			2.50								10000	3000	sul 1500	504	72 ms + 78 us + 10 vip +50 uae + 94 fdi		30.0	
PC51	FBM	46.25		44.25	11.80	oa			1.35								23000	1000	lo 100	496	338 + 158 up		25.0	28.0
PC52a	FBM	32.90			8.40				1.25											190			33.0	
PC52b	FBM	32.90		29.50	8.32	oa	3.00		1.25						213		2 x 1250	1 x 100	lo 2x100	190			34.0	37.0
PC53	Båtservice	37.15	33.00		10.87	oa	3.90		1.70										erg 14	199			32.0	
PC54	Austal	42.10		37.00	11.50	mld	3.70	mld	1.35								13400	1500		352	232 + (112+8) up		34.0	
PC55	Incat Designs / Gladding Hearn	33.33		28.96	9.22				1.25	2.75							2 x 5300	1 x 380	sul 1x380	147	70 + (29+48) up			34.0
PC56a	Incat Designs / Gladding Hearn	37.07		33.96	9.95				1.60	2.75							2 x 4960			350	184 + ((90+30)+70) up			33.0
PC56b	Incat Designs / Gladding Hearn	37.12		33.96	9.95				1.77	2.75							2 x 4960			350	184 + ((90+30)+70) up		34.0	38.0
PC57a	Derecktor / NGA	45.60		40.15	11.80	mld			1.50					202						304	248 + (52+4) up		50.0	52.0
PC57b	Derecktor / NGA	45.60		40.15	11.80	mld			1.80					202			20000	2000	bw 2000	300	244md + 52ud + 4vip	12	50.0	53.0
PC58	Austal	48.00			13.00	mld			1.40											516	388 + (80+48) up		41.0	
PC59a	Iris	42.77		39.75	13.05	oa			1.80			51.00					7000	1200		240			29.0	
PC59b	Iris	42.77		39.75	13.30	oa			2.00			72.00					8800	1900		398			30.0	
PC60	Lindstøl	33.30			10.30	oa			1.70								2 x 3700	1 x 1000		322	238 + 84 up		36.0	
PC61	Austal	41.75			12.50	mld			1.60											358	199 + 159 up		35.0	
PC62	AMD / Dakota Creek	43.70			12.00	oa			1.50			40.00					13600	1100		358	218 + (132+8) up			37.0
PC63	Austal	47.60		41.60	13.00	mld	4.00	mld	1.40			54.00					16500			330	196 + (54+80) up		38.0	
PC64a	Sabre	25.49		21.92	8.00	oa			1.80								6000	1000		229	169 ms + 60 up		28.0	30.0
PC64b	Sabre (Royal Ferry 2)	25.50		21.90	7.90	mld	2.20		1.70								4000	1000		229	169ms + 60us		28.0	
PC65a	Austal	52.40		45.40	13.00	mld			1.50											366	256 ms + 90 us + 20 vip		34.5	
PC65b	Austal	52.40		45.40	13.00	mld	4.50	mld	1.50			58.00					13500			432	298ms+134us+33ude	12		40.0
PC66a	Sabre (Royal Ferry 1)	22.30		19.80	7.90	mld	1.70		1.50								4000	1000		212	132ms + 30us + 50ud		28.0	
PC66b	Sabre (Makana)	22.30		19.80	7.90	mld	1.70		1.50								4000	1000		146	102ms + 24us + 20ud		28.0	
PC66c	Sabre (Cape of Good Hope)	22.30		19.80	7.90	mld	1.70		1.50								4000	1000		172	117ms + 32us + 23ud		28.0	
PC67	SBF	31.00		26.60	6.50	mld			1.50								5000	1000		224	151ms + 25us +16md + 32ud		32.0	
PC68a	WaveMaster	30.50		25.40	6.50	mld	3.80	mld	0.95			19.40					5000	1000	sul 750	179	127ms + 52us		29.0	30.0
PC68b	WaveMaster	30.50		25.40	6.50	mld	3.80		1.10			17.16					1 x 5000	2 x 500	sul 1x750	176	127ms + 38us + 11VIP	9	29.0	
PC69	Teknicraft	17.70		15.40	6.40	mld			0.76					27			2100			74		2	32.0	38.0
PC70	Allen Marine	30.50		27.10	8.50				0.90					72	80		7600	380		150	106md + 44ud	6	28.0	
PC71	Allen Marine	19.80			6.70				0.90						27		1 x 1825	1 x 210	sew 1x360	110	68md + 30ud + 12ex	4	25.0	
PC72a	Allen Marine	23.80			8.50				0.76						91		2 x 4175	2 x 210		148	108md + 40ud	4	25.0	
PC72b	Allen Marine	23.80			8.50				0.76						91		2 x 4175	2 x 210		148	108md + 40ud	4	28.0	
PC73	Kvaerner Fjellstrand	36.00		31.60	9.60		3.70		1.74						251		2 x 3750	1 x 1500	sew 1x1500	290	221md + 69ud		33.0	
PC74	Kvaerner Fjellstrand	37.60			10.40				1.60			35.00			450		2 x 3500	1 x 1800	sew 1x800	300	220md + 80ud		35.0	37.0
PC75a-b	Kvaerner Fjellstrand	28/29.2			9.00												2 x 1500	1 x 500	lo 1x250 + sew 1x500	201			30.0	
PC76	Kvaerner Fjellstrand	44.00			11.60				1.60								2 x 4000	1 x 1800	sew 1x1000	354			35.5	
PC77	Incat Designs	26.80		23.30	8.40		2.70		1.20			18.40					5300	380	sew 380 + ho 110	150	112ms + 38ude	3		30.0
PC78	Incat Designs	28.10		24.48	9.10	oa	3.17		1.74			28.91					2 x 3975			250	124ms + 56uds + 70ex		25.0	27.0
PC79	Ulstein	36.80		29.80	9.40	oa	3.50		1.25											206	168md + 38ud		37.0	
PC80	WaveMaster	32.00		29.00	8.80	oa	3.00	mld	1.60			30.20	pax 22.5 + f 6.7 + fw 1				8000	1000	sul 1500 + gw 500	300	186mds + 114ude		27.0	
PC81	Aluminium Marine CMCS	18.22		16.55	6.09		2.03		1.43											90	62ms + 18us + 10ude		26.0	
PC82	Aluminium Marine CMCS	21.43		19.45	6.64				1.55								2000	600		125	80ms + 20us + 25ude		25.0	
PC83	Aluminium Marine CMCS	23.43		22.00	7.44		2.40		1.73					35			3000	850		149	90ms + 24us + 35ude		25.0	
PC84	Aluminium Marine CMCS	25.08		23.30	7.44		2.50		1.75					40			3000	500		200	132ms + 68us		28.0	
PC85	Aluminium Marine CMCS	32.31		29.97	8.18		2.75		1.75								10000	1000		274	198ms + 76us		32.0	
PC86	Aluminium Marine CMCS	19.90		18.80	6.40				1.35			7.00		27			2500			100	74ms+26us	2	26.0	
PC87	Allison CMCS Fastcat	23.00		21.20	7.00				1.00					48			7000	1000		90	70ms+20us		30.0	37.0
PC88	Cougar	36.00			9.00				1.20											330		6	33.5	36.5
PC89a	Cougar	24.00			8.00				1.35											150		5	29.0	
PC89b	Cougar	24.00			8.00				1.50											160		5	31.0	
PC90	FBM	41.00		35.00	10.50				1.40			30.80					8000	750	lo 200	302	217ms + 50us + 35ude	4	36.0	
PC91	Incat / Nicholas	43.50		39.70	11.90		4.10		1.90			57.53					2 x 8450	2850	sew 2850	471	253ms + 124us + 48ude + 46sde		35.5	
PC92	Incat Designs / Gladding Hearn	34.10		30.10	9.20		3.00		1.60			34.93								325			31.0	
PC93	Incat Designs / Nicholas	40.00			12.00				1.50											400	342in + 58ex		35.0	
PC94	FBM	35.00		29.50	8.32				1.25			21.00					3400	250		177	144 ms + 48ud	4	33.0	
PC95	Austal Ships	42.16	40.90		12.50	mld			1.80						738		7500	3000	lo 500 + sul 1000	358	199 md + 159 ud	8	34.0	
PC96	Oma Baatbyggeri	24.00			9.00	oa	3.40	mld	1.40						177	3000	1000		lo 150				29.0	
PC97	Oma Baatbyggeri	30.00			10.60	oa	3.50	mld	1.50						340	4000	1000		lo 240				33.5	
PC98	FBM	52.75		47.50	13.00				1.62			67.25	pax + lug 38 , cr 0.75 , f 27 , fw 1.5				27000	1500	sew 1500 + hoil 150 + bil 1000	447	346 ms + 96 us + 5 vip	10	41.0	
PC99	NQEA Australia	37.00		34.00	8.30	mld	2.60	mld	1.60			16.04	pax 11.25 + cr 0.24 + f 3.4 + fw 0.5 + lo 0.045 + pro 0.2 + bike 0.4				4000	1500	sul 500 + doil 50 + 20 bike	148		3	31.0	
PC100	SBF Shipbuilders	32.00		27.00	9.20	mld			1.00								20000	2000	sul 750	110	110 ms	9	34.0	
PC101	Marinteknik Shipbuilders	26.15			8.00	mld	3.20	mld	1.18					72			3000	1000	erg 5	60			26.0	
PC102	FBMA	28.00		25.20	8.50				1.60			20.45	pax 11.7 + lug 1.8 + cr 0.6 + f 5.1 + fw 0.75 + lo 0.2 + str 0.3				2 x 3000	1 x 750	lo 2x100	180		8		28.0
PC103	FBMA	25.00		22.90	8.50				1.50			20.45					2 x 3000	1 x 750	lo 2x100	204	180 ms + 24 ud	4		25.0
PC104	Incat Designs/CFI Designs	46.91	47.00	43.12	11.90				1.65	3.20		58.25	pax 30 + lug 6 + f 20 + fw 2 + lo 0.25							400			40.0	
PC105a	CNB	27.20		23.80	8.50	oa			1.70								10000	1000		206	130 fl + 76 ud	4	27.0	29.0
PC105b	CNB	27.20		23.80	8.50	oa			1.70								10000	1000		206	130 fl + 76 ud	4	28.0	32.0
PC106	OCEA Fast Ferry	41.20	40.00	35.85	11.20	mld	3.90		1.40			42.40			290		10000	2000	lo 450	434	282 md + 152 ud	5	31.0	

Ship Code	SFC	RPM	Range (nm)	Propulsion Plant (kW)	Auxliary Power (kW)	Propulsor	GA	BC million	Page	Source	Fn_{SWL}	Fn_{MWL}	L_{OA}/B	L_{WL}/B	S/L_{WL}	$A_S (m^2)$	$A_S/\rho (m^2)$	$A_P (m^2)$	$A_P/\rho (m^2)$	A_P/A_S	B/T	$L_{WL}*B$	B_H/T	L_{WL}/B_H	$L_{WL}/\nabla^{1/3}$	∇
PC30c				D 2 x 2000			*			FF / IV '97			3.846								7.704					
PC32				D 2 x 1260						FF / VI '96			3.441								5.471					
PC33				D 4 x 600						BWPV '97			3.596								7.746					
PC34a				D 4 x 735			*			FF / XII '96																
PC34b				D 4 x 735			*			FF / XII'98			3.951								4.378					
PC35	1067 lt/h		350	D 2 x 2180	2 x 90		*			FF / III'99	0.880		4.237	3.823							8.741	532.298				
PC36				D 2 x 2000						SB / I-II '97			3.795													
PC37				D 2 x 1360			*			F		1.190	3.750	3.274							7.636	231.000				
PC38				D 2						F		1.050	3.920	3.530							7.407	353.000				
PC39			400	D 2 x 2032			*			FF / I-II '97	0.702	0.783	3.417	3.083							5.455	444.000				
PC40				D 2 x 1415			*			FF / I-II '97			3.366								6.733					
PC41			185	D 4 x 1960			*			FF / IV '97		1.204	3.500	3.000							8.000	432.000			7.202	124.878
PC42				D 4 x 1740			*			FF / V '97			3.833													
PC43a				D 4 x 610			*			FF / V '97			3.465								6.313					
PC43b				D 4 x 610			*			FF / III'99			3.465								6.313					
PC44a				D 2 x 610						FF / V '97			3.765								5.667					
PC44b				D 4 x 610						FF / V '97			3.765								5.667					
PC45				D 4 x 610						FF / V '97			3.670								5.556					
PC46			400	D 2 x 2000			*			FF / V '97	1.002	1.045	3.770	3.290							5.556	329.000			6.343	139.512
PC47				D 2			*			FF / VII-VIII '97	0.810		3.389	3.158							9.500	285.000				
PC48				D 4 x 1939			*			FF / IX '97		1.005	4.083	3.558							7.500	512.400				
PC49				D 2 x 1499			*			FF / IX '97	1.026		3.448	3.017							7.838	228.375			6.583	63.415
PC50a				D 2 x 2000						FF / X '97			3.729								4.720					
PC50b		2000		D 2 x 2000	1 x 100 + 1 x 135	2 prop	*		28_29	FF IX'99	0.772		3.729	3.449							4.720	480.260				
PC51			1250	D 2 x 1210			*			FF / X '97	0.617	0.691	3.919	3.750							8.741	522.150				
PC52a				D 2 x 1500						FF / XI '97			3.917								6.720					
PC52b			120	D 2 x 1500			*			FF / X'98	1.028	1.119	3.954	3.546							6.656	245.440				
PC53				D 4 x 625			*			FF / XII '97			3.418								6.394					
PC54				D 2 x 1980			*			FF / XII '97	0.918		3.661	3.217							8.519	425.500				
PC55			400	D 4 x 1100			*			FF / I-II '98		1.038	3.615	3.141							7.376	267.011	2.200	10.531		
PC56a				D 4 x 955			*			FF / I-II '98		0.930	3.726	3.413							6.219	337.902	1.719	12.349		
PC56b				D 4 x1300			*			FF / XI'98	0.958	1.071	3.731	3.413							5.621	337.902	1.554	12.349		
PC57a				G 2 ~ 5970			*			FF / III '98	1.296	1.348	3.864	3.403							7.867	473.770			6.899	197.073
PC57b				D 2 x 5535	2 x 99		*			FF / I-II'98	1.296	1.374	3.864	3.403							6.556	473.770			6.899	197.073
PC58				D 4 x 2320						FF / III '98			3.692								9.286					
PC59a				D 2 x 1740						FF / III '98	0.755		3.277	3.046							7.250	518.738				
PC59b				D 2 x 2320						FF / III '98	0.781		3.216	2.989							6.650	528.675				
PC60				D 2 x 1500			*			FF / III '98			3.233								6.059					
PC61				D 2 x 2320			*			FF / V '98			3.340								7.813					
PC62				D 4 x 1343		4 wj	*	US$ 9.7	25	FF / V '98 and X'99			3.642								8.000					
PC63				D 4 x 1980			*			FF / V '98	0.968		3.662	3.200							9.286	540.800				
PC64a			400	D 2 x 1350			*			FF / X'98	0.982	1.052	3.186	2.740							4.444	175.360				
PC64b			400	D 2 x 1007	2 x 60kVA		*			FF / XII'98	0.983		3.228	2.772							4.647	173.010				
PC65a		2100		D 4 x 790		4 wj	*		13	FF / XI'98 and X'99	0.841		4.031	3.492							8.667	590.200				
PC65b	1.75 t/h	2000		D 4 x 2320			*			FF / VII-VIII'99		0.975	4.031	3.492							8.667	590.200				
PC66a			350	D 2 x 820			*			FF / XII'98	1.033		2.823	2.506							5.267	156.420				
PC66b			350	D 2 x 820			*			FF / XII'98	1.033		2.823	2.506							5.267	156.420				
PC66c			350	D 2 x 820			*			FF / XII'98	1.033		2.823	2.506							5.267	156.420				
PC67				D 3 x 610	2 x 37.5kVA		*			FF / XII'98	1.019		4.769	4.092							4.333	172.900				
PC68a			250	D 3 x 660			*			FF / XII'98	0.945	0.978	4.692	3.908							6.842	165.100				
PC68b	501 lt/h		250/ 95%fuel	D 3 x 660			*			FF / III'99	0.945		4.692	3.908							5.909	165.100				
PC69	258lt/h		300(28kn)	D 2 x 515			*			FF / I-II'98	1.339	1.590	2.766	2.406							8.421	98.560			5.208	25.854
PC70				D 4 x 560	1 x 35					FF / I-II'98	0.883		3.588	3.188							9.444	230.350			6.568	70.244
PC71	330lt/h			D 4 x 319	1 x 30		*			FF / I-II'98			2.955								7.444					
PC72a	450 lt/h			D 4 x 412	1 x 30					FF / I-II'98			2.800								11.184					
PC72b	450 lt/h			D 4 x 450	1 x 30					FF / I-II'98			2.800								11.184					
PC73				D 4 x 788	2 x 48		*			FF / III'99	0.964		3.750	3.292							5.517	303.360				
PC74				D 2 x 2012	2 x 48		*			FF / III'99			3.615								6.500					
PC75a-b				D 2 x 960	2 x 60		*			FF / III'99																
PC76				D 4 x 1050	2 x 100		*			FF / III'99			3.793								7.250					
PC77				D 2 x 788			*			FF / IV'99		1.021	3.190	2.774							7.000	195.720				
PC78	405 lt/hr	2300	500	D 2 x 783	2 x 40		*			FF / V'99	0.830	0.896	3.088	2.690							5.230	222.768				
PC79		13000		GT 2 x 2300			*		43	FF / V'99	1.113		3.915	3.170							7.520	280.120				
PC80	482lt/hr	1800	400	D 2 x 1016	2 x 40kVA	2 prop	*		46 and 13	FF / VI'99 and XI'99	0.823		3.636	3.295							5.500	255.200				
PC81				D 2 x 395			*		47	FF / VI'99	1.050		2.992	2.718							4.259	100.790				
PC82		2100		D 2 x 507	1 x 25kVA				47	FF / VI'99	0.931		3.227	2.929							4.284	129.148				
PC83		2100	200	D 2 x 507			*		47	FF / VI'99	0.875		3.149	2.957							4.301	163.680			6.781	34.146
PC84		1810		D 2 x 895			*		47	FF / VI'99	0.953		3.371	3.132							4.251	173.352			6.869	39.024
PC85		2100		D 4 x 790			*		47	FF / VI'99	0.960		3.950	3.664							4.674	245.155				
PC86		2100	250	D 2 x 358	1 x 25kVA				48.000	FF / VI'99	0.985		3.109	2.938							4.741	120.320			6.318	26.341
PC87			300	D 2 x 790			*		49	FF / VI'99	1.070	1.320	3.286	3.029							7.000	148.400			5.882	46.829
PC88				D 4 x 801					49	FF / VI'99			4.000								7.500					
PC89a		2100		D 2 x 787						FF / VI'99			3.000								5.926					
PC89b				D 2 x 801					50	FF / VI'99			3.000								5.333					
PC90	1052 lt/hr	2000		D 2 x 2320	2 x 65 at 1800rpm		*		50	FF / VI'99	0.999		3.905	3.333							7.500	367.500				
PC91		1835		D 4 x 1460	2 x 105 at 1800rpm		*		51	FF / VI'99	0.925		3.655	3.336							6.263	472.430				
PC92				D 4 x 716			*		52	FF VII-VIII'99	0.928		3.707	3.272							5.750	276.920				
PC93		2000		D 2 x 2320						FF VII-VIII'99			3.333								8.000					
PC94	740 lt/hr	1900	160	D 2 x 1738	2.0		*			FF VII-VIII'99	0.998		4.207	3.546							6.656	245.440				
PC95		2000		D 2 x 2320	2 x 135 at 1300rpm		*	NOK 1.3	15-18	FF IX'99			3.373								6.944					
PC96		2100		D 2 x 670	2 x 37				20_21	FF IX'99			2.667								6.429					
PC97		2100		D 2 x 670	2 x 37		*		20_21	FF IX'99			2.830								7.067					
PC98	2800 lt/h	13000		GT 2 x 4208	2 x 100 at 1500 rpm	2 wj	*		30_32	FF IX'99	0.977		4.058	3.654							8.025	617.500				
PC99		2100		D 2 x 960	1 x 65	2 prop	*		35_36	FF IX'99	0.873		4.458	4.096							5.188	282.200				
PC100		2100		D 4 x 790		4 wj	*	US$ 4	21	FF X'99	1.075		3.478	2.935							9.200	248.400				
PC101			200	D 2 x 910		2 wj	*		34	FF XII'99			3.269								6.780	0.000				70.244
PC102		2300		D 2 x 820		prop	*		10	FF I-II'00		0.916	3.294	2.965							5.313	214.200				
PC103				D 2			*		11	FF I-II'00		0.858	2.941	2.694							5.667	194.650				
PC104				D 4 x 1960		4 wj			28	FF XI'99	1.000		3.942	3.624							7.212	513.128	1.939	13.475		
PC105a		1880		D 2 x 870	2 x 16				59	FF I-II'00	0.909	0.976	3.200	2.800							5.000	202.300				
PC105b		1800		D 2 x 1210	2 x 24				59	FF I-II'00	0.943	1.077	3.200	2.800							5.000	202.300				
PC106	920 lt/h	1835	365	D 2 x 1939	120 kVA at 1500 rpm	2 wj			22	FF III'00	0.850		3.679	3.201							8.000	401.520				

Ship Code	Des./Cons./Yard	L_{OA} (m)	L_{BP} (m)	L_{WL} (m)	B (m)		D (m)		T (m)	DWT (t)	Δ (t)	GRT	Fuel (lt)	Fresh Water (lt)	Other Capacities (lt) / Weights (t)	Pax	Pax Distribution	Crew	Cars	V_S (kn)	V_M (kn)	SFC	RPM
VM1	Pelmatic	71.30	60.40	60.40	11.30	mld			2.10				25000	7500		450			43	33.0 / 34.0			
VM2	Marinteknik	85.00		75.15	15.00				3.00	300						584			104	35.0	36.0		
VM3	Pelmatic	100.00	87.50	87.50	17.30	mld			3.50						fo 90 + fw 7.5	650			170	34.0			
VM4	Pelmatic	125.00	114.50	114.50	17.30	mld			5.10							750			180	34.0			
VM5a	Fincantieri	118.00	106.00	106.00	19.40	oa	11.80		3.40		2350					900			334	40.0	42.0		
VM6a	Fincantieri	95.00	82.00	82.00	16.00		4.60		2.60	400+						600			173	36.0			
VM7a	Bazan	124.70		109.80	18.70	oa	11.20		2.50		1810				fo 70/450 + fw 8	1250			246	38.0	40.0		
VM7b	Bazan	124.70		109.80	18.70	oa	11.20		2.50							1250			244	38.0			
VM8	FFM / Rodriquez	141.84		122.70	21.10		12.20		3.11 / 3.43	706 / 1185	2700 / 3179					1500			425	36.0 / 34.0	35.5 / 37.5		
VM9	JSC Meteor	100.00		86.00	16.40	oa			2.40	525	1250					540			112	55.0 / 60.0			
VM10a	Mjellem & Karlsen	95.00	86.45	88.90	17.40	mld	6.00		3.65	500		4675/1402	196000	27000	lo 7000 + sew 20000 + bw 183000	626			160	35.0			
VM10b	Mjellem & Karlsen	95.00	86.45	88.90	17.40	mld	6.00		3.60							600			160	33.0	38.0		
VM10c	Mjellem & Karlsen	95.00	86.45	88.90	17.40				3.60	500		4000				600			160	33.0	35.0		
VM11a	Mjellem & Karlsen	115.00		101.68	17.40	mld	6.00		3.70							800			210	33.0			
VM11b	Mjellem & Karlsen	115.00		101.68	17.40	mld	6.00		3.70							800			210	40.0			
VM12	Mjellem & Karlsen	135.00		119.36	20.00	mld			4.10							1200			400	30.0			
VM13a	Fincantieri	100.00	88.00	88.00	17.10	mld	10.70		2.75	340						800			175	37.8	40.0		
VM14	Royal Schelde	128.00		115.00	18.40/18.00		7.00		2.80 / 4.00				85000	7000	lo 3500 + sew 7000 + bil 10000	778			234	37.5			
VM15a	Fincantieri	82.00	72.00	72.00	14.00		8.50			170						450			70	32.0			
VM15b	Fincantieri	82.00	72.00	72.00	14.00		8.50			170						450			70	39.0			
VM16a	Fincantieri	96.50	83.80	83.80	16.00		10.50			320 / 400						650			175	31.5			
VM16c	Fincantieri	96.00			16.20	mld	10.50		2.90	400						800			188	35.0	37.0		
VM17	Fincantieri	143.10	128.60	128.60	22.00		12.60			775 / 930						1500			420	36.8			
VM18a	Royal Schelde	135.00		119.36	17.50				3.30	400						750			156	35.0			
VM18b	Royal Schelde	135.00		119.36	17.50				3.30	400						750			156	38.0			
VM19	Marinteknik	86.00		76.04	14.30		5.00		3.50							550			130	35.0			
VM20	Bazan	129.00		115.35	21.50				2.90							1000			375		39.0		
VM21	I H I	199.00		175.95	25.00											515			203	29.4			
VM22	Schischau Seebeckwerft	173.70	158.00	165.40	24.00	mld	8.80		6.25	5240			1 350 000	300 000	do 90000 + bw 1 270 000	1400				26.8			
VM23	Rodriquez	101.75		85.30	14.50				2.12	233	1033					450			150	43.0			
VM24a	Bazan	96.00		84.88	14.60						1070					450			116	34.0			
VM24b	Bazan	96.00		84.88	14.60						1070					600			84	34.0			
VM24c	Bazan	96.00		84.88	14.60						1070					450			113	41.0			
VM25	Bazan	122.50		108.31	18.70				2.40							750			170		43.0		
VM26	Royal Schelde	90.00		78.25	15.00				2.10							400			144	37.0			
VM5b	Fincantieri	120.00	106.00	106.00	19.00	oa	11.50		3.50	850						900			310	40.0			
VM5c	Fincantieri	120.00	106.00	106.00	19.00	oa	11.50		3.50	850						900			310	33.0			
VM6b	Fincantieri	94.00	82.00	82.00	16.50	oa	10.25		2.70	260						450 - 600			150	40.0			
VM6c	Fincantieri	94.00	82.00	82.00	16.50	oa	10.25		2.70	245						450 - 600			150	36.0			
VM6d	Fincantieri	94.00	82.00	82.00	16.50	oa	10.25		2.70	245						450 - 600			150	33.0			
VM7c	Bazan	124.70		109.80	18.70	oa	6.20		2.44		1840		70000/490000			1250	828 + 422 up		238	38.0			
VM7d	Bazan	125.00	110.00		18.70		11.30		2.70	448-574						1200			219	36.5			
VM13b	Fincantieri	100.00	88.00		17.10	mld	10.70		2.60							782			175	38.0	40.0		
VM15c	Fincantieri	82.00	72.00	72.00	14.00		9.25		2.20							600			70	40.0	44.0		
VM27a	Fincantieri	146.00	128.60	128.60	22.00		12.60		3.60	800 / 1200						1800			460	40.0			
VM27b	Fincantieri	145.60	128.60		22.00		12.60			805-1200		10200				1800			450	40/33/22	(4+2/4+1/4)		
VM28	Leroux & Lotz	102.00		87.50	15.00	mld	5.20		3.05	200 - 320	1100		84000	8000		500			148	37.0			
VM29	Leroux & Lotz	137.00		122.50	21.00	mld	6.20		3.20	750			130000	16000		1000			308	42.0			
VM30	Rodriquez	103.50		87.00	14.50	oa	9.50		2.30	280	1170		89000			507			150	35.0	37.0		
VM31	Finnyards	150.00			20.00				4.00	1500						600			130	35-40			
VM32a	Fincantieri	128.00	112.20	112.20	19.40	mld	12.20			600						1000			308	40.0	42.0		
VM32b	Fincantieri	128.00	112.20		19.40	mld	12.20			600						1200			300	42.0	40.0		
VM33	Finnyards	100.00	89.40	89.40	16.00	mld	6.10		3.00	310 / 450						600			160	34.0			
VM34	Leroux & Lotz	66.00	58.00	58.00	10.90	mld			2.00	92-120			26000	8000		450			42	30.0			
VM35	Leroux & Lotz	72.00			11.10				2.10	102-130			30000	10000		450			50	32.0			
VM36	Samsung	99.50														630			160	35.0			
VM37	Leroux & Lotz	112.00	100.00		15.00	mld	5.40		2.50	360-450						700			140	35.0			
VM38	Finnyards	100.00			16.40				3.00	310						600			160	35-40			
VM39	C. M. N.	73.00			13.00	oa			2.00							500			15	34-37			
VM40a	Rodriquez	70.90		64.00	12.40	oa	8.60		2.45	200	625		46000			550			57		35.0		
VM40b	Rodriquez	70.90		64.00	12.40	oa	8.60		2.30		562		1x16000			520	364 md + 156 ud		57	28.5	32.0	517gkw/hr	
VM41	Samsung	99.50														630			160		35.0		
VM42	Fincantieri	112.00			17.10	mld	11.00		3.00							1000			200	42.0	44.0		
VM43	Mitsubishi	100.56			14.90		10.30		2.70			1498				423			106		42.4		
VM44	Tenix Fast Ferry designs	106.00			18.00		6.50		4.00	2000			100000	10000		448-650			153	40.0			1000
VM45	Cantiere Navale De Poli	95.00	86.50		16.80	mld	10.30	mld	2.55	400						803	607 md + 196 ud	22	170	28.0			1200
VM46	Alstom Leroux Naval	140.00	126.00		21.80		6.2/14.9		3.80	1300						1800		22	450	40.0			
VM47	Van Der Giersen AMD	142.00	123.70		22.00				2.60	1365						1400				42.0			3600
VM48	Rodriquez Cantieri Naval	75.30		63.90	13.50		9.00		1.65							598	414 md + 184 ud		80	36.0			
VM49	Rodriquez Cantieri Naval	127.00		107.25	19.10		11.30		2.60							1300			306	37.0			

Ship Code	Range (nm)	Propulsion Plant (kW)	Auxiliary Power (kW)	Propulsor	GA	Page	Source	Fn_{SWL}	Fn_{MWL}	L_{OA} / B	L_{WL} / B	A_S (m^2)	A_S/p (m^2)	A_P (m^2)	A_P/p (m^2)	A_P / A_S	A_V (m^2)	A_V/v(m^2)	B / T	L_{WL} * B	∇	$L_{WL}/\nabla^{1/3}$
VM1		4 x 2300					FF / III '95	0.698/0.717		6.310	5.345								5.381	682.520	573.317	7.271
VM2	750	D 3			*		FF / IV '95	0.663	0.682	5.667	5.010	680.000	1.164	787.000	1.348	1.157	1393.000	13.394	5.000	1127.250	1352.700	6.795
VM3		4 x 6000					FF / IV '95	0.597		5.780	5.058								4.943	1513.750	2119.250	6.812
VM4		G 1 x 21000 + D 2 x 6000					FF / IV '95	0.522		7.225	6.618								3.392	1980.850	4040.934	7.189
VM5a	500	G 2 x 21000 + D 2 x 6000					FF / V '95	0.638	0.670	6.082	5.464								5.706	2056.400	2796.704	7.524
VM6a	300	D 4 x 6000			*		FF / V '95	0.653		5.938	5.125	523.000	0.872	863.000	1.438	1.650	1685.000	9.740	6.154	1312.000	1364.480	7.393
VM7a	300	D 6 x 5800			*		FF / V '95	0.596	0.627	6.668	5.872	1172.000	0.938	1437.000	1.150	1.226	2377.000	9.663	7.480	2053.260	2053.260	8.639
VM7b		D 6 x 5650			*		NA / XI '95	0.596		6.668	5.872	1494.000	1.195	2026.000	1.621	1.356	2377.000	9.742	7.480	2053.260	2053.260	8.639
VM8	290 / 300	G 1 x 21000 + D 4 x 6000			P		FF / VI '95	0.534/0.504	0.526/0.556	6.722	5.815								6.78/6.15	2588.970	3220.679	8.309
VM9	1300	G 4 x 15000			*		FF / VII-VIII '95	0.974/1.063		6.098	5.244	941.000	1.743	1279.000	2.369	1.359	1556.000	13.893	6.833	1410.400	1353.984	7.774
VM10a		D 4 x 5800			+		FF / IX '95	0.610		5.460	5.109	647.000	1.034	917.000	1.465	1.417	1959.000	12.244	4.767	1546.860	2258.416	6.776
VM10b		D 4 x 5800					FF / IX '95	0.575	0.662	5.460	5.109								4.833	1546.860	2227.478	6.807
VM10c		D 4 x 5800			*		SB / VII-VIII '94	0.575	0.610	5.460	5.109	789.000	1.315	972.000	1.620	1.232	1959.000	12.240	4.833	1546.860	2227.478	6.807
VM11a		D 4 x 5800					FF / IX '95	0.538		6.609	5.844								4.703	1769.232	2618.463	7.377
VM11b		G					FF / IX '95	0.652		6.609	5.844								4.703	1769.232	2618.463	7.377
VM12							FF / IX '95	0.451		6.750	5.968								4.878	2387.200	3915.008	7.573
VM13a		D 4 x 6875			*		FF / XII '95	0.662	0.700	5.848	5.146								6.218	1504.800	1655.280	7.439
VM14		D 4 x 6875			*		FF / I-II '96	0.574		7.033	6.319	843.000	1.084	1190.000	1.530	1.412	2820.000	12.051	6.500	2093.000	2318.400	8.689
VM15a		D 2 x 5600					FF / I-II '96	0.619		5.857	5.143									1008.000		
VM15b		D 4 x 4200					FF / I-II '96	0.755		5.857	5.143									1008.000		
VM16a		D 4 x 5650					FF / I-II '96	0.565		6.031	5.238									1340.800		
VM16c	300	4 x 6500 / D 4 x 7080 / D 4 x 7200					FF / X'98			5.926									5.586			
VM17		D 2 + G 1 ~ 54000					FF / I-II '96	0.533		6.505	5.845									2829.200		
VM18a		D 4 x 7380 / G 2 x 14800					FF / I-II '96	0.526		7.714	6.821								5.303	2088.800	2757.216	8.512
VM18b		G 2 x 18900					FF / I-II '96	0.571		7.714	6.821								5.303	2088.800	2757.216	8.512
VM19		D 4					FF / I-II '96	0.659		6.014	5.317								4.086	1087.372	1522.321	6.610
VM20	360 - 400	G 2 x 20800 + D 2 x 5000			*		SB / V '94	0.000	0.596	6.000	5.365	1140.000	1.140	1584.000	1.584	1.389	4225.000	11.267	7.414	2480.025	2876.829	8.110
VM21		D 2 x 23850					NA / III '95	0.364		7.960	7.038									4398.750		
VM22		D 4 x 7920			*		NA / IV '95	0.342		7.238	6.892								3.840	3969.600	9924.000	7.697
VM23	370 / 680	G 1 x 20500 + D 2 x 3565			*		SB / XI '93	0.765		7.017	5.883	503.000	1.118	690.000	1.533	1.372	1449.000	9.660	6.840	1236.850	1048.849	8.395
VM24a		D 4 x 5000					SB / V '94	0.606		6.575	5.814									1239.248	1043.902	8.367
VM24b		D 4 x 5000					SB / V '94	0.606		6.575	5.814									1239.248	1043.902	8.367
VM24c		G 1 x 20800 + D 2 x 5000					SB / V '94	0.731		6.575	5.814									1239.248	1043.902	8.367
VM25		G 1 x 20800 + D 2 x 5000					SB / V '94	0.000	0.679	6.551	5.792								7.792	2025.397	1944.381	8.678
VM26		D 4 x 6000			*		SB / I-II '95	0.687		6.000	5.217	499.000	1.248	677.000	1.693	1.357	1450.000	10.069	7.143	1173.750	985.950	7.862
VM5b	300 - 500	G 2 + D 2 ~ 54000			*		D	0.638		6.316	5.579								5.429	2014.000	2819.600	7.503
VM5c	300 - 500	D 6 x 6000			*		D	0.527		6.316	5.579								5.429	2014.000	2819.600	7.503
VM6b	300 - 500	G 1 + D 2 ~ 28200			*		D	0.726		5.697	4.970								6.111	1353.000	1461.240	7.226
VM6c	300 - 500	D 4 x 6000			*		D	0.653		5.697	4.970								6.111	1353.000	1461.240	7.226
VM6d	300 - 500	D 4 x 5250			*		D	0.599		5.697	4.970								6.111	1353.000	1461.240	7.226
VM7c	300 / 1700	D 6 x 5650			*		FF / XII '96	0.596		6.668	5.872								7.664	2053.260	1795.122	9.035
VM7d	300	D 6 x 5650			*		FF / IV '97			6.684									6.926			
VM13b		D 4 x 6875			*		FF / VI '97			5.848									6.577			
VM15c	300	D 4 x 4000			P		B	0.774	0.852	5.857	5.143								6.364	1008.000		
VM27a	300	G 2 x 21000 + D 4 x 6500					FF / III,IV '96	0.579		6.636	5.845								6.111	2829.200	2716.032	9.217
VM27b		G 2 x 21000 + D 4 x 6500			*		FF / VII-VIII '97			6.618												
VM28	300 / 700	D 4 x 6000/6500			*		FF / VII-VIII '96	0.650		6.800	5.833								4.918	1312.500	1260.000	8.101
VM29		G 2 x 25000 + D 2 x 6000			*		FF / VII-VIII '96	0.623		6.524	5.833								6.563	2572.500	3292.800	8.234
VM30		D 4 x 6000			*		FF / IX '96	0.616	0.651	7.138	6.000								6.304	1261.500	1160.580	8.279
VM31		D 6 x 7000					FF / IV '97			7.500									5.000			
VM32a					*		F	0.620	0.651	6.598	5.784									2176.680		
VM32b		D 2 x 21000					FF / X'98			6.598												
VM33		D 4 x 6500					F	0.591		6.250	5.588								5.333	1430.400		
VM34		D 4			*		F	0.647		6.055	5.321								5.450	632.200		
VM35		D 4 ~ 10300			*		F			6.486									5.286			
VM36		D 4 x 7080			*		NA / VI '97															
VM37	500	D 4 x 7080			*		FF / IV '97			7.467									6.000			
VM38		D 4 x 6500					FF / IV '97			6.098									5.467			
VM39		D 4 x 3250-4000			*		FF / VI '97			5.615									6.500			
VM40a	280	D 4 x 2350					FF / VI '97		0.719	5.718	5.161								5.061	793.600	609.756	7.547
VM40b	330	D 4 x 2350			*		FF / I-II'99	0.585	0.657	5.718	5.161								5.391	793.600	548.293	7.819
VM41		D 4 x 7080					SB / XI '97															
VM42	300	G 2 x 15000					FF / X'98			6.550									5.700			
VM43		D 4 x 6500			*		HIPER			6.749									5.519			
VM44	400	D 5 x 7080				6	FF / X'99			5.889									4.500			
VM45	500+	D 3 x 5400			*	32	FF / XI'99			5.655									6.588			
VM46		GT 2 x 25 MW + D 2 x 8100		4 wj		19	FF / III'00			6.422									5.737			
VM47	400	GT 3 x 22 MW			*	27	FF / III'00			6.455									8.462			
VM48		D 3 x 3900		3 wj		23	FF / III'00	0.740		5.578	4.733								8.182	862.650		
VM49		D 6 x 6500		5 wj		23	FF / III'00	0.587		6.649	5.615								7.346	2048.475		

Ship Code	Des./Cons./Yard	L_{OA} (m)	L_{BP} (m)	L_{WL} (m)	B (m)		D (m)		T (m)	b (m)	S (m)	DWT (t)	DW Distribution (t)	Δ (t)	GRT	Fuel (lt)	Fresh Water (lt)	Other Capacities (lt), Weights (t)	Pax	Pax Distribution	Crew	Cars	V_s (kn)
VC1a	Incat Australia	70.40		63.94	19.50	oa			2.20										450			63	
VC1b	Incat Australia	70.36		63.90	19.50	oa	5.65		2.10	5.00	13.75	142							294			53	45.0
VC1c	Incat Tasmania / A.M.D	71.00		64.49	19.50	oa			2.20										450			65	
VC2a	Incat Australia	78.00		71.37	19.50	oa			2.10										750			32	47.0
VC2b	Incat Australia	78.40		71.94	19.50	oa			2.18			742							750			30	47.0
VC2c	Incat Tasmania / A.M.D.	78.00		71.37	19.50	oa													750			32	47.0
VC2d	A.M.D. / Incat	78.70		72.01	19.50	oa						123				35000	2500		769			32	50.0
VC2e	Incat Australia / A.M.D.	79.25		72.30	19.50	oa			2.16	5.00		123				35000 / 100000	2000	sul 2500 + do 1000	769			32	49.0
VC3	Royal Schelde	76.60		68.00	22.15	oa	7.20		3.00 / 3.25	6.30	10.45	360				92000	4000	lo 500 + sew 4000	620			152	36.0
VC4a (S)	Danyard	76.10		62.95	23.40	mld			3.36			250				2 x 25000	2 x 5000	fo 36 + fw 10	450			120	43.6
VC5	WaveMaster	52.50		45.90	16.80	mld			2.00							30000	16000		450			46	32.0
VC6	Westamarin	58.00		49.80	16.80	mld	5.90	mld	2.60		13.00				2000	20000	3000		600			54	37 - 43
VC7	Westamarin	75.00		64.35	25.50	mld	9.20	mld	3.40		19.65				4000	40000	6000		964			187	35 - 40
VC8a	Kvaerner Fjellstrand	60.00		54.65	16.50	oa	5.70	mld	2.15			140							450			52	30 - 45
VC9	Kvaerner Fjellstrand	60.00		52.77	19.90	oa	6.67	mld	2.10			170							450	(cars) 68 + 26 up		94	30 - 45
VC10	Incat Designs	85.58		80.53	23.20				3.00			372.7							794			190	36.0
VC11	JSC Meteor	120.00		105.54	36.00	oa			2.60			1433		3500					1500			440	37.0
VC12	Mitsui	50.00		43.98	14.00	oa									380				300			30	40.0
VC13	Mitsui	56.00		49.25	17.00	oa									699				350			44	31.0
VC14	Mitsui	83.00		73.00	19.20	oa									1400				400			60	42.0
VC15	Mitsui	88.00		77.40	21.60	oa									2200				400			80	36.0
VC16	Kvaerner Fjellstrand	59.20		54.00	16.50				2.90							2 x 15000	1 x 3000	lo 1x1000 + sew 1x3000 + sul 1x500 + 15 con	437			46	33.0
VC17	Oceanfast	44.00		40.10	12.50		3.70	mld	1.50							14000	1500		255	110 + 145 up		12	28.0
VC18	Oceanfast	44.70		41.10	12.50		3.70	mld	2.20							14000	1500		404	262 + 142 up		18	28.0
VC19	Oceanfast	55.00		48.30	15.00		4.30	mld	1.50							22000	1500		296	296 up		31	35.0
VC20	Oceanfast	59.00		51.30	18.50		4.30	mld	1.80							35000	5000		296	296 up		70	30.0
VC21a (S)	Ferries Australia	82.30		69.00	23.00	mld	6.50	mld	2.50 / 3.20	5.05	13.85					2 x 30000	2 x 2000		600			175	36.0
VC22a	Incat Australia	58.10		52.80	14.46	oa			1.80	4.00		77.1 / 102.4				18000	2000	lo 1000 + do 1000 + sul 2500	351			30	36.0
VC22b	Incat Australia	58.10		52.80	14.46	oa			1.80	4.00		77.1 / 102.4				18000	2000	lo 1000 + do 1000 + sul 2500	351			42	34.0
VC22c	Advanced Multihull Designs	59.43		52.80	14.46	mld			1.40	4.00		76.6 / 102.4				2 x 4200 / 18000	2000	lo 1000 + bil 200 + sul 2000	351			30	39.0
VC23a	Ferries Australia	78.60		68.50	23.00	mld			2.50 / 3.10	5.05	17.35	300			4859	2 x 30000	2 x 2000		600			163	34.0
VC23b	Austal	78.60		68.50	23.00	mld	7.00	mld	2.40	4.25	18.90					2 x 30000	2 x 2000		600			184	
VC23c	Ferries Australia	78.60		68.50	23.00	mld			2.40		19.10	150 / 350							600			184	40.0 / 36.0
VC24a	Ferries Australia	95.00		88.80	27.00	mld	7.50	mld	2.50 / 3.20							2 x 40000	2 x 3000		1000			241	
VC24b	Ferries Australia	93.60		78.90	27.00	mld			2.50		21.80	250 / 500							1000			252	37.0 / 34.0
VC25	WaveMaster	44.00		38.60	12.00				1.75 / 2.40	3.25	8.75							crg 24	236	128 + 66 up + 30 up1 + 12 VIP		10	28.0
VC26a	Incat Designs	122.00		96.20	24.80				3.80			531							1000			250	37.0
VC27 (W)	Daewoo	40.25		35.40	9.30	mld			1.50										280			8	38.0
VC28	Daewoo	78.00		68.60	16.40														600	114 + 166 up		60	35.0
VC29	Art Anderson Associates	45.00		40.25	12.40				2.00	2.05	9.05								375			28	30.0
VC30	Austal	75.60		66.85	23.00	mld			2.20 / 4.00					850		20000	2000		400			82	40.0
VC31a	Austal	59.90		50.30	18.00	mld	5.50	mld	2.00	3.75	14.40					35000	3000		442			109	
VC1d	Incat Tasmania / A.M.D.	70.40			19.50				2.15			142				35000	2000		436			56	45.0
VC3b	Royal Schelde	76.60		68.00	22.00		7.20		3.60							2 x 45000	4000	lo 2x500 + sew 4000 + bil 2x7500 + sul 2x1000	600			154	33.0 / 31.0
VC4b (S)	Danyard	76.10		66.93	23.40	mld													450			120	43.6
VC4c (S)	Danyard	76.10		66.93	23.40	mld													550			110	42.5
VC4d (S)	Danyard	76.10		66.93	23.40	mld													600			110	41.0
VC4e (S)	Danyard	76.12			23.40		8.05					236							450			120	40.8
VC8b	Kvaerner Fjellstrand	60.00			16.50		5.85	mld	2.53			135				2 x 15000	3000	lo 500 + sew 3000 + sul 1000	428			52	36.0
VC8c	Kvaerner Fjellstrand	60.00			16.80		5.85	mld	2.53			135				2 x 30000	1 x 5000	lo 1x500 + sew 1x1500 + sul 1x1000	450			49	38.0
VC8d	Kvaerner Fjellstrand	60.00			16.80	oa	5.85	mld	2.53			175				2 x 30000	10000	lo 1x500 + sew 1x1500 + sul 1x1000	450			49	38.0
VC21b	Ferries Australia	82.30		69.00	23.00	mld	6.50	mld	2.85						5333	2 x 30000	4000	fw 2000 + lo 2x300 + ho 2x100 + sew 2000	600			175	37.5
VC21c	Austal	82.30		70.70	23.00	mld	6.70	mld	2.80			340							900			175	38.5
VC26b	CFI	122.50		96.00	25.80	oa	6.60	mld	3.90	6.00		535		1816		2 x 35000	7000		1000	694 md + 276 ud + 48 uc	27	250	34.0
VC31b	Austal	59.90		51.20	17.50	mld	6.65	mld	3.35			173				24000	2000		450			94	33.8
VC32a	Marinteknik	55.00		48.37	15.00				2.00							12000			440	146+242+52		42	32.0
VC32b	Marinteknik	55.00			15.00	mld			2.00										400	340 + 60 up		48	38.0
VC32c	Marinteknik	55.00			15.00	mld			2.00							4 x 7500	2 x 3000	sew 1 x 2000	380	128bs + 188 as +64us		48	38.0
VC33	Almaz/Agat/Sukhoi	74.00		65.08	25.00	oa	4.00												850			220	36.0
VC34	Almaz/Agat/Sukhoi	80.00		70.36	23.00	oa	4.00												800			200	45.0
VC35	Westamarin	81.10		71.33	27.00	mld	8.50		3.70			450				60000			700			200	32 - 43
VC36	Westamarin	91.30		80.30	32.00	mld	10.50		4.00			600			9000	140000			1000			270	40 - 46
VC37	Westamarin	103.30		90.85	32.00	mld	10.50		4.50			850			12000	140000			1250-1500			310	36 - 45
VC38 (S)	Westamarin / Stena	88.00		77.40	30.00	mld	12.60		3.70			450			8650	104000			900			212	40.0
VC39 (S)	Danyard	56.80		49.96	18.00	mld													325			60	34.0
VC40 (S)	Danyard	76.80		67.55	25.10	mld													600			180	40.0
VC41 (S)	Danyard	96.00		84.43	28.00	mld													750			240	42.0
VC42a	Bazan / A.M.D.	77.34		69.96	19.46				2.15							35000	2000		450	70 + 380 up		52	57.0
VC42b	Bazan / AMD	77.32		69.94	19.00	oa			2.13	5.65		142		721	1737				446			52	
VC43	IHI	153.50			27.50		8.50		3.50			750			11000				1000			350	36.0
VC44	IHI	199.90			29.80		10.50		4.90			2500			18000				500			100	37.0
VC45 (S)	RITS	110.00	105.00		36.00		14.50		4.50			1140		4100					1500			320	40.0
VC46	A.M.D.	59.43			14.46	oa			1.60			130				18000	2000	lo 1000	350			52	40.0
VC47	Finnyards	113.00		95.00	29.00	mld	10.00		3.90										1000			300	40.0
VC48	Finnyards	130.00			40.00	mld	12.50		4.40			1500							1500			375	40.0
VC49	Finnyards	77.00			23.10				2.50			340							700			180	35-40
VC50	Finnyards	107.00			28.40				3.20			580							1100			290	35-40
VC51a	Kvaerner Fjellstrand	46.00			12.00	oa						57				2 x 10000	1 x 1500	sew 1x1500 + sul 500	360	145 + 162 up		12	
VC51b	Kvaerner Fjellstrand	46.00			12.00	oa						57				2 x 10000	1 x 1500	sew 1x1500 + sul 500	220	145 + 162 up		25	
VC51c	Kvaerner Fjellstrand	46.00			12.00	oa						50				2 x 12000	1 x 1500	sul 1x500	308			12	38.0
VC52	Hyundai		80.00		20.80														800			92	
VC53	Daewoo			70.00								328							600			175	34.0
VC54	Samsung	83.50			23.00														600			175	38.0
VC55	Austal	47.60		41.60	13.00	mld	4.00	mld	1.40			54				16500			329			10	
VC56	Mitsubishi	101.00			14.90		10.30		2.70						1498				423	cars 76 + 30 up		106	35.0
VC57	Ferries Australia	86.60		74.20	24.00		7.30	mld	3.65			340-400				70000	4000	lo 1000 + ho 400 + bw-gw 4000 + bil 1000 + sul 50	800			200	37.0
VC58	CNM	43.10		40.10	10.40		4.10	mld	1.44			60				13000			150			30	30.0
VC59	IHI	72.09			12.90	mld	4.50	mld	2.05					204	1680				430	325 + 105 up		51	
VC60	Incat / Afai	80.10		72.30	19.00	oa			2.20	5.00		178				4 x 12000	1 x 2500	lo 1000 + sul 1x2500 + obil 300	398			89	

Ship Code	V_M (kn)	SFC	RPM	Range (nm)	Propulsion Plant (kW)	Auxiliary Power (kW)	Propulsor	GA	Page	Source	$Fn_{S/WL}$	$Fn_{M/WL}$	L_{OA} / B	L_{WL} / B	S / L_{WL}	A_S (m^2)	A_S/p (m^2)	A_P (m^2)	A_P/p (m^2)	A_P / A_S	A_V (m^2)	A_V/v(m^2)	B / T	L_{WL} * B	B_H / T	L_{WL} / B_H	$L_{WL}/\nabla^{1/3}$	∇
VC1a	55.0				D 4 x 5310					FF / I-II '95		1.130	3.610	3.279									8.864	1246.830				
VC1b	50.0				D 4 x 5420			*		FF / III '95	0.925	1.027	3.608	3.277	0.215	373.000	1.269	642.000	2.184	1.721	536.000	10.113	9.286	1246.050	2.381	12.780	9.906	536.76
VC1c	55.0				D 4 x 5310					SB / I-II '95		1.125	3.641	3.307									8.864	1257.555				
VC2a	51.0				D 4 x 5420					FF / I-II '95	0.914	0.992	4.000	3.660									9.286	1391.715				
VC2b	50.0				D 4 x 5420					FF / III '95	0.910	0.968	4.021	3.689									8.945	1402.830				
VC2c	51.0				D 4 x 5310					SB / I-II '95	0.914	0.992	4.000	3.660										1391.715				
VC2d	52.7				D 4 x 5420					SB / XI '95	0.968	1.020	4.036	3.693										1404.195				
VC2e	53.0			300	D 4 x 5420			*		FF / XII '95	0.947	1.024	4.064	3.708		667.000	0.867	1011.000	1.315	1.516	400.000	12.500	9.028	1409.850	2.315	14.460	10.656	624.67
VC3				300	D 4 x 5700					FF / IV '95	0.717		3.458	3.070	0.154	726.000	1.171	987.000	1.592	1.360	2017.000	13.270	7.380	1506.200	2.100	10.794	8.489	######
VC4a (S)	46.4			240	G 2 x 12400			*		FF / IV '95	0.903	0.961	3.252	2.690		782.000	1.738	1314.000	2.920	1.680	1469.000	12.242	6.964	1473.030				
VC5					D 4 x 1940					FF / IV '95	0.776		3.125	2.732									8.400	771.120				
VC6					11000 - 16000			*		FF / IV '95	0.861 - 1.001		3.452	2.964	0.261	386.000	0.858	669.000	1.487	1.733	655.000	12.130	6.462	836.640				
VC7					22000 - 30000			*		FF / IV '95	0.717 - 0.819		2.941	2.524	0.305	984.000	1.021	1292.000	1.340	1.313	2183.000	11.674	7.500	1640.925				
VC8a					D 2 / D 4 / G 2					FF / VI '95	0.667 - 1.000		3.636	3.312									7.674	901.725				
VC9					D 2 / D 4 / G 2					FF / VI '95	0.678 - 1.018		3.015	2.652									9.476	1050.123				
VC10	39.0			350	D 4 x 5500					FF / VI '95	0.659	0.714	3.689	3.471									7.733	1868.296				
VC11	40.0			700	G 4 x 15000					FF / VII-VIII '95	0.592	0.640	3.333	2.932									13.846	3799.440			8.830	######
VC12					4 x 2647					FF / VII-VIII '95	0.991		3.571	3.141										615.720				
VC13					2 x 3897					FF / VII-VIII '95	0.726		3.294	2.897										837.250				
VC14					4 x 3897					FF / VII-VIII '95	0.807		4.323	3.802										1401.600				
VC15					4 x 3897					FF / VII-VIII '95	0.672		4.074	3.583										1671.840				
VC16					D 2 x 5400			*		FF / VII-VIII '95	0.738		3.588	3.273		358.000	0.819	498.000	1.140	1.391	648.000	14.087	5.690	891.000				
VC17	30.0			200	D 2					FF / VII-VIII '95	0.726	0.778	3.520	3.208									8.333	501.250				
VC18	30.0			200	D 2					FF / VII-VIII '95	0.717	0.769	3.576	3.288									5.682	513.750				
VC19	37.0			350	D 4					FF / VII-VIII '95	0.827	0.875	3.667	3.220									10.000	724.500				
VC20	32.0			450	D 4					FF / VII-VIII '95	0.688	0.734	3.189	2.773									10.278	949.050				
VC21a (S)					D 4 x 6000			*		FF / IX '95	0.712		3.578	3.000	0.201	815.000	1.358	1118.000	1.863	1.372	2144.000	12.251	9.200	1587.000	2.020	13.663	9.805	696.90
VC22a					D 2 x 4320					FF / XII '95	0.814		4.018	3.651									8.033	763.488	2.222	13.200	9.892	304.13
VC22b					D 2 x 4320					FF / XII '95	0.769		4.018	3.651									8.033	763.488	2.222	13.200	9.892	304.13
VC22c				100	D 2 x 5420					FF / I-II '96	0.882		4.110	3.651		270.000	0.769	380.000	1.083	1.407	476.000	11.333	10.329	763.488	2.857	13.200	10.757	236.54
VC23a					D 4 x 5500			*		FF / XII '95	0.675		3.417	2.978	0.253	534.000	0.890	943.000	1.572	1.766	1344.000	8.245	9.200	1575.500	2.020	13.564	9.758	691.85
VC23b					D 4			*		D			3.417	2.978	0.276	541.000	0.902	931.000	1.552	1.721	1205.000	6.549	9.583	1575.500	1.771	16.118	10.477	558.96
VC23c	42.0 / 38.0				D 4 x 5500			*		D	0.794 / 0.715	0.834 / 0.754	3.417	2.978	0.279	599.000	0.998	871.000	1.452	1.454	1286.000	6.989	9.583	1575.500				
VC24a										FF / XII '95			3.519	3.289									10.800	2397.600				
VC24b	39.0 / 36.0				D 4 x 6000			*		D	0.684 / 0.629	0.721 / 0.666	3.467	2.922	0.276	1232.000	1.232	1665.000	1.665	1.351	3155.000	12.520	10.800	2130.300				
VC25	29.0			540	D 2 x 2000			*		FF / XII '95	0.740	0.767	3.667	3.217	0.227	192.000	0.814	241.000	1.021	1.255	129.000	12.900	6.860	463.200	1.857	11.877	8.684	175.63
VC26a					D 4					FF / XII '95	0.620		4.919	3.879									6.526	2385.760				
VC27 (W)	40.0				D 2 x 2000					SB / I-II '95	1.049	1.104	4.328	3.806									6.200	329.220				
VC28					D 2 x 5420					SB / I-II '95	0.694		4.756	4.183										1125.040				
VC29					D 2 x 2700			*		SB / XI '95	0.777		3.629	3.246	0.225	382.000	1.019	494.000	1.317	1.293	395.000	14.107	6.200	499.100	1.025	19.634	9.959	132.02
VC30								*		D	0.804		3.287	2.907		503.000	1.258	673.000	1.683	1.338	1112.000	15.444	10.450	1537.550			8.965	829.27
VC31a					D 2			*		D			3.328	2.794	0.286	386.000	0.873	681.000	1.541	1.764	750.000	6.881	9.000	905.400	1.875	13.413	9.448	301.80
VC1d	50.0				D 4 x 5420			*		F			3.610										9.070					
VC3b	(36 LS)			310	D 4 x 5700			*		FF / VI '96													6.111	1496.000				
VC4b (S)	46.4				G ~ 24800					FF / IX '96	0.875	0.931	3.252	2.860										1566.174				
VC4c (S)					D/G ~ 24800					FF / IX '96	0.853		3.252	2.860										1566.174				
VC4d (S)					D/G ~ 24800					FF / IX '96	0.823		3.252	2.860										1566.174				
VC4e (S)	46.4				G 2 x 12400					BWPV '97			3.253															
VC8b					D 2 x 7200			*		FF / X'98			3.636										6.522					
VC8c					D 2 x 7200	2 x 240		*		FF / III'99			3.571										6.640					
VC8d			1050		D 2 x 7200	2 x 240	2 wj	*	16	FF I-II'00			3.571										6.640					
VC21b	40.2			350	D 4 x 6000			*		FF / VI '96	0.741	0.795	3.578	3.000									8.070	1587.000				
VC21c	41.0				D 4 x 6500			*		SB / I-II '98	0.752	0.801	3.578	3.074									8.214	1626.100				
VC26b	37.0		1250	360	D 4 x 6500	4x 190 kW at 1800 rpm		*	19	FF XI'99	0.570	0.620	4.748	3.721									6.615	2476.800	1.538	16.000	7.934	######
VC31b	35.5				D 2 x 6500			*		FF / IX '97	0.776	0.815	3.423	2.926									5.224	896.000				
VC32a				180	D 4 x 2000			*		FF / III,IV '96	0.756		3.667	3.225									7.500	725.594				
VC32b					G 2 x 2840 + D 2 x 2000			*		FF / VII-VIII '97			3.667										7.500					
VC32c					G 2 x 2840 + D 2 x 2000			*		FF / XII'98			3.667										7.500					
VC33				300	D 2 x 6500					FF / III,IV '96	0.733		2.960	2.603										1627.089				
VC34				400	G 2 x 25000					FF / III,IV '96	0.881		3.478	3.059										1618.294				
VC35				450	D4 / G2 ~ 20000-34000					FF / III,IV '96			3.004	2.642									7.297	1925.858				
VC36				500	G2 ~ 35000-52000			*		FF / III,IV '96			2.853	2.509									8.000	2569.569				
VC37				500	G2 ~ 35000-52000					FF / III,IV '96			3.228	2.839									7.111	2907.300				
VC38 (S)				400	G 2 x 17000			*		FF / III,IV '96	0.747		2.933	2.580									8.108	2321.900				
VC39 (S)					D ~ 12400					FF / IX '96	0.790		3.156	2.775										899.208				
VC40 (S)					G ~ 24800					FF / IX '96	0.799		3.060	2.691										1695.409				
VC41 (S)					G ~ 32000					FF / IX '96	0.751		3.429	3.015										2364.116				
VC42a	60.0				G 2 x 16100			*		FF / XII '96	1.119	1.178	3.974	3.595									9.051	1361.422				
VC42b	56.0			200	G 2 x 16100			*		FF / XII '97		1.100	4.069	3.681									8.920	1328.860	2.653	12.379	7.864	703.41
VC43				400	G 2 x 20600 + 2 x 5150					NA			5.582										7.857					
VC44				300	G 4 x 20600					NA			6.708										6.082					
VC45 (S)					G 4 x 17000					NA / IV '97			3.056										8.000					######
VC46					D 4 x 5440			*		F			4.110										9.038					
VC47					D 2 x 6000 + G 2 x 21500					F	0.674		3.897	3.276									7.436	2755.000				
VC48					G 2 x 21500 + G 2 x 14915					F			3.250										9.091					
VC49					D 4 x 6500					FF / IV '97			3.333										9.240					
VC50					D 2 x 6500 + G 2 x 17000					FF / IV '97			3.768										8.875					
VC51a	38.0				D 4 x 1740			*		FF / V '97			3.833															
VC51b	38.0				D 4 x 1740			*		FF / V '97			3.833															
VC51c					D 4 x 2000			*		FF / VI '98			3.833															
VC52	60.0							*		SB / XI '97																		
VC53					D 4 x 5650					SB / XI '97	0.667																	
VC54					D 4 x 6500					SB / XI '97			3.630															
VC55	39.0				D 4 x 1980			*		FF / VII-VIII '97		0.993	3.662	3.200									9.286	540.800				
VC56	42.0				D 4 x 6500			*		FF / IX '97			6.779										5.519					
VC57				350	D 4 x 6500			*		FF / IX '97	0.705		3.608	3.092									6.575	1780.800				
VC58					D 2 x 2088			*		FF / XI '97	0.778		4.144	3.856									7.222	417.040				
VC59	30.0				D 2 x 3925			*		FF / VI '98			5.588										6.293					199.02
VC60	48.0			440	D 4 x 5500			*		FF / X'98		0.927	4.216	3.805									8.636	1373.700	2.273	14.460		

Ship Code	Des./Cons./Yard	L_{OA} (m)	L_{BP} (m)	L_{WL} (m)	B (m)		D (m)		T (m)	h (m)	S (m)	DWT (t)	DW Distribution (t)	Δ (t)	GRT	Fuel (lt)	Fresh Water (lt)	Other Capacities (lt), Weights (t)	Pax	Pax Distribution	Crew	Cars	V_S (kn)
VC62	Royal Schelde	85.00		76.80	24.40	mld	7.20		3.30			400				124000	14000	lo 1800 + sew 5000 + bil 15000 + sul 2000	1100	762md + 226udb + 112ud1	30	200	41.0
VC63	Incat Designs	72.65		68.00	17.20	oa			2.20							26500			303	235md + 68ud		65	40.0
VC64a	Austal Auto Express	86.60		74.20	24.00	mld	7.30	mld	3.20			400				162000			768	618md + 150ud	30	203	40.0
VC64b	Austal Auto Express	86.60		74.10	24.00	mld	7.80	mld	3.65			500				140000	20000	lo 900 + sew 20000	1037	653 ms + 384 us	30	186	41.0
VC65	Kvaerner Fjellstrand	49.00			12.50	mld	4.65	mld	1.95			50				2 x 12000	1500	sew 1500 + sew trt 2400 + rosm 500 + bil-sul 500	408	131ms + 277us		21	37.5
VC66	Kvaerner Fjellstrand	73.40			22.50							220				2 x 23000	6000	sew 1500	509			145	
VC67	Austal Auto Express	72.00			17.50														620			70	42.0
VC68	Austal Auto Express	92.00			24.00							470							1050			188	42.0
VC69	Oma Baatbyggeri	24.50			9.00	oa	3.40	mld	1.40						154	3000	1000	lo 150	84			3_4	28.0
VC70	Oma Baatbyggeri	30.00			10.60	oa	3.50	mld	1.50						304	5000	1250	lo 220	185			3_4	34.0
VC71	Austal Ships	86.80		74.20	24.00	mld	7.30	mld	3.20			400				162000	4000	lo 0.87 + sul 4000	800		30	200	40.0
VC72	Tenix Fast Ferry Designs	60.00		56.60	15.80				2.50										1000		67		
VC73	Incat / CFI Designs	55.10	54	49.00	13.00					3.30		120	pax 21.6 + lug 4.3 + veh 50 + f 30 + fw 5 + lo 1						288			40	52.0
VC74	Incat / CFI Designs	72.65	72	68.00	17.20		6.18	mld	2.53	4.25		183	pax 24.4 + lug 4.9 + f 20 + fw 3 + lo 1						325			77	38.0
VC75	FBM Marine	71.00		66.00	17.00				1.60										500-600		22	50-70	46.0
VW1	Kawasaki	99.78		88.93	19.98	mld	7.30		3.10	5.60	14.40	570			2200				460			94	30.0
VW2a	Incat Australia	81.15		66.30	26.00				3.00	4.33	21.90	310		1050		2 x 16400 / 2 x 104200	5400	lo 2x470 + sul 2x2000 + edo 500	677			181	37.0
VW2b	Incat Tasmania	81.15		66.30	26.00	oa			3.00	4.33		300		1100		2 x 16400 / 2 x 104200	5400	lo 2x470 + sul 2x2000 + edo 500	693	436 + 257 up		180	39.0
VW3	Incat Australia	83.85		71.63	26.00				3.05	4.45		330		1150		2 x 16400 / 2 x 104200	5400	lo 2x470 + sul 2x2000 + edo 500	777			200	38.0
VW4	Incat Designs	92.90		83.40	29.62				3.27	4.94	24.65	409							800			225	37.0
VW5	Incat Designs	78.21		73.46	19.10				2.50			190							452	314 + 138 up		72	49.0
VW6	Samsung	80.00		77.55	19.50														600			55	35.0
VW7	Incat/Hitachi	62.00			15.40	mld	10.8/5.4	mld	2.30			140			860/835				296	284 + 12 up		48	30.0
VW8	A.M.D.	94.80			27.10				2.70			440				70000	10000		888			238	40.0
VW9a	Incat	91.30		81.33	26.00				3.70	4.33		400				50000 / 292000			900			240	
VW9b	Incat Tasmania	91.30		81.30	26.00	oa	6.80	mld	3.70	4.30		400				58000 / 292000	5000	lo 1600 + sul 5000	876	470 + 406 up		240	43.0
VW10	Incat Tasmania	86.62		76.41	26.00	oa	6.75	mld	3.50	4.33				1165		4 x 15250 / 2 x 245000	5000	lo 2 x 820 + sul 5000	776	450 + 326 up		200	40.0
VW11	A.M.D.	102.10		86.00	22.40	oa			3.00			450				70000	10000		1250	838 + 412 up		244	42.0
VW12a	CFI	95.50		89.60	22.60	oa			2.90			432							770			204	
VW12b	Incat / CFI	95.50		89.60	22.60	oa			2.90			432							780			223	
VW12c	Incat / CFI Designs	95.50	95	89.50	23.00				2.70	5.70		425	pax 58.5 + lug 11.7 + f 27.8 + fw 7 + lo 3						780			176	41.0
VW12d	Incat / CFI Designs	95.50	95	89.50	22.60				2.90	5.70		500	pax 60 + lug 15 + f 40 + fw 10 + lo 3						800			174	52.0
VW13a	CFI	109.50		96.00	28.30	oa			3.90			544							1000			227	
VW13b	Incat / CFI	109.50		96.00	28.30	oa			3.80	6.50		560	pax 75 + lug 15 + f 45 + fw 7 + lo 6						1000			250	38.0
VW14a	Incat Tasmania	120.00	102.50	117.50	29.00	oa			4.80	4.70		1200				4 x 50000 / 2 x 1700000	2 x 5	sew 1x1500	1200			460	51.0
VW14b	Incat Tasmania / Revolution	120.00	102.3	117.50	30.00				4.70	4.70		1200				200000			1200			460	50.0
VW15	Incat Tasmania	96.00	86.30	86.00	26.20	oa			3.70	4.50		800				4 x 30000 / 2 x 170000	1 x 5	sew 1x5000	735		20	230	37.5
VW16	Incat Evolution	96.00		86.00	26.00	oa			3.70			675+				4x30000	1x5000	sew 1x5000	850		50	265	
VW17	Incat Tasmania Evolution	97.20		92.00	26.60	oa			3.40	4.50		750				4 x 40000, 2 x 170000	1x5000	sew 1x5000	900			260	
VS1	Mitsui	39.50		31.57	13.20	oa									570				200			20	32.0
VS2	Mitsui	64.00		51.16	20.00	oa									1600				400			62	31.0
VS3	NQEA	81.00		64.75	23.40				3.40			330							600			180	40.0
VS4	NQEA	109.00		85.30	31.50				4.40	5.35	25.15	600							1100			320	40.0
VS5 (C)	Ferries Australia	82.00		68.15	23.00				2.60	5.15	17.90								600			175	36.0
VS6	Schischau Seebeckwerft	54.60		47.40	23.40							250							600			90	36.0
VS7	NTUA	51.50		37.60	31.70		9.46		5.00	3.80	24.40	226		1060	2544 / 763				752			84	30.0
VS8	NTUA	58.00		46.25	31.40		9.50		4.92	3.80	24.40	314		1051					500 - 696			100	40.0
VS9	Finnyards / Stena	126.60	107.50		40.00	mld	12.50		4.50			1500				224000	20000	do 11 + lo 13 + sew 16 + sul 4 + bil 15 + bw 1725	1500			375	40.0
VSE1	Oceanfast / Ulstein	55.00		48.15	15.00		4.30	mld	1.50							22000	1500		300			31	35.0
VS10	Almaz/Agat/Sukhoi	53.20			19.20	oa	3.70					155				57600	3500		400			60	35.0
VS11	SWATH International	75.50			31.00	oa			6.00										876			250	37.0
VS12	SWATH International	39.50			18.60	oa			3.80										550			31	26-34

Ship Code	V_M (kn)	SFC	RPM	Range (nm)	Propulsion Plant (kW)	Auxiliary Power (kW)	Propulsor	GA	Page	Source	$Fn_{S/WL}$	$Fn_{M/WL}$	L_{OA} / B	L_{WL} / B	S / L_{WL}	A_S (m^2)	A_S/p (m^2)	A_P (m^2)	A_P/p (m^2)	A_P / A_S	A_V (m^2)	A_V/v(m^2)	B / T	L_{WL} * B	B_H / T	L_{WL} / B_H	$L_{WL}/\nabla^{1/3}$	∇
VC62	47.0				D 4 x 7200	4 x 280		*		FF / I-II'98	0.768	0.881	3.484	3.148									7.394	1873.920				
VC63		3323 lt/hr		325	D 4 x 3300	2 x 170		*		FF / IV'99	0.797		4.224	3.953									7.818	1169.600				
VC64a	42.0	5.3 t/h			D 4 x 7200			*		FF / IV'99	0.763	0.801	3.608	3.092									7.500	1780.800				
VC64b		7.4 t/h	3600		GT 2 x 18MW		4 wj	*	16	FF / III'00	0.782		3.608	3.088									6.575	1778.400				
VC65		2169lt/hr	2000		D 4 x 2320	2 x 135		*	45	FF / VI'99			3.920										6.410					
VC66	36.0				D 4 x 18000	2 x 235		*	45	FF / VI'99			3.262															
VC67	45.0				D 4				52	FF VII-VIII'99			4.114															
VC68	45.0				D 4					FF VII-VIII'99			3.833															
VC69			2100		D 2 x 610	2 x 27			20_21	FF IX'99			2.722										6.429					
VC70			2100		D 2 x 670	2 x 37		*	20_21	FF IX'99			2.830										7.067					
VC71	42.0	5.3 t/h	1050		D 4 x 7200	4 x 240 at 1500 rpm		*	22_24	FF IX'99	0.763	0.801	3.617	3.092									7.500	1780.800				
VC72								*	6	FF X'99			3.797	3.582									6.320	894.280				
VC73					D 4 x 2925		4 wj		28	FF XI'99	1.220		4.238	3.769										637.000		14.848		
VC74					D 4 x 3300		4 wj		28	FF XI'99	0.757		4.224	3.953									6.798	1169.600	1.680	16.000		
VC75					D 4 or GT 4				20	FF / III'00	0.930		4.176	3.882									10.625	1122.000				
VW1					D 2 x 5420 + D 2 x 4060			*		FF / III '95	0.523		4.994	4.451	0.162								6.445	1776.821	1.806	15.880		
VW2a					D 4 x 5500			*		FF / XII '95	0.746		3.121	2.550	0.330	712.000	1.052	890.000	1.315	1.250	1947.000	10.757	8.667	1723.800	1.443	15.312	8.286	######
VW2b	40.0				D 4 x 5500			*		FF / VI '96	0.787	0.807	3.121	2.550									8.667	1723.800	1.443	15.312	6.476	######
VW3					D 4 x 6875					FF / XII '95	0.738		3.225	2.755									8.525	1862.380	1.459	16.097	8.685	######
VW4	39.0				D 4 x 6190			*		FF / XII '95	0.666	0.702	3.136	2.816	0.296	956.000	1.195	1519.000	1.899	1.589	2800.000	12.444	9.058	2470.308	1.511	16.883		
VW5	52.0				D 4 x 6500					FF / XII '95	0.939	0.997	4.095	3.846									7.640	1403.086				
VW6					D 4 x 5000			*		FF / V '95	0.653		4.103	3.977		585.000	0.975	807.000	1.345	1.379	874.000	15.891		1512.225				
VW7	32.0				D 4 x 2023			*		FF / VI '97			4.026										6.696					
VW8	46.0				D 4 x 7200			*		F			3.498										10.037					
VW9a	43.0				D 4 x 7080			*		F		0.783	3.512	3.128									7.027	2114.580	1.170	18.783		
VW9b					D 4 x 7080			*		FF / IV '97	0.783		3.512	3.127									7.027	2113.800	1.162	18.907		
VW10	44.0				D 4 x 7080			*		FF / III '97	0.752	0.827	3.332	2.939									7.429	1986.660	1.237	17.647	7.322	######
VW11					D 4 x 7200 + 2 x 4060			*		FF / IV '97	0.744		4.558	3.839									7.467	1926.400				
VW12a	44.0				26000					B		0.763	4.226	3.965									7.793	2024.960				
VW12b	44.0				D 4 x 6500			*		FF / VI '98		0.763	4.226	3.965									7.793	2024.960				
VW12c					D 4 x 6500		4 wj		28	FF Nov'99	0.712		4.152	3.891									8.519	2058.500	2.111	15.702		
VW12d					GT 4 x 24400		2 wj		28	FF Nov'99	0.903		4.226	3.960									7.793	2022.700	1.966	15.702		
VW13a	42.0				36000					B		0.704	3.869	3.392									7.256	2716.800				
VW13b					D 4 x 8275		4 wj	*	28	FF / VI '98 and XI'99	0.637		3.869	3.392									7.447	2716.800	1.711	14.769		
VW14a					G 4 x 13124 / 15633 / 17370	2 x 230 + Turbines		*		FF / XII'98	0.773		4.138	4.052									6.042	3407.500	0.979	25.000		
VW14b				1000	GT 4 x 13000				18	FF X'95	0.758		4.000	3.917									6.383	3525.000	1.000	25.000		
VW15	38.0			232	D 4 x 7080	4 x 230		*		FF / IV'99	0.664	0.673	3.664	3.282									7.081	2253.200	1.216	19.111		
VW16	38.0	7000- 6300 lt/h	1030	700+	D 4 x 7200	4 x 230		*	17	FF VII-VIII'99 and X'99		0.673	3.692	3.308									7.027	2236.000				
VW17	38.0				D 4		4 wj	*	9	FF I-II'00		0.651	3.654	3.459									7.824	2447.200	1.324	20.444		
VS1					2 x 3897					FF / VII-VIII '95	0.936		2.992	2.392										416.724				
VS2					4 x 5368					FF / VII-VIII '95	0.712		3.200	2.558										1023.200				
VS3					G 2					FF / XII '95	0.817		3.462	2.767									6.882	1515.150				
VS4					G 2			*		FF / XII '95	0.711		3.460	2.708	0.295								7.159	2686.950	1.216	15.944		
VS5 (C)					D 4 x 6000			*		SB / XI '95	0.716		3.565	2.963	0.263	815.000	1.358	1118.000	1.863	1.372	2144.000	12.251	10.450	1567.450	2.341	13.233		
VS6					G 2 x 10000			*		SB / XI '93	0.859		2.333	2.026		671.000	1.118	809.000	1.348	1.206	1599.000	17.767		1109.160				
VS7				360	D 4 x 3676			*		D	0.804		1.625	1.186	0.649	481.000	0.640	540.000	0.718	1.123	751.000	8.940	6.340	1191.920	0.760	9.895	4.685	######
VS8	42.5			500	G 2 x 14915			*		D	0.966	1.027	1.847	1.473	0.528	926.000	1.852	1356.000	2.712	1.464	1425.000	14.250	6.382	1452.250	0.772	12.171	5.779	######
VS9					G 2 x 13500 + G 2 x 20500			*		FF / III,IV '96			3.165										8.889					
VSE1	37.0			350	D 4			*		FF / III '95	0.829	0.876	3.667	3.210									10.000	722.250				
VS10				400	D 2 x 6000			*		FF / III,IV '96			2.771															
VS11					G 2 x 21500			*		F			2.435										5.167					
VS12								*		F			2.124										4.895					

APPENDIX II

A2. COMPUTER PROGRAM FOR CONCEPT DESIGN OF A FAST FERRY

A2.1. BACKGROUND

As part of the research a number of computer programs have been created to implement the preliminary design stages of fast ferries. Four main separate programs which estimated the main dimensions, main power, masses and costs of each vessel types (four types of vessel, namely passenger-only monohull, vehicle-passenger monohull, passenger-only catamaran and vehicle-passenger catamaran) have been developed. Each estimation method has been explained in detail in this thesis. The following table summarises all the inputs and outputs of each program.

PROGRAM	INPUTS	OUTPUTS
Dimension	N_{PAX}, N_{CAR}, V_S, V_{TYPE}, C_B, B/T, S/L, B_H/T, $L/\nabla^{1/3}$	L_{OA}, L_{WL}, B, b, T, D_{OA}, S, A_S, A_P, Δ_1.
Power	Outputs from "Dimension", V_{TYPE}, E_{TYPE}, N_E, V_S, RPM	P_D, P_E, P_I.
Mass	Outputs from "Dimension" and "Power", N_{PAX}, N_{CAR}, V_{TYPE}, E_{TYPE}, V_S, N_E, R, N_{CREW}, N_{DECK}.	W_H, W_O, W_M, W_{PAX}, W_{FUEL}, W_{FWPROV}, W_{CREW}, LS, DW, Δ_2.
Cost	Outputs from "Mass", N_{PAX}, N_{CAR}, V_S.	C_H, C_O, C_M, BC, ABC.

Table A2.1: Early Computer Programs Description.

A2.2. GENERAL DESCRIPTION

Research entailed modifying and combining all programs into one major program to create new designs efficiently and easily. This program inputs and outputs all the variables listed in the above table within one unique run. Table A2.2 displays all the inputs and outputs of this whole program. As shown in the relevant table, the user can select the number of passengers, cars, service speed, type of the vessel, type of the main engine and some variables at the beginning of each run.

PROGRAM	**INPUTS**	**OUTPUTS**
Pre-Fast	N_{PAX}, N_{CAR}, V_S, V_{TYPE}, E_{TYPE}, N_E, RPM, N_{DECK}, N_{CREW}, R, $L/\nabla^{1/3}$, B/T, B_H/T, S/L, C_B.	L_{OA}, L_{WL}, B, b, T, D_{OA}, S, A_S, A_P, P_D, P_E, P_I, W_H, W_O, W_M, W_{PAX}, W_{CAR}, W_{FUEL}, W_{FWPROV}, W_{CREW}, BC, ABC, LS, DW, Δ_1, Δ_2.

Table A2.2: Computer Program "Pre-Fast" Description.

The program is especially designed for very simple use where the process can be repeated as much as it is necessary. At the end of each run the program is designed to display all the inputs and outputs into a sheet, which can then be printed out.

It is important to mention how the mass balance study is included in the program. At the end of the each run the program assesses the final outcomes namely DISP1 and DISP2. This procedure has been detailed in chapter 2 under the name of mass balance. If there is no balance between these two variables, which means DISP1 and DISP2 have more than 1% of a difference, then the program asks the user to choose whether to carry on with a non balanced design or to create a mass balance. If the user chooses to create a mass balance the program follows the procedure detailed in chapter 2, and builds a mass balance between these two variables. If not, the run ends up with no mass balance.

Passenger comfort is another issue to point out. There are two variables which alter the passenger comfort, these are $\mathbf{A_S/N_{PAX}}$ and $\mathbf{A_P/A_S}$. These variables can be changed with a quick alteration in the code. The ranges of these variables are mentioned in chapter 2, and by staying within these ranges they can be modified for different passenger comforts.

The computer program has been written in FORTRAN language. A full listing of the source code is included at the end of this appendix. The meanings of all the abbreviations can be found in the nomenclature of this thesis.

CODE "PRE-FAST"

```
      PROGRAM ESTI OF DIME POWER MASS COST
      CHARACTER *1 YESNO,YN
      CHARACTER *2 VTYPE,ETYPE
      COMMON/ONE/LOA,LWL,B,S,BH,T,D,CB,DISP1,WME,WP,WGB,WM,CME,CP,CGB,
     $
CM,WO,CO,WH,CH,BC,WFUEL,WFWPROV,WCREW,WPAX,WCAR,DW,DISP2,VS,SOL,
     $ LOD,WSA,FN,RN,CFM,CFS,FN1,FN2,FN3,CR1,CR2,CR3,CR4,CR5,CR6,CR7,
     $ CR8,CR9,D1,A,B1,C,CR,CRS2,k,bk,CTS,RTS,PE,PD,PI,EFF,N,ABC,
     $
AJ,AKT,AKQ,DIAM,RPM,NPAX,NCAR,NCREW,AS,AP,NDECK,NE,R,BHOT,BOT,LS
      COMMON/TWO/VTYPE,ETYPE
      REAL
NPAX,NCAR,NCREW,AS,AP,AV,LB,LWL,LOA,B,D,BH,T,S,DISP1,LOD,BOT,
     $ CB,PB,RPM,R,VS,LOB,LOBH,LOBH1,SOL,BHOT,NE,NDECK,PI,PE,PD,FN,RN,
     $ CO,WSA,CFM,CFS,FN1,FN2,FN3,CR1,CR2,CR3,CR4,CR5,CR6,CR7,CR8,CR9,
     $
D1,A,B1,C,CR,CRS2,k,bk,CTS,RTS,EFF,n,AJ,AKT,AKQ,DIAM,DISP2,LS,ABC
500   WRITE (*,*) ' '
      WRITE (*,*) ' **************************************'
      WRITE (*,*) ' PRELIMINARY DERIVATION OF DIMENSIONS'
      WRITE (*,*) ' ESTIMATIONS OF POWERING, MASSES AND COSTS'
      WRITE (*,*) ' FOR ADVANCED FAST FERRIES'
      WRITE (*,*) ' **************************************'
C---------------------------------------------------------------------
--
C-----INPUT REQUIREMENTS
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT NUMBER OF PASSENGERS. '
      READ (*,*) NPAX
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT NUMBER OF CARS. '
      READ (*,*) NCAR
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT SERVICE SPEED OF THE VESSEL (kn).'
      READ (*,*) VS
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT VESSEL TYPE (PM/VM/PC/VC): '
      WRITE (*,*) ' PM=PASSENGER-ONLY MONOHULL,        '
      WRITE (*,*) ' VM=VEHICLE-PASSENGER MONOHULL,     '
      WRITE (*,*) ' PC=PASSENGER-ONLY CATAMARAN,       '
      WRITE (*,*) ' VC=VEHICLE-PASSENGER CATAMARAN.    '
      READ (*,520) VTYPE
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT MAIN ENGINE TYPE: '
      WRITE (*,*) ' (D=DIESEL ENGINE  T=GAS TURBINE). '
      READ (*,520) ETYPE
      IF ((ETYPE.EQ.'D').OR.(ETYPE.EQ.'d')) THEN
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT NUMBER OF ENGINES AND THEIR SPEED (RPM). '
      READ (*,*) NE,RPM
      ELSE
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT NUMBER OF ENGINES. '
      READ (*,*) NE
      ENDIF
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT THE NUMBER OF DECKS. '
      WRITE (*,*) ' Majority: passenger-only vessels 2,     '
```

```
      WRITE (*,*) '          vehicle-passenger vessels 3. '
      READ (*,*) NDECK
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT NUMBER OF CREW. '
      READ (*,*) NCREW
      WRITE (*,*) ' '
      WRITE (*,*) 'INPUT RANGE OF THE VESSEL (nmiles). '
      READ (*,*) R
C-----------------------------------------------------------------------
--
C-----DERIVATION OF DIMENSIONS FOR PASSENGER-ONLY MONOHULLS
      IF ((VTYPE.EQ.'PM').OR.(VTYPE.EQ.'pm')) THEN
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT LENGTH-DISPLACEMENT RATIO: '
      WRITE (*,*) ' Majority: passenger-only monohulls     5.5-6.5,   '
      READ (*,*) LOD
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT BREADTH-DRAUGHT RATIO: '
      WRITE (*,*) ' Majority: passenger-only monohulls     4.0-6.5,   '
      READ (*,*) BOT
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT BLOCK COEFFICIENT: '
      WRITE (*,*) ' Majority: passenger-only monohulls  0.35-0.45.'
      READ (*,*) CB
      AS=0.6*NPAX
      AP=1.15*AS
      LB=146.0+(1.86E-3*(AP**2.0))
      LOB=SQRT(((LOD**3.0)*CB)/BOT)
      LWL=(LB*LOB)**0.5
      LOA=1.14*LWL
      B=LWL/LOB
      T=B/BOT
      D=4.0+(0.6*B)
      DISP1=1.025*LWL*B*T*CB
      WRITE (*,*) ' '
      WRITE (*,*) ' DERIVATION OF DIMENSIONS       '
      WRITE (*,*) ' ----------------------- metres '
      WRITE (*,*) ' '
      WRITE (*,560) LOA
      WRITE (*,561) LWL
      WRITE (*,562) B
      WRITE (*,563) T
      WRITE (*,564) D
      WRITE (*,565) CB
      WRITE (*,566) DISP1
 560  FORMAT ('  OVERALL LENGTH:           ',F10.2)
 561  FORMAT ('  WATERLINE LENGTH:         ',F10.2)
 562  FORMAT ('  BREADTH:                  ',F10.2)
 563  FORMAT ('  DRAUGHT:                  ',F10.2)
 564  FORMAT ('  DEPTH:                    ',F10.2)
 565  FORMAT ('  BLOCK COEFFICIENT:        ',F10.2)
 566  FORMAT ('  DISPLACEMENT1:            ',F10.2)
C-----------------------------------------------------------------------
-
C-----DERIVATION OF DIMENSIONS FOR VEHICLE-PASSENGER MONOHULLS
      ELSEIF ((VTYPE.EQ.'VM').OR.(VTYPE.EQ.'vm')) THEN
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT LENGTH-DISPLACEMENT RATIO: '
      WRITE (*,*) ' Majority: vehicle-passenger monohulls  7.0-8.5.'
      READ (*,*) LOD
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT BREADTH-DRAUGHT RATIO: '
      WRITE (*,*) ' Majority: vehicle-passenger monohulls  4.5-6.5. '
```

```
        READ (*,*) BOT
        WRITE (*,*) ' '
        WRITE (*,*) ' INPUT BLOCK COEFFICIENT: '
        WRITE (*,*) ' Majority: vehicle-passenger monohulls  0.35-0.45.'
        READ (*,*) CB
        AS=0.95*NPAX
        AP=1.2*AS
        AV=156.0+(10.2*NCAR)
        LB=121.0+(0.27*AP)+(0.60*AV)
        LOB=SQRT(((LOD**3.0)*CB)/BOT)
        LWL=SQRT(LB*LOB)
        LOA=1.14*LWL
        B=LWL/LOB
        T=B/BOT
        D=4.0+(0.6*B)
        DISP1=1.025*LWL*B*T*CB
        WRITE (*,*) ' '
        WRITE (*,*) ' DERIVATION OF DIMENSIONS       '
        WRITE (*,*) ' ----------------------- metres'
        WRITE (*,*) ' '
        WRITE (*,570) LOA
        WRITE (*,571) LWL
        WRITE (*,572) B
        WRITE (*,573) T
        WRITE (*,574) D
        WRITE (*,575) CB
        WRITE (*,576) DISP1
  570 FORMAT ('  OVERALL LENGTH:           ',F10.2)
  571 FORMAT ('  WATERLINE LENGTH:         ',F10.2)
  572 FORMAT ('  BREADTH:                  ',F10.2)
  573 FORMAT ('  DRAUGHT:                  ',F10.2)
  574 FORMAT ('  DEPTH:                    ',F10.2)
  575 FORMAT ('  BLOCK COEFFICIENT         ',F10.2)
  576 FORMAT ('  DISPLACEMENT1:            ',F10.2)
C----------------------------------------------------------------------
-
C-----DERIVATION OF DIMENSIONS PASSENGER-ONLY CATAMARAN
      ELSEIF ((VTYPE.EQ.'PC').OR.(VTYPE.EQ.'pc')) THEN
        WRITE (*,*) ' '
        WRITE (*,*) ' INPUT LENGTH-DISPLACEMENT RATIO:  '
        WRITE (*,*) ' Majority: passenger-only catamarans  8.5-9.5. '
        READ (*,*) LOD
        WRITE (*,*) ' '
        WRITE (*,*) ' INPUT DEMIHULL BREADTH-DRAUGHT RATIO:  '
        WRITE (*,*) ' Majority: passenger-only catamarans  1.5-3.0. '
        READ (*,*) BHOT
        WRITE (*,*) ' '
        WRITE (*,*) ' INPUT SEPARATION-LENGTH RATIO:  '
        WRITE (*,*) ' Majority: passenger-only catamarans  0.20-0.25. '
        READ (*,*) SOL
        WRITE (*,*) ' '
        WRITE (*,*) ' INPUT BLOCK COEFFICIENT: '
        WRITE (*,*) ' Majority: passenger-only catamarans  0.40-0.55. '
        READ (*,*) CB
C-----AS/NPAX=0.55-0.85
        AS=0.7*NPAX
C-----AP/AS=1.10-1.30
        AP=1.2*AS
        LB=138.0+(0.910*AP)
        LOBH=SQRT(((LOD**3.0)*CB)/BHOT)
        LOBH1=1.0/LOBH
        LOB=1.0/(SOL+LOBH1)
        LWL=SQRT(LB*LOB)
```

```
      LOA=1.14*LWL
      B=LWL/LOB
      S=LWL*SOL
      BH=LWL*LOBH1
      T=BH/BHOT
      D=4.0+(0.44*B)
      DISP1=2.0*1.025*LWL*BH*T*CB
      WRITE (*,*) ' '
      WRITE (*,*) ' DERIVATION OF DIMENSIONS'
      WRITE (*,*) ' ------------------------ metres '
      WRITE (*,*) ' '
      WRITE (*,580) LOA
      WRITE (*,581) LWL
      WRITE (*,582) B
      WRITE (*,583) S
      WRITE (*,584) BH
      WRITE (*,585) T
      WRITE (*,586) D
      WRITE (*,587) CB
      WRITE (*,588) DISP1
  580 FORMAT ('  OVERALL LENGTH;                ',F10.2)
  581 FORMAT ('  WATERLINE LENGTH:              ',F10.2)
  582 FORMAT ('  BREADTH:                       ',F10.2)
  583 FORMAT ('  SEPARATION BETWEEN DEMIHULLS:  ',F10.2)
  584 FORMAT ('  DEMIHULL BREADTH:              ',F10.2)
  585 FORMAT ('  DRAUGHT:                       ',F10.2)
  586 FORMAT ('  DEPTH:                         ',F10.2)
  587 FORMAT ('  BLOCK COEFFICIENT:             ',F10.2)
  588 FORMAT ('  DISPLACEMENT1:                 ',F10.2)
C---------------------------------------------------------------------
C-----DERIVATION OF DIMENSIONS FOR VEHICLE-PASSENGER CATAMARANS
      ELSE
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT LENGTH-DISPLACEMENT RATIO:  '
      WRITE (*,*) ' Majority: vehicle-passenger catamarans 9.5-10.5. '
      READ (*,*) LOD
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT DEMIHULL BREADTH-DRAUGHT RATIO: '
      WRITE (*,*) ' Majority: vehicle-passenger catamarans 1.5-3.0. '
      READ (*,*) BHOT
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT SEPARATION-LENGTH RATIO: '
      WRITE (*,*) ' Majority: vehicle-passenger catamarans 0.20-0.25.'
      READ (*,*) SOL
      WRITE (*,*) ' '
      WRITE (*,*) ' INPUT BLOCK COEFFICIENT: '
      WRITE (*,*) ' Majority: vehicle-passenger catamarans 0.40-0.55.'
      READ (*,*) CB
C-----AS/NPAX=0.80-1.40
      AS=1.40*NPAX
C-----AP/AS=1.30-1.70
      AP=1.70*AS
      AV=12.4*NCAR
      LB=471.0+(0.55*AP)+(0.28*AV)
      LOBH=SQRT(((LOD**3.0)*CB)/BHOT)
      LOBH1=1/LOBH
      LOB=1/(SOL+LOBH1)
      LWL=SQRT(LB*LOB)
      LOA=1.14*LWL
      B=LWL/LOB
      S=LWL*SOL
      BH=LWL/LOBH
      T=BH/BHOT
```

```
      D=4.0+(0.44*B)
      DISP1=2.0*1.025*LWL*BH*T*CB
      WRITE (*,*) ' '
      WRITE (*,*) ' DERIVATION OF DIMENSIONS'
      WRITE (*,*) ' ------------------------ metres'
      WRITE (*,*) ' '
      WRITE (*,590) LOA
      WRITE (*,591) LWL
      WRITE (*,592) B
      WRITE (*,593) S
      WRITE (*,594) BH
      WRITE (*,595) T
      WRITE (*,596) D
      WRITE (*,597) CB
      WRITE (*,598) DISP1
  590 FORMAT ('  OVERALL LENGTH:              ',F9.2)
  591 FORMAT ('  WATERLINE LENGTH:            ',F9.2)
  592 FORMAT ('  BREADTH:                     ',F9.2)
  593 FORMAT ('  SEPARATION BETWEEN DEMIHULLS:',F9.2)
  594 FORMAT ('  DEMIHULL BREADTH:            ',F9.2)
  595 FORMAT ('  DRAUGHT:                     ',F9.2)
  596 FORMAT ('  DEPTH:                       ',F9.2)
  597 FORMAT ('  BLOCK COEFFICIENT:           ',F9.2)
  598 FORMAT ('  DISPLACEMENT1:               ',F9.2)
      ENDIF
C---------------------------------------------------------------------
--
C-----ESTIMATION OF MASSES
C-----Hull Mass
      IF ((VTYPE.EQ.'PC').OR.(VTYPE.EQ.'pc')) THEN
      EC=(2*LOA*(BH+T))+(0.85*LOA*(D-T))+(1.6*LOA*(B-(2*BH)))
      IF (EC.LE.3025) THEN
      WH=0.00064*(EC**1.7)
      ELSE
      WH=0.39*(EC**0.9)
      ENDIF
      ELSEIF ((VTYPE.EQ.'VC').OR.(VTYPE.EQ.'vc')) THEN
      EC=(2*LOA*(BH+T))+(0.85*LOA*(D-T))+(1.6*LOA*(B-(2*BH)))
      IF (EC.LE.3025) THEN
      WH=0.00064*(EC**1.7)
      ELSE
      WH=0.39*(EC**0.9)
      ENDIF
      ELSEIF ((VTYPE.EQ.'PM').OR.(VTYPE.EQ.'pm')) THEN
      EM=(LOA*(B+T))+(0.85*LOA*(D-T))
      WH=0.032*(EM**1.2)
      ELSE
      EM=(LOA*(B+T))+(0.85*LOA*(D-T))
      WH=0.032*(EM**1.2)
      ENDIF
C-----Outfit Mass
      WO=0.027*NDECK*LOA*B
C-----Machinery Mass and Powering Estimation
      CALL POWER
C-----Diesel Engines
      PB=PI/NE
      IF ((ETYPE.EQ.'D').OR.(ETYPE.EQ.'d')) THEN
      PSRATIO=PB/RPM
      WME=NE*6.82*(PSRATIO**0.85)
      WGB=NE*0.00348*(PB**0.75)
C-----Gas Turbines
      ELSE
      WME=NE*(3+(0.00056*PB))
```

```
      WGB=NE*0.00348*(PB**0.75)
      ENDIF
C-----Water Jets
      WP=NE*0.00018*(PB**1.18)
      WMM=WME+WP+WGB
C-----Remaining machinery mass is a function of WMM.
      FACTOR=1.55
      WM=WMM*FACTOR


C-----------------------------------------------------------------------
--
C-----ESTIMATION OF COSTS
C-----Hull Costs
      IF ((VTYPE.EQ.'PC').OR.(VTYPE.EQ.'pc')) THEN
      CH=((WH*5250*1.1)+(WH*900*30))*1E-6
      ELSEIF ((VTYPE.EQ.'VC').OR.(VTYPE.EQ.'vc')) THEN
      CH=((WH*5250*1.1)+(WH*900*30))*1E-6
        ELSEIF ((VTYPE.EQ.'PM').OR.(VTYPE.EQ.'vm')) THEN
        CH=((WH*5250*1.1)+(WH*600*30))*1E-6
          ELSE
          CH=((WH*5250*1.1)+(WH*600*30))*1E-6
      ENDIF
C-----Outfit Costs
      CO=22000.0*WO*1E-6
C-----Machinery Costs (Main engine, Gearbox, Propulsor).
      IF ((ETYPE.EQ.'D').OR.(ETYPE.EQ.'d')) THEN
      CME=NE*(0.0003*PB-0.0423)
      ELSE
      CME=NE*((-4E-9*(PB**2))+(0.0004*PB))
      ENDIF
      CGB=NE*(2E-5*PB-(3E-10*(PB**2)))
      CP=NE*0.0031*(PB**0.6122)
      CM=(CP+CME+CGB)*1.40
C-----Total Building Costs (million US$)
      BC=(CM+CO+CH)
C-----Approximate Building Costs (million US$)
      IF ((VTYPE.EQ.'PM').OR.(VTYPE.EQ.'pm')) THEN
      ABC=-37.6+(0.0115*NPAX)+(0.121*NCAR)+(1.23*VS)
      ELSEIF ((VTYPE.EQ.'VM').OR.(VTYPE.EQ.'vm')) THEN
      ABC=-37.6+(0.0115*NPAX)+(0.121*NCAR)+(1.23*VS)
      ELSEIF ((VTYPE.EQ.'PC').OR.(VTYPE.EQ.'pc')) THEN
      ABC=-18.4+(0.0294*NPAX)+(0.111*NCAR)+(0.445*VS)
      ELSE
      ABC=-18.4+(0.0294*NPAX)+(0.111*NCAR)+(0.445*VS)
      ENDIF
C-----------------------------------------------------------------------
--

      WRITE (*,*) ' '
      WRITE (*,*) ' POWER ESTIMATION                    kW '
      WRITE (*,600) PD
      WRITE (*,601) PE
      WRITE (*,602) PI
  600 FORMAT (' DELIVERY POWER:                     ',F20.2)
  601 FORMAT (' EFFECTIVE POWER:                    ',F20.2)
  602 FORMAT (' INSTALLED POWER:                    ',F20.2)

C-----------------------------------------------------------------------
--

      WRITE (*,*) ' '
      WRITE (*,*) ' HULL MASS ESTIMATION              t'
```

```
      WRITE (*,605) WH
  605 FORMAT ('  TOTAL HULL MASS:          ',F7.2)

C----------------------------------------------------------------------
--

      WRITE (*,*) ' '
      WRITE (*,*) ' OUTFIT MASS ESTIMATION          t '
      WRITE (*,610) WO
  610 FORMAT ('  TOTAL OUTFIT MASS              ',F7.2)

C----------------------------------------------------------------------
--

      WRITE (*,*) ' '
      WRITE (*,*) ' MACHINERY MASS ESTIMATION          t '
      WRITE (*,615) WME
      WRITE (*,616) WP
      WRITE (*,617) WGB
      WRITE (*,618) WM
  615 FORMAT (' MAIN ENGINES:                    ',F20.2)
  616 FORMAT (' PROPULSORS:                      ',F20.2)
  617 FORMAT (' GEARBOXES:                       ',F20.2)
  618 FORMAT (' TOTAL MACHINERY MASS:            ',F20.2)

C----------------------------------------------------------------------
--

      WRITE (*,*) ' '
      WRITE (*,*) ' HULL COST ESTIMATION           KUS$'
      WRITE (*,625) CH
  625 FORMAT ('  TOTAL HULL COST:          ',F20.1)

C----------------------------------------------------------------------
--

      WRITE (*,*) ' '
      WRITE (*,*) ' OUTFIT COST ESTIMATION        KUS$'
      WRITE (*,626) CO
  626 FORMAT ('  TOTAL OUTFIT COST              ',F10.1)

C----------------------------------------------------------------------
--

      WRITE (*,*) ' MACHINERY COST                   K$US '
      WRITE (*,630) CME
      WRITE (*,631) CP
      WRITE (*,632) CGB
      WRITE (*,633) CM
  630 FORMAT (' MAIN ENGINES:                    ',F20.2)
  631 FORMAT (' PROPULSORS:                      ',F20.2)
  632 FORMAT (' GEARBOXES:                       ',F20.2)
  633 FORMAT (' TOTAL MACHINERY COST:            ',F20.2)

C----------------------------------------------------------------------
--

      WRITE (*,*) ' '
      WRITE (*,*) ' BUILDING COST ESTIMATION       KUS$'
      WRITE (*,635) BC
  635 FORMAT ('  TOTAL BUILDING COST:      ',F20.1)
```

```
C-------------------------------------------------------------------
--
C-----Deadweight Analysis
      SFC=0.22
      WFUEL=((PE*SFC*(R/VS))*1.09*1.1)/1000.0
      WFWPROV=0.00125*NPAX*(R/VS)
      WPAX=NPAX*0.105
      WCREW=NCREW*0.135
      WCAR=NCAR*1.0
      DW=1.06*(WFUEL+WFWPROV+WPAX+WCREW+WCAR)
C-----Lightship
      LS=WH+WO+WM
C-----Displacement from 'LS+DW'
      DISP2=DW+LS
      WRITE (*,*) ' '
      WRITE (*,*) ' DEADWEIGHT ANALYSIS'
      WRITE (*,*) ' -------------------'
      WRITE (*,*) '                              t'
      WRITE (*,640) WFUEL
      WRITE (*,641) WFWPROV
      WRITE (*,642) WCREW
      WRITE (*,643) WPAX
      WRITE (*,644) WCAR
      WRITE (*,645) DW
      WRITE (*,646) LS
      WRITE (*,647) DISP2
  640 FORMAT ('  FUEL & LUBRICANT                 ',F8.2)
  641 FORMAT ('  WATER & PROVISIONS               ',F8.2)
  642 FORMAT ('  CREW & EFFECTS                   ',F8.2)
  643 FORMAT ('  PASSENGERS & LUGGAGE             ',F8.2)
  644 FORMAT ('  CARS                             ',F8.2)
  645 FORMAT ('  DEADWEIGHT                       ',F8.2)
  646 FORMAT ('  LIGHTSHIP                        ',F8.2)
  647 FORMAT ('  DISPLACEMENT2=LS+DW              ',F8.2)

C-------------------------------------------------------------------
--
C-----MASS BALANCE CALCULATIONS

      IF (((ABS(DISP2-DISP1)*100)/DISP1).GE.1.0) THEN
      WRITE (*,*) ' '
      WRITE (*,*) ' There is not a balance between DISP1 & DISP2.'
      WRITE (*,*) ' Do you want to perform the calculations for '
      WRITE (*,*) ' a different CB and LOD (Y/N)?'
      READ (*,520) YN
      IF ((YN.EQ.'Y').OR.(YN.EQ.'y')) THEN
      CONTINUE
      ELSE
      GOTO 510
      ENDIF
      CB=(DISP2*CB)/DISP1
C-----CB2=CB1*(LOD2/LOD1)**(1.0/3.0) with these equations without
C-----changing the dimension of the vessel, we can balance the mass.
      LOD=LOD*((DISP1/DISP2)**(1.0/3.0))
      IF ((VTYPE.EQ.'PM').OR.(VTYPE.EQ.'pm')) THEN
      DISP1=1.025*LWL*B*T*CB
      ELSEIF ((VTYPE.EQ.'PC').OR.(VTYPE.EQ.'pc')) THEN
      DISP1=1.025*2*LWL*BH*T*CB
      ELSEIF ((VTYPE.EQ.'VM').OR.(VTYPE.EQ.'vm')) THEN
      DISP1=1.025*LWL*B*T*CB
      ELSE
      DISP1=1.025*2*LWL*BH*T*CB
      ENDIF
```

```
      ELSE
      CONTINUE
      ENDIF

C-----------------------------------------------------------------------
--

  510 WRITE (*,*) ' '
      WRITE (*,*) ' DO YOU WANT TO PERFORM CALCULATIONS'
      WRITE (*,*) ' FOR ANOTHER VESSEL (Y/N)?'
      READ (*,520) YESNO
      IF ((YESNO.EQ.'Y').OR.(YESNO.EQ.'y')) THEN
      GOTO 500
      ELSE
        GOTO 530
      ENDIF
  520 FORMAT (A)
  530 CALL HARDCOPY
      STOP
      END
C-----------------------------------------------------------------------
--

      SUBROUTINE HARDCOPY
      CHARACTER *2 VTYPE,ETYPE
      COMMON/ONE/LOA,LWL,B,S,BH,T,D,CB,DISP1,WME,WP,WGB,WM,CME,CP,CGB,
     $
CM,WO,CO,WH,CH,BC,WFUEL,WFWPROV,WCREW,WPAX,WCAR,DW,DISP2,VS,SOL,
     $ LOD,WSA,FN,RN,CFM,CFS,FN1,FN2,FN3,CR1,CR2,CR3,CR4,CR5,CR6,CR7,
     $ CR8,CR9,D1,A,B1,C,CR,CRS2,k,bk,CTS,RTS,PE,PD,PI,EFF,N,ABC,
     $
AJ,AKT,AKQ,DIAM,RPM,NPAX,NCAR,NCREW,AS,AP,NDECK,NE,R,BHOT,BOT,LS
      COMMON/TWO/VTYPE,ETYPE
      REAL
NPAX,NCAR,NCREW,AS,AP,AV,LB,LWL,LOA,B,D,BH,T,S,DISP1,LOD,BOT,
     $ CB,PB,RPM,R,VS,LOB,LOBH,LOBH1,SOL,BHOT,NE,NDECK,PI,PE,PD,FN,RN,
     $ CO,WSA,CFM,CFS,FN1,FN2,FN3,CR1,CR2,CR3,CR4,CR5,CR6,CR7,CR8,CR9,
     $
D1,A,B1,C,CR,CRS2,k,bk,CTS,RTS,EFF,n,AJ,AKT,AKQ,DIAM,DISP2,LS,ABC
      OPEN (16,FILE='G:\HARDCOPY.DAT',STATUS = 'unknown')
      WRITE (16,10) NPAX,LOD,WO,NCAR,BOT,WM,VS,BHOT,WPAX,LOA,SOL,WCAR
      WRITE (*,10) NPAX,LOD,WO,NCAR,BOT,WM,VS,BHOT,WPAX,LOA,SOL,WCAR
   10 FORMAT(' NPAX = ',F8.2,' LOD    = ',F8.2,' WO           =
',F8.2/,
     $       ' NCAR = ',F8.2,' BOT    = ',F8.2,' WM           =
',F8.2/,
     $       ' VS   = ',F8.2,' BHOT   = ',F8.2,' WPAX         =
',F8.2/,
     $       ' LOA  = ',F8.2,' SOL    = ',F8.2,' WCAR         =
',F8.2)
      WRITE (16,20) LWL,NE,WFUEL,B,RPM,WFWPROV,BH,PD,WCREW,T,PE,BC
      WRITE (*,20) LWL,NE,WFUEL,B,RPM,WFWPROV,BH,PD,WCREW,T,PE,BC
   20 FORMAT(' LWL  = ',F8.2,' NE     = ',F8.2,' WFUEL        =
',F8.2/,
     $       ' B    = ',F8.2,' RPM    = ',F8.2,' WFWPROV      =
',F8.2/,
     $       ' BH   = ',F8.2,' PD     = ',F8.2,' WCREW        =
',F8.2/,
     $       ' T    = ',F8.2,' PE     = ',F8.2,' BC(milUS$) =
',F8.2)

WRITE(16,30)D,PI,ABC,S,R,LS,CB,NCREW,DW,AS,NDECK,DISP1,AP,WH,DISP2
```

```
WRITE(*,30)D,PI,ABC,S,R,LS,CB,NCREW,DW,AS,NDECK,DISP1,AP,WH,DISP2
   30 FORMAT('   D     = ',F8.2,'  PI     = ',F8.2,'  ABC(milUS$)=
',F8.2/,
     $       '   S     = ',F8.2,'  R      = ',F8.2,'  LS          =
',F8.2/,
     $       '   CB    = ',F8.2,'  NCREW  = ',F8.2,'  DW          =
',F8.2/,
     $       '   AS    = ',F8.2,'  NDECK  = ',F8.2,'  DISP1       =
',F8.2/,
     $       '   AP    = ',F8.2,'  WH     = ',F8.2,'  DISP2       =
',F8.2)
      CLOSE(16)
      RETURN
      END

C-------------------------------------------------------------

      SUBROUTINE POWER
      CHARACTER *2 VTYPE,ETYPE
      COMMON/ONE/LOA,LWL,B,S,BH,T,D,CB,DISP1,WME,WP,WGB,WM,CME,CP,CGB,
     $
CM,WO,CO,WH,CH,BC,WFUEL,WFWPROV,WCREW,WPAX,WCAR,DW,DISP2,VS,SOL,
     $ LOD,WSA,FN,RN,CFM,CFS,FN1,FN2,FN3,CR1,CR2,CR3,CR4,CR5,CR6,CR7,
     $ CR8,CR9,D1,A,B1,C,CR,CRS2,k,bk,CTS,RTS,PE,PD,PI,EFF,N,ABC,
     $
AJ,AKT,AKQ,DIAM,RPM,NPAX,NCAR,NCREW,AS,AP,NDECK,NE,R,BHOT,BOT,LS
      COMMON/TWO/VTYPE,ETYPE
      REAL
NPAX,NCAR,NCREW,AS,AP,AV,LB,LWL,LOA,B,D,BH,T,S,DISP1,LOD,BOT,
     $ CB,PB,RPM,R,VS,LOB,LOBH,LOBH1,SOL,BHOT,NE,NDECK,PI,PE,PD,FN,RN,
     $ CO,WSA,CFM,CFS,FN1,FN2,FN3,CR1,CR2,CR3,CR4,CR5,CR6,CR7,CR8,CR9,
     $
D1,A,B1,C,CR,CRS2,k,bk,CTS,RTS,EFF,n,AJ,AKT,AKQ,DIAM,DISP2,LS,ABC
C-----PASSENGER MONOHULL
      IF ((VTYPE.EQ.'PM').OR.(VTYPE.EQ.'pm')) THEN
        FN=(VS*0.5144)/SQRT(9.81*LWL)
        RN=(VS*0.5144*LWL)/1.19E-6
        CFM=0.075/(((ALOG10(FN*5.56E+6))-2)**2)
        CFS=0.075/(((ALOG10(RN))-2)**2)
        WSA=(1.7*LWL*T)+(LWL*B*CB)
        FN1=0.60
        FN2=0.80
        FN3=1.0
        CR1=(1702.0*LOD**(-2.96))*0.001
        CR2=(533.0*LOD**(-2.58))*0.001
        CR3=(122.0*LOD**(-1.96))*0.001
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR1*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR2*FN3**2-CR3*FN2**2)
     $    +(FN1**2)*(CR2*FN3-CR3*FN2))/D1
        B1=((CR2*FN3**2-CR3*FN2**2)-CR1*(FN3**2-FN2**2)
     $    +FN1**2*(CR3-CR2))/D1
        C=((FN2*CR3-FN3*CR2)-FN1*(CR3-CR2)+CR1*(FN3-FN2))/D1
        CR=A+B1*FN+C*FN**2
        k=0.15
        CTS=(CFS+CR)-(k*(CFM-CFS))
C-----VEHICLE MONOHULL
      ELSEIF ((VTYPE.EQ.'VM').OR.(VTYPE.EQ.'vm')) THEN
        FN=(VS*0.5144)/SQRT(9.81*LWL)
        RN=(VS*0.5144*LWL)/1.19E-6
        CFM=0.075/((ALOG10(FN*5.56E+6)-2)**2)
        CFS=0.075/((ALOG10(RN)-2)**2)
        WSA=(1.7*LWL*T)+(LWL*B*CB)
```

```
        FN1=0.60
        FN2=0.80
        FN3=1.0
        CR1=(1702.0*LOD**(-2.96))*0.001
        CR2=(533.0*LOD**(-2.58))*0.001
        CR3=(122.0*LOD**(-1.96))*0.001
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR1*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR2*FN3**2-CR3*FN2**2)
     $    +(FN1**2)*(CR2*FN3-CR3*FN2))/D1
        B1=((CR2*FN3**2-CR3*FN2**2)-CR1*(FN3**2-FN2**2)
     $    +FN1**2*(CR3-CR2))/D1
        C=((FN2*CR3-FN3*CR2)-FN1*(CR3-CR2)+CR1*(FN3-FN2))/D1
        CR=A+B1*FN+C*FN**2
        k=0.15
        CTS=(CFS+CR)-(k*(CFM-CFS))
C-----PASSENGER CATAMARAN
      ELSEIF ((VTYPE.EQ.'PC').OR.(VTYPE.EQ.'pc')) THEN
        WSA=2*((1.7*LWL*T)+(LWL*BH*CB))
        FN=(VS*0.5144)/SQRT(9.81*LWL)
        RN=(VS*0.5144*LWL)/1.19E-6
        CFM=0.075/((ALOG10(FN*5.56E+6)-2)**2)
        CFS=0.075/((ALOG10(RN)-2)**2)
        FN1=0.60
        FN2=0.80
        FN3=1.0
        CR4=(1774.0*LOD**(-2.87))*0.001
        CR5=(180.0*LOD**(-1.97))*0.001
        CR6=(48.0*LOD**(-1.41))*0.001
        CR7=(5084.0*LOD**(-3.30))*0.001
        CR8=(130.0*LOD**(-1.82))*0.001
        CR9=(22.0*LOD**(-1.06))*0.001
c-----S/L=0.3
        IF (SOL.EQ.0.3) THEN
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR4*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR5*FN3**2-CR6*FN2**2)
     $    +(FN1**2)*(CR5*FN3-CR6*FN2))/D1
        B1=((CR5*FN3**2-CR6*FN2**2)-CR4*(FN3**2-FN2**2)
     $    +FN1**2*(CR6-CR5))/D1
        C=((FN2*CR6-FN3*CR5)-FN1*(CR6-CR5)+CR4*(FN3-FN2))/D1
        CR=A+B1*FN+C*FN**2
C-----S/L=0.2
        ELSEIF (SOL.EQ.0.2) THEN
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR7*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR8*FN3**2-CR9*FN2**2)
     $    +(FN1**2)*(CR8*FN3-CR9*FN2))/D1
        B1=((CR8*FN3**2-CR9*FN2**2)-CR7*(FN3**2-FN2**2)
     $    +FN1**2*(CR9-CR8))/D1
        C=((FN2*CR9-FN3*CR8)-FN1*(CR9-CR8)+CR7*(FN3-FN2))/D1
        CR=A+B1*FN+C*FN**2
C-----0.4>S/L>0.3
        ELSEIF (SOL.GT.0.3.AND.SOL.LE.0.4) THEN
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR4*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR5*FN3**2-CR6*FN2**2)
     $    +(FN1**2)*(CR5*FN3-CR6*FN2))/D1
        B1=((CR5*FN3**2-CR6*FN2**2)-CR4*(FN3**2-FN2**2)
     $    +FN1**2*(CR6-CR5))/D1
        C=((FN2*CR6-FN3*CR5)-FN1*(CR6-CR5)+CR4*(FN3-FN2))/D1
        CR=A+B1*FN+C*FN**2
C-----0.3>S/L>0.2
        ELSEIF (SOL.GE.0.2.AND.SOL.LE.0.3) THEN
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR7*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR8*FN3**2-CR9*FN2**2)
     $    +(FN1**2)*(CR8*FN3-CR9*FN2))/D1
```

```
        B1=((CR8*FN3**2-CR9*FN2**2)-CR7*(FN3**2-FN2**2)
     $     +FN1**2*(CR9-CR8))/D1
        C=((FN2*CR9-FN3*CR8)-FN1*(CR9-CR8)+CR7*(FN3-FN2))/D1
        CRS2=A+B1*FN+C*FN**2
        CR=CRS2-((SOL-0.2)/(0.3-0.2))*(CR2-CR3)
        ELSE
        WRITE (*,*) 'S/LWL RATIO IS OUT OF RANGE.'
        STOP
        ENDIF
        bk=0.25
        CTS=(CFS+CR)-(bk*(CFM-CFS))
C-----VEHICLE CATAMARAN
      ELSE
        WSA=2*((1.7*LWL*T)+(LWL*BH*CB))
        FN=(VS*0.5144)/SQRT(9.81*LWL)
        RN=(VS*0.5144*LWL)/1.19E-6
        CFM=0.075/((ALOG10(FN*5.56E+6)-2)**2)
        CFS=0.075/((ALOG10(RN)-2)**2)
        FN1=0.60
        FN2=0.80
        FN3=1.0
        CR4=(1774.0*LOD**(-2.87))*0.001
        CR5=(180.0*LOD**(-1.97))*0.001
        CR6=(48.0*LOD**(-1.41))*0.001
        CR7=(5084.0*LOD**(-3.3))*0.001
        CR8=(130.0*LOD**(-1.82))*0.001
        CR9=(22.0*LOD**(-1.06))*0.001
C-----S/L=0.3
        IF (SOL.EQ.0.3) THEN
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR4*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR5*FN3**2-CR6*FN2**2)
     $     +(FN1**2)*(CR5*FN3-CR6*FN2))/D1
        B1=((CR5*FN3**2-CR6*FN2**2)-CR4*(FN3**2-FN2**2)
     $     +FN1**2*(CR6-CR5))/D1
        C=((FN2*CR6-FN3*CR5)-FN1*(CR6-CR5)+CR4*(FN3-FN2))/D1
        CR=A+B1*FN+C*FN**2
C-----S/L=0.2
        ELSEIF (SOL.EQ.0.2) THEN
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR7*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR8*FN3**2-CR9*FN2**2)
     $     +(FN1**2)*(CR8*FN3-CR9*FN2))/D1
        B1=((CR8*FN3**2-CR9*FN2**2)-CR7*(FN3**2-FN2**2)
     $     +FN1**2*(CR9-CR8))/D1
        C=((FN2*CR9-FN3*CR8)-FN1*(CR9-CR8)+CR7*(FN3-FN2))/D1
        CR=A+B1*FN+C*FN**2
C-----0.4>S/L>0.3
        ELSEIF (SOL.GT.0.3.AND.SOL.LE.0.4) THEN
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR4*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR5*FN3**2-CR6*FN2**2)
     $     +(FN1**2)*(CR5*FN3-CR6*FN2))/D1
        B1=((CR5*FN3**2-CR6*FN2**2)-CR4*(FN3**2-FN2**2)
     $     +FN1**2*(CR6-CR5))/D1
        C=((FN2*CR6-FN3*CR5)-FN1*(CR6-CR5)+CR4*(FN3-FN2))/D1
        CR=A+B1*FN+C*FN**2
C-----0.3>S/L>0.2
        ELSEIF (SOL.GE.0.2.AND.SOL.LE.0.3) THEN
       D1=(FN2*FN3**2-FN3*FN2**2)-FN1*(FN3**2-FN2**2)+FN1**2*(FN3-FN2)
        A=(CR7*(FN2*FN3**2-FN3*FN2**2)-FN1*(CR8*FN3**2-CR9*FN2**2)
     $     +(FN1**2)*(CR8*FN3-CR9*FN2))/D1
        B1=((CR8*FN3**2-CR9*FN2**2)-CR7*(FN3**2-FN2**2)
     $     +FN1**2*(CR9-CR8))/D1
        C=((FN2*CR9-FN3*CR8)-FN1*(CR9-CR8)+CR7*(FN3-FN2))/D1
        CRS2=A+B1*FN+C*FN**2
```

```
          CR=CRS2-((SOL-0.2)/(0.3-0.2))*(CR2-CR3)
          ELSE
          WRITE (*,*) 'S/LWL RATIO IS OUT OF RANGE.'
          STOP
          ENDIF
          bk=0.25
          CTS=(CFS+CR)-(bk*(CFM-CFS))
        ENDIF
          RTS=CTS*0.5*1.025*WSA*((VS*0.5144)**2.0)
C-----Effective power (kW)
          PE=RTS*VS*0.5144
C-----Water jet efficiency
          EFF=1.0/(1.0+(16.8/VS))
C-----Delivery power (kW)
        PD=PE/EFF
C-----15%resistance increase due to hull roughness, fouling and
weather.
        PI=PD*1.15
        RETURN
        END
```