Assessing High Speed Waterborne (HSW) Services, Based on Synthetic Aspects of Route Characteristics, Transport Economy, and Vessel Performance

by

LEONIDAS M. TH. KAMBANIS

B.E. in Mechanical Engineering
Stevens Institute of Technology, 1990

M.Sc. in Naval Architecture and Marine Engineering
M.Sc. in Mechanical Engineering
Massachusetts Institute of Technology, 1995

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Signature of Author..
Department of Ocean Engineering
June 16, 1995

Certified by..
Ernst Frankel
Professor, Ocean Systems and Management
Thesis Supervisor

Accepted by..
A. Douglas Carmichael
Chairman, Departmental Graduate Committee

[redacted]

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Abstract

The motivation for the demand of speed in transport is usually explained from the issue of saving both time and money for travel. As highways become more congested, the HSW crafts regain momentum as an increasingly used mode of transportation.

In this thesis, the major potential categories of HSW crafts were presented. The technical, cost and physical characteristics of their technologies were analyzed in terms of how they affect the evaluation and selection of these vessels as potential candidates of an ideal waterborne vehicle for mainly transporting passengers. A procedure was etablished in evaluating a site based on economic and geographic factors. Aspects of the vessels were examined in terms of economic factors and performance, in a methodical manner that can assist a potential operator of an HSW service to select the ideal vessel for a site that has been evaluated as suitable for such a service.

Thesis Supervisor: Ernst Frankel

Title: Professor, Ocean Systems and Management

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I appreciate the owners, operators and builders of many vessels and services that shared their valuable data with me.

Once more, I want to thank my parents, who both supported me to the end of this work, each on a special way. My father financially, my mother with her unique skills to collect me that extra bit of data that always made a difference. Both with their love that has helped me to look at the future with optimism.

I dedicate this thesis to my parents, who, since I was a child, shared my curiosity for what is out there. Also, to the operators of MEGALOHARI, ELENA B., ANNA L., CRYSI AMMOS, CRYSI AVGI, EPTANISOS, SUPERFERRY, DELFINI, HERMES and to all the vessels that will continue to bridging the narrows of Cavo d'Oro and bringing "*Andros*" closer to me.

Leonidas M.Th. Kambanis

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Chapter 1

Introduction and Background

1.1 Introduction

The end of this century will find marine technology, ship design and ship operations entering an era of dramatic change, revolutionary developments and economic variability. Although the airline industry is becoming more efficient, more competitive with other means of transportation and is entering new markets, such as the transportation of high-value goods, which have been traditionally carried by fast container-ships, the need for efficient sea transport is growing rather than diminishing. This is especially true for countries that heavily depend upon shipping, which will benefit from both the development of the technologies and from the operation of these new vessels. Australians believe that fast marine cargo transport will become increasingly important. [12] High-value commodities, for which air-freight is too expensive, will use fast vessels and new technologies for shipment, and will create new markets that could not be reached timely with conventional vessels. Also, fast ships will change the structure of commercial shipping, since the future fleets will be synthesized by fewer but much faster ships, with more efficient operation, utilizing aircraft derivative technologies.

Although the first attempt for developing an advanced marine vehicle belongs to the previous century, it was much after the second World War that the efforts became more serious and more numerous. In the early sixties there was an overall, significant development in the maritime sector. Advances in ship-building and all related technologies marked the future of international shipping and, in general, the use of ocean going vehicles as means of transportation. Both the size and the speeds of the new vessels were taken to much higher levels. New types of vessels emerged. With the construction of the VLCC's (300,000 DWT) and the ULCC's (500,000 DWT) the size of the commercial vessels crossed any expected limit. On the other hand, pushing the operating speeds in excess of 40 knots for the Air Cushioned Vehicles (ACV), the design envelope was pushed even more.

Since then, with the exception of the early and mid seventies (during the oil crisis) naval architects have pulled out of their drafting boards some non-controversial designs. The challenge to conquer a new speed-record, set new standards and produced some new interesting products. In the transportation of goods, design practices have reached a more mature level. On the other hand, the use of ocean going vehicles as means of public transportation and recreation has yet a long way to go before someone could argue that little space has been left for development.

The vessels of new technologies or else High Speed Waterborne (HSW) vessels are getting better, bigger and faster. Along with the ACV's of the sixties new Catamarans make their appearance in the early seventies. In 1985 more than 300 HSW's, in 100 different passenger transportation services, operating in over 30 countries proved that there is a big share of the market to shift towards the new technologies. Today, the speed-record of crossing the Atlantic Ocean with a ferry boat is credited to the Wave Piercer Catamaran HOVERSPEED GREAT BRITAIN, which in 1990 averaged a speed of 36.9 knots. At the same time new Surface Effect Ships (SES) reach a top speed of 100 knots.

The goal is faster and cheaper. Technologies are continuously adopting to modern demand, while the growing environmental concern puts new obstacles to the designers.

1.2 Background

There have been several efforts in the past to assess and evaluate the potential of high speed waterborne transportation. Since a foil-assisted boat was tested in 1891 by Count Lambert, it was the Maritime Administration that in 1957 studied the feasibility of operating vessels cruising in speeds between 50 and 200 knots. These vessels were evaluated for an operational range of up to 3,600 nautical miles and their displacement was limited to 3,000 tons. This early study concluded that hydrofoils are superior in efficiency and practicality as means of waterborne transportation than the conventional displacement ships, while cruising in much higher speeds.

In the late 1960s, Grumman Aircraft Engineering Corporation, which was assigned the feasibility study of 1957 by MarAd, evaluated for a second time the potential market for commercial high speed vessels, emphasizing in the analysis of hydrofoils. The result of this second evaluation was encouraging enough for the company to order two Dolphin-class hydrofoils from the Blohm and Voss shipyard in Hamburg, Germany. The interest was such, that the Department of Defense set a waiver of the Jones Act, so that a military version of these hydrofoils could be imported in the United States.

At the same time, Arthur D. Little, Inc., in a report to the San-Francisco Board of Supervisors recommended the development of a ferry link at the San Francisco area. semi-planning hulls were selected to service this route after a number of transportation studies initiated by the Golden Gate Bridge, Highway, and Transportation District, as a result of concern over the continually increasing Golden Gate Bridge automobile traffic.

It was not until the early 1970s that High Speed Waterborne (HSW) vessels were considered and evaluated for the commercial markets. In the early 1970s, the FMC Corporation built a surface-piercing hydrofoil which was evaluated as a potential candidate for passenger ferry operations.

In 1979, a study indicated that 1.5 percent of the 15 million tourists visiting the Toronto/Niagara area annually, could be attracted by an HSW service and turn it into a profitable enterprise.

Of the studies performed in the past, which aimed in the evaluation of High Speed Waterborne vessels and the assessment of their potential in commercial services, the most significant and complete one was done by Advanced Marine Systems Associates, Inc. for the Urban Mass Transportation Administration [1], [2], [3]. This study examined several HSW vessels for commercial use in several routes in the United States and analyzed their performance as well as their economic effectiveness. In the same study it was found that several HSW services that pioneered in the 1950s and the 1960s were doomed to failure for a list of reasons:

- As most of these services were introduced for the first time, they consisted of one-craft operations. It is only a matter of time before the vessel will be out of service.

- Many services depended on either inextensively tested crafts, or on vessels under development. In both cases the service demonstrated poor reliability.
- Several of these original operations were managed by the ship's designers or builders, who were always focused on the crafts
- characteristics and not on the customer's satisfaction and thus, the service's profitability.
- The anxiety for the success of the new ideas frequently resulted to over-optimistic projections for market's capture and future growth.[1]

Other factors that affected the performance of the early HSW services included politics, union concerns, delays in obtaining craft certification and lack of integration of the HSW service with other transportation systems.

1.3 Thesis Objective

In the early years of High Speed Waterborne services, the owners and the operators of the vessels were mainly attracted by their speed, rather than by their overall efficiency and cost effectiveness. Since there was little information to be analyzed, vessel selection was based solely on financial considerations. Without many different types of vessels competing for a service under consideration, the purchasing companies were paying little attention in selecting the ideal vessel for a potential service, based on combined economic, route, technology, performance, and comfort considerations. Thus, many HSW services were terminated as unsuccessful due to a variety of technical, financial, regulatory and other reasons.[1]

In this thesis, some of the major potential technologies are going to be presented. The technical, cost and physical characteristics of these technologies are going to be analyzed in terms of how they affect their selection as potential candidates of an ideal waterborne vehicle for transporting passengers and/or cars.

Before that, a methodology of assessing a route considered for an HSW service is going to be assembled from a compilation of well known processes.

Furthermore, some of the global trends are going to be shown along with a methodology on how to evaluate candidate location to be serviced by HSW crafts. All the categories of HSW's, mentioned above, are going to be defined and presented in a more detailed manner in the following chapters.

In the following chapter the vessels' definitions and operating principles are going to be presented.

Chapter 2

Definitions and Craft Characteristics

2.1 Introduction

A craft called an High Speed Waterborne vessel (HSW) or a High Speed Marine Vehicle (HSMV), could mean different things under different conditions. To the hydrodynamicist it could mean a vessel operating at Froude numbers over 1.0, while to an operator it could mean exceeding the speed of about 30 knots in calm water, while traveling with certain comfort in rough water at speeds over 25 knots. These speeds for most of the HSMV's are well over 50 percent greater than the speeds of most conventional ferries. As a result, HSW's provide some time-savings in their water crossings.

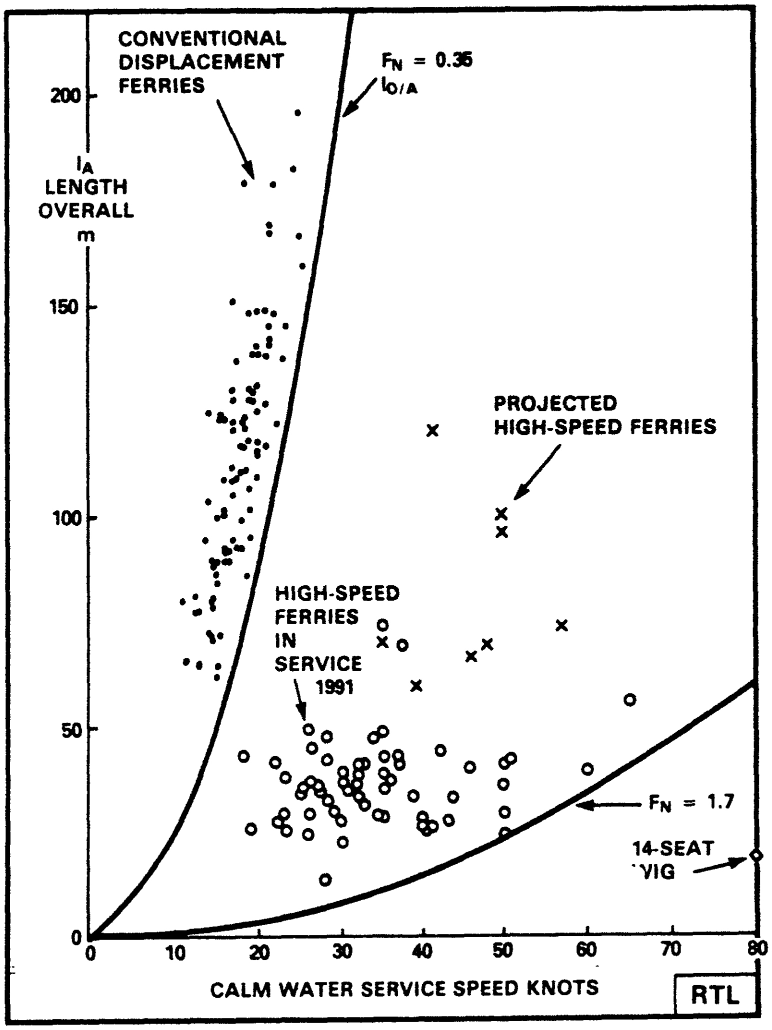


Figure 2.1 The Relative positions of conventional Displacement Ferries and High-Speed Ferries in 1991.

Although it was more than 100 years ago that the idea of a foil-assisted boat was tested on the Seine, it is only in the past 25 years, that several of the types of vessels, that are widely used, have been developed. The first commercial service was established in 1953 on Lake Maggiore between Italy and Switzerland.[13]. The limitations of the early vessels delayed the evolution of these vessels for achieving more economical solutions and better seakeeping. All of the technologies applied aim to the reduction of the vessels resistance without giving up any comfort or safety of the passengers. The principle behind this concept is to lift the vessel above its waves. The earlier vessels were small and simple, leaving a gap in the speed-size diagram shown in Figure 1. In the past five years more complex shapes and much larger vessel tend to emerge. The new vessels combine two or three lifting principles to raise the vessel's payload areas above the waves.

Waterborne vessels range from buoyancy, planing and foil-supported craft in the water, air-cushion vehicles partially or wholly supported on the water, ram-wing or wing-in-the-ground-effect craft wholly supported aerodynamically but dependent upon a water or ground surface beneath them for efficient operation. Designers deliberately use lifting devices to achieve the highest efficiency and best riding qualities.

The gap once developed between the conventional monohulls and the early HSW vessels is closing in terms of work capacity.[14] This closing of the gap shown in Figure 2.1 is coming mainly from the design thinking of the high-speed craft industry, rather than from the conventional shipbuilding industry. Both speed and displacement of the HSW vessels are increasing. Although the average calm-water service speed of the modern HSW vessels is steadily increasing, it has not yet passed the top speed of 65 knots developed by the SRN4s of the 1960s. On the other hand, the displacement of the new vessels is being projected to about 3,000 tons.

Figure 2.2, shows the most representative categories of HSW designs. The so called Jewell's triangle shows how the different methods or concepts of supporting the displacement of the vessel difines its type as an HSW craft. These vessels are defined in terms of their major characteristics and lifting principles. Since it is very difficult to follow the development of all the new types of vessels, emphasis is given only to those examined by industry experts.

2.2 Vessel Definitions

2.2.1 Hydrofoils

Hydrofoils are advanced marine crafts that use airfoil-shaped structures to lift the hull above the water surface. It has been produced in the greatest number of passenger service. The early success of the hydrofoil encouraged the development of other HSW vessels. Their ship-like displacement or planing hulls are lifted free of the water by underwater wings attached to the hull. They use dynamic lift in the same manner airplanes use it in take off. The main difference in the design principles, between the two modes of transportation, is the fluid that generates the lift (water vs. air). There are two major types of hydrofoils. The surface piercing and the submerged-foil types. Each one derives its name from

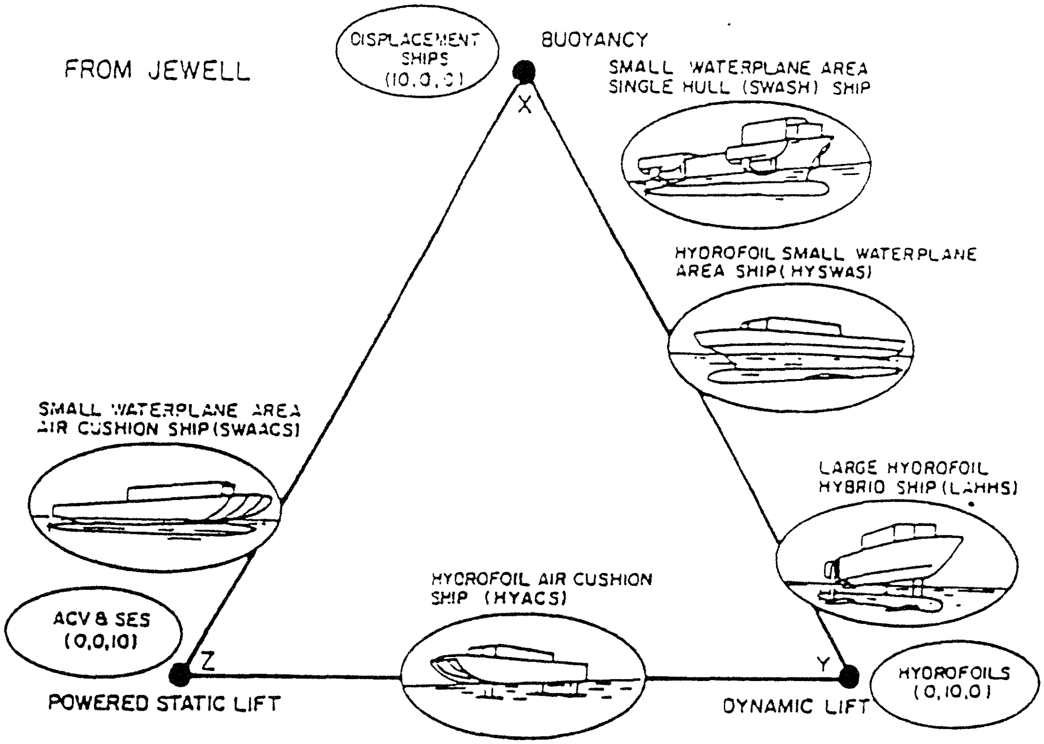


Figure 2.2 Jewell's triangle. The Vrious Types of HSW Vehicles are Determined by the Means they use to support their Displacement

the way the foils are placed with respect to the water surface. Surface piercing hydrofoils use lifting surfaces that generate lift which is proportional to forward speed and wetted foil area. On the other hand, fully submerged hydrofoils use non lifting struts to connect the hull to the lifting surfaces which are always submerged. The former type of hydrofoils is extremely stable, while the latter type uses controlled flaps to assist the foils. Recent designs have tried to combine both systems together. Hydrofoils are not really vessels carrying any new technology. They were developed in the late sixties - early seventies and have been used widely in many services.

2.2.2 Air-Cushion Vehicles (ACV)

This is the second most popular type of HSW vessel. It develops its high speed by the use of fans which blow air under the hull and lift the craft clear of the water. Thus, the draft of these vessels is significantly reduced. The air is trapped with the help of flexible skirts that surround the craft. In calm water the ACV provides a small clearance which makes it truly amphibious. The ACV has found several applications in various terrain, which makes it unique as a vessel.

2.2.3 Surface Effect Ship (SES)

Known also as the rigid, side-wall Air-Cushion Vehicle (ACV), it also uses a cushion of air to lift the craft from the water surface. The main difference from the ACV is that its side skirts are rigid and only the fore and aft parts are flexible. Usually SES's speeds are a little lower than those of the ACV's. Nevertheless, when the two are compared it should be taken under consideration the lower maintenance and better seakeeping that result from the solid walls of the SES.

2.2.4 Catamarans

Catamarans are the type of new technology vessels that are currently going through major development in their design. They are candidate designs with great potential. They have two displacement or planning hulls supporting the main body of the ship. By having two slimmer hulls instead of a single and wider one they have much less resistance and smoother motions through the water. A lot of work has been done to eliminate their main disadvantage; seakeeping in rough, following seas. The Catamarans develop lower top-speeds than the ACV's and the SES's and there exist many variations that have been developed. They offer simplicity of construction and operation and are relatively low in cost. Another attractive characteristic is their wide overall beam. They are developed and used widely in New Zealand., Australia and Scandinavia.

2.2.5 Wave-Piercing Catamarans

These are the latest development in catamaran design. Instead of two hulls this type of catamaran has three. The two side-ones are even more slender than those of the ordinary Catamarans. They provide the necessary buoyancy for the vessel to run fast and smooth by piercing the waves, and that's how they get their name. The third (middle) hull looks a lot like one of a small mono-hull and it spends most of the cruising time hanging above the water surface. Only in high sea-states does it provide additional buoyancy. These vessels are now built up to 130 meters long and develop speeds of about 50 knots.

2.2.6 Planning Mono-Hulls

This type of craft was developed by the U.S. Navy a few decades ago. They use dynamic lift developed by their large bottom area in order to plane off the water. Planning Mono-hulls are very appealing to the high speed ocean racers and the motor yacht industry. They operate in lower speeds than 25 knots in order to conserve fuel.

2.2.7 Small-Water Plane Area Twin Hull (SWATH)

As its name implies a SWATH has two hulls that support the craft. Unlike the catamaran, the two hulls have shaped structures underwater that act much like a submerged submarine and that offer a low waterplane area. The major advantage of this concept is the reduced motions in rough seas with less drag than a conventional catamaran. In the mean time, they require much higher powering in calm water at low speeds. Also called the "Semi-Submerged Catamarans", SWATH's can operate in speeds over 25 knots, as wide beam ferries with good ride qualities and passenger accommodations.

2.3 General Remarks

There are many other types or combinations of the above technologies and characteristics that could be presented, but since they aren't extensively used, they have been excluded from this thesis.

In order for someone to understand how these HSW vessels could compete with the conventional crafts, it is important to specify the competitors.

Although the average number of passengers carried on a fast ferry is around 210, today the trend is to build larger HSW crafts. Already crafts that are used for many years in crossing the English Channel or the Pearl-River Delta can carry more than 400 passengers and over 100 cars.

On average, HSW vessels operate in routes having riding times under 1.5 hours and cover route-distances of less than 50 nautical miles. Since the value of time has rapidly increased, lately, HSW crafts operators have been able to charge more than other competing transportation modes that serve the same route (with the exception of airplanes). Since their fares are sometimes significantly higher than those of the conventional ferries, HSW vessel operators have introduced discount features such as those used in the airline industry (group discounts, frequent travelers, elderly persons, students or prepaid tickets, etc.), in order to attract more passengers. With the exception of some routes in the Mediterranean, Scandinavia and the Far East, all HSW services compete with other travel modes. Most of the times, the ridership is seasonal and an average annual loading factor can be as low as 45 percent, while seasonal minimums rarely become lower than 79 percent. These riderships cover two major categories of travel markets; business trips (commuting) and recreational trips. Hence, selecting for a service area the appropriate vessel to serve it, is a complicated task and as it will be shown in the following chapters it consists of several steps which evaluate the candidate vessels under design, performance and suitability criteria.

Chapter 3

The Effect of Route Characteristics in the Selection of the HSW Vessel

3.1 Introduction

A primary step in selecting the appropriate HSW vessel for a considered service is the identification of the route on which the vessel will operate. A route is described by its type and its physical characteristics. Although the type of the route may not be universally determined, there are three major types of services that are globally recognized.

- Urban Services,
- Inter-city Services and
- Island Services.

Another way to define HSW services would based on the geographic location of the site served. There are:

- Ocean Services,
- Island Services,
- Coastal Services and
- River and Estuarial Services.

Cruising-Top Speed (knots)	5 Nautical miles	10 Nautical miles	20 Nautical miles	40 Nautical miles
25	16	28	52	100
30	14	24	44	84
35	12.5	21	38	72.5
40	11.5	19	35	64
45	10.5	17.5	30.5	57
50	10	16	28	52

Table 3.1 Total Time Required for Trips at Different Serving Speeds by an SES for Various Distances

The Urban services are usually based in greater metropolitan areas providing services to commuters. They are usually composed of work trips, non-work trips made by residents and trips made by visitors to the served area. Work trips transport the bulk of their customers during the morning and early evening hours, while the rest of the passengers are transported throughout the day. Urban services can be either coastal or river services, connecting major cities/business centers located on the coast or on the banks of a river with commuting sites located on either locations.

The Inter-city service is a larger scale service that connects two cities separated by a body of water, where land modes of transportation run in a more circuitous route. These sites are of particular interest since they allow to the vessels to demonstrate their superior characteristics. These trips are usually for business or tourism and recreation. As it will be shown in a later section the distance covered by an HSW vessel and the number of stops are two of the factors influencing the route's characterization. Inter-city services can be of both the coastal and river type. Inter-city services can also sometimes be of the ocean type (Japan-South Korea and China).

Island Services connect island locations with a mainland or/and with other island locations (Inter- Island). Passengers on this type consist of some commuters, of people visiting a location for short business trips and of many tourists. The location of the islands with respect to the mainland or any other port consisting the service, dictates the percentage of each group of passengers. Depending on the distance separating the islands from the mainland, Island services can either be of the island geographic type, or can be of the ocean type.

For an HSW service, ridership is influenced to a great extend by the fare structure. The determination of the fare structure is not a static event. The competitiveness in the region to be serviced can alone influence fares and outcomes. Union movements and legislation can also play an important role in the selection of a service area.

A market analysis carried in conjunction with the vessel selection is necessary, as the former affects the characteristics of the latter.

3.2 Market Assessment

A preliminary market assessment could determine the general feasibility of an HSW passenger operation for a particular route before an operator invests significant resources to the purchase of a vessel. It usually provides a wide selection of sites to be serviced, or alternative routes connecting the same sites. The objective is to clarify the service, identify and evaluate the options within a more general service area. Each service option (site) is identified by the type of market to be served. These types are the three categories mentioned earlier in this chapter. Sites that are eligible for this stage of the selection combine high resident and tourist populations that will use the HSW service for transportation.

Cruising-Top Speed (knots)	5 Nautical miles	10 Nautical miles	20 Nautical miles	40 Nautical miles
25	18.8	21.4	23.1	24.0
30	21.4	25.0	27.3	28.6
35	24.0	28.6	31.6	33.1
40	26.1	31.6	34.3	37.5
45	28.6	34.3	39.3	42.1
50	30.0	37.5	42.9	46.2

Table 3.2 Average Speed (Knots) for Different Distance Trips at Various Serving Speeds for an SES

As mentioned before the type of the market in terms of trip purpose and volumes is a key factor in the assessment of both the market and the route to be serviced. It is very important to develop an estimate of total travel demand, which in a break-even analysis would determine the fare structure and ridership characteristics. In a break even analysis first the service has to be determined and the market penetration to be estimated considering the competing transportation modes. Then by estimating the number of trips, the annual cost can be estimated, which will give the required fare. Several iterations of this process can result in a successful HSW service. Yet just a break even analysis is not adequate. Figure 3.1 shows this iterative process in a schematic form.

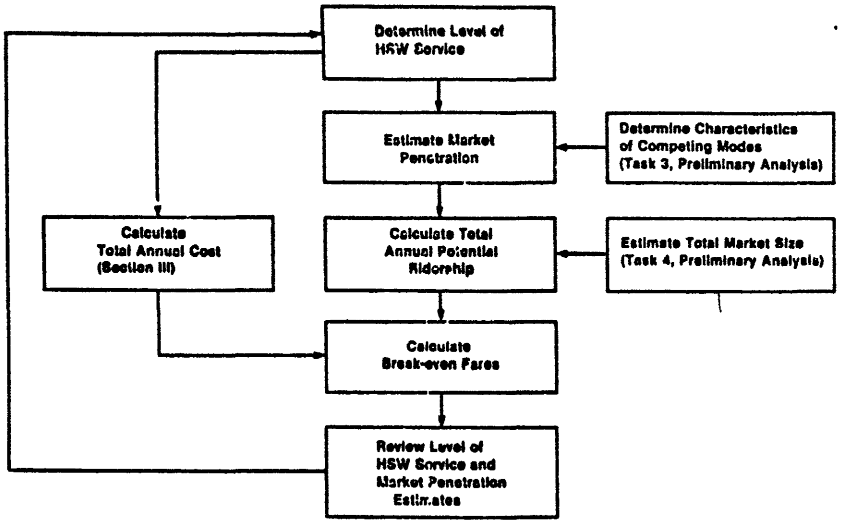


Figure 3.1 Break Even Ridership Estimation Approach.

Usually, when evaluating a new venture, future demand is estimated based on a proforma calculation, a projection of past, known data to the future using similar growth rates (patterns) as these observed in the past. Similar adjustments have to be performed for travel estimates. Current travel data could easily be adjusted for future projections by using several economic measures, for which more accurate projections have been established. Such factors can be unemployment, population and tourism. Multiplying the travel estimate of a known year with the ratio of an economic factor of the future year to that of the year that the estimate was got, will yield a reasonable adjusted estimate. More clearly, if TR is the number of trips for year Y1, the trips of future year Y2 can be estimated by:

$$\text{Trips year Y2} = \text{TR} \times (\text{Unemployment Y2}) / (\text{Unemployment Y1}) \quad (3.1)$$

In estimating the demand of the HSW service both market surveys and mathematical models can be used to better estimate the market's size and the market's capture. Figure 3.2 shows the results of such a model as it was performed by AMSA Inc. [2] for an urban site. Figure 3.2 demonstrates the effect of fare and speed variability to the number of passengers using the HSW service.

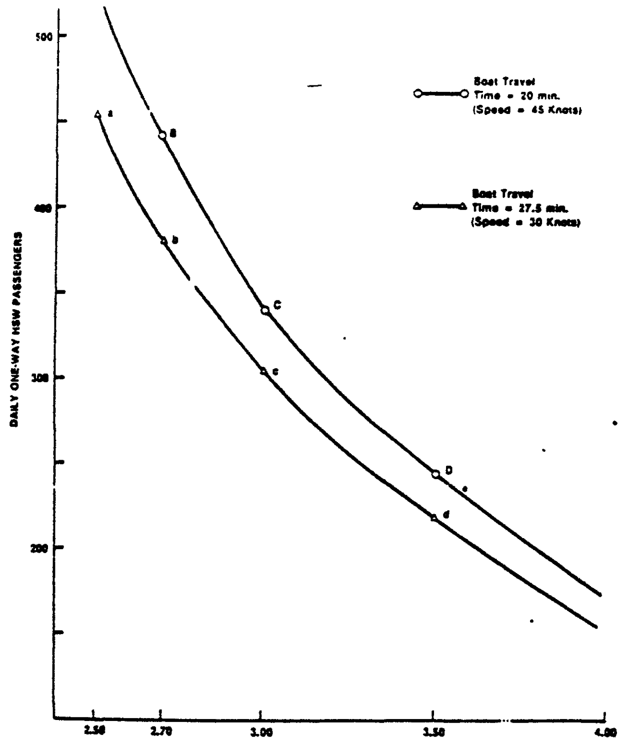


Figure 3.2 Example HSW Ridership Curves for two Different Crafts

Alternative markets such as urban markets that are typically composed of work, residential or tourist trips, and inter-city or inter-island markets composed of business and recreational trips can demonstrate great variability in demand, depending on seasonality, time weather and many other factors. The accuracy of demand prediction is crucial for the success of a new HSW service.

Speed (knots)	33	35	37	39	41	43.5
Output (HP) Full Payload	4,350	5,070	5,850	6,600	7,450	8,400
Output % of HP at 33 knots	100	117	134	152	171	193
Fuel Consumption (lr/hr)	815	950	1,100	1,240	1,975	2,230

Table 3.3 Power Requirements for a 42 meter Catamaran under Fully-Loaded Conditions

From Foss'91 [16] it can be shown that a lower than the predicted demand, can be fatal in the operation and survivability of a High Speed Waterborne service. Although not explicitly expressed, from Tables (3.3) and (3.4) it can be shown that lower passenger demand for the service can force a fast-ferry to less efficient operation. Lower demand obviously expresses lower payload aboard the vessel. A lower payload translates to either higher speeds for the same output of Horsepower, or a lower Horsepower rating for the same speed as with full payload. In either case the engines will consume more fuel as they will operate at lower than the design point efficiencies. Table (3.3) shows the effect of higher speeds to the fuel consumption, while Table (3.4) demonstrates that at 50% payload, a 42-meter fast catamaran requires only 10% less power from that required at full payload when operating at the same speeds. The cost factor that would be affected would be the fuel cost. A measure of fuel cost is the specific fuel consumption (SFC), which is the amount of fuel burnt per unit of time per HP used. The SFC's value grows rapidly when the engines operate at points away the optimum design point. The total fuel burnt in a trip is the product of the average HP used, times the SFC, times the units of time (T) of operation of the vessel during that trip (HPxSFCxT). A 10% reduction in HP, will rise the SFC by a much higher percentage and thus drive the final fuel consumption at higher levels contributing to a loss from the vessels income. Considering the fact that most of the payload difference is passengers, it is obvious that the net loss is quite higher.

Speed (knots)	33	35	37	39	41	43.5
Output (HP) Half Payload	3,730	4,590	5,280	5,950	6,750	7,530
Output % of Full Payload	86	90	90	90	91	90
Fuel Consumption (lr/hr) Half Payload	695	860	990	1,110	1,790	1,950

Table 3.4 Power Requirements for a 42-meter Catamaran under Half-Loaded Conditions

A potential operator should clarify the type of service to be provided and the market to be serviced, so that potential ridership can be estimated. All the alternative routes as well as terminal locations should be considered and evaluated. HSW routes that are successful, usually have significant time advantages when compared with overland routes. This fact is usually true in lakes, bays or in the ocean, where land routes either do not exist, or they are too circuitous and congested. The terminal facilities should provide convenient access to the origin and destination of people using the service. The terminals should be selected based on customer convenience and access to the markets served and the vessels' needs. The use of existing terminals or the construction of new ones should be the outcome of the balance of these considerations along with the cost factors involved with leasing or constructing a terminal.

Once the more general area to be served has been established, all the alternative routes should be examined and evaluated. For an HSW service to be successful, its sites when connected via a water route would demonstrate obvious advantages when compared to existing or more conventional (even waterborne) means of transportation.. By clarifying the type of service, the operator can better estimate the ridership. Secondary markets that will enhance the financial performance of the HSW service may emerge alongside the primary ones originally considered for service. The larger the area attracted by the HSW service the larger the ridership shed, the larger the possibility for a successful service.

After the preliminary assessment, the operator should decide on the most profitable market based upon a more in depth analysis. The operator should identify the market's size, and potential capture and should estimate its projected growth. Also, all the competing transportation modes, serving the underlined market, should be evaluated as potential threats to the HSW service, for both the present and the projected future.

3.3 Comparing HSW Vessels with other Transportation Modes, Based on Economic Factors

Once the potential routes have been selected and the ridership sheds have been defined, a comparative analysis of the alternative modes of transportation should be carried out. Such an analysis will provide an estimation on whether the HSW service can provide travel times and fares that are competitive with other modes of transportation. Of the aforementioned types of markets that can be served by HSW services, each market has different modes of transportation serving the same site as competitors.

In Urban routes, HSW crafts compete with:
- Buses;
- Commuter rail;
- Automobiles;
- Limousine services.

For Inter-city routes, HSW vessels compete with:
- Commuter airlines;
- Railway;
- Buses;
- Automobiles;
- Limousine Service.

In the Island services, HSW crafts compete with:
- Conventional vessels;
- Other HSW crafts;
- Trunk airlines;
- Automobiles/Railway/Buses in the existence of bridges and/or tunnels.

In comparing the HSW craft under consideration with the competing transportation modes, one should consider the traveling time and cost of travel. Traveling time is the time it takes to cover the distance (linehaul), the time to approach the terminal (access), the time to leave the terminal (egress) and the time to reach or leave the terminal door to door. This latter time should include the time spent in other modes of transportation (taxis, subway, bus, automobile to and from the HSW terminal, airport, railway station etc.), before using the HSW craft or the competing modes. The cost of using these additional modes should be included in the final cost of traveling. It is important to understand that the travel data (times and costs) of the competing transportation modes should be organized to coincide with the HSW ridership shed. Before such comparison takes place, the constituents of HSW vessels' efficiency should be well analyzed and understood.

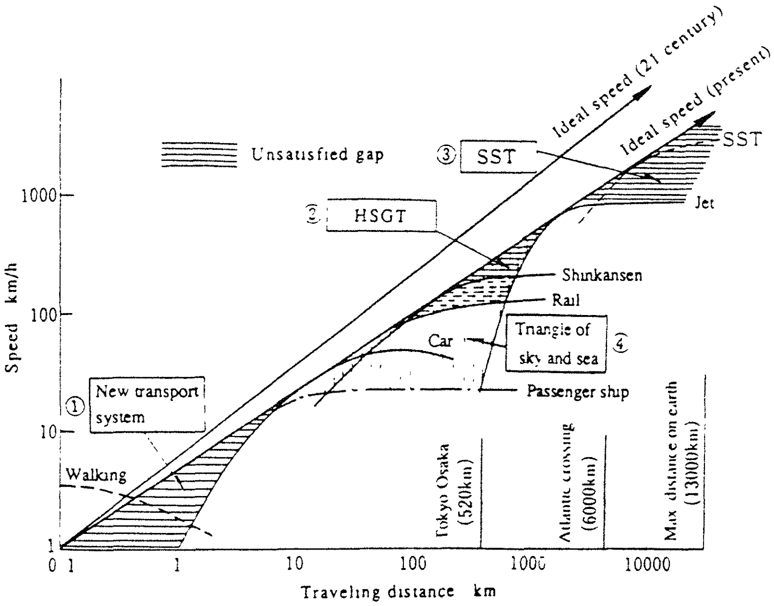


Figure 3.3 Traveling Distance and the Speed Required by Different Modes of Transportation

3.2.1 The Effect of Cruising Speed and Sailing Distance on the HSW vessel's Efficiency

For an HSW service to be competitive, it should take advantage of the vessel's high speed in both the route selection and the trip planning Bouladon (1970). There is a strong relationship between the vessel's minimum required speed and the distance covered by the HSW service in the area. Figure 3.3 is a graphic interpretation of this relationship for several modes of transportation. The straight line determines the ideal relationship between distance and speed when the duration of the trip is constant and around two to three hours. In this diagram, HSW crafts

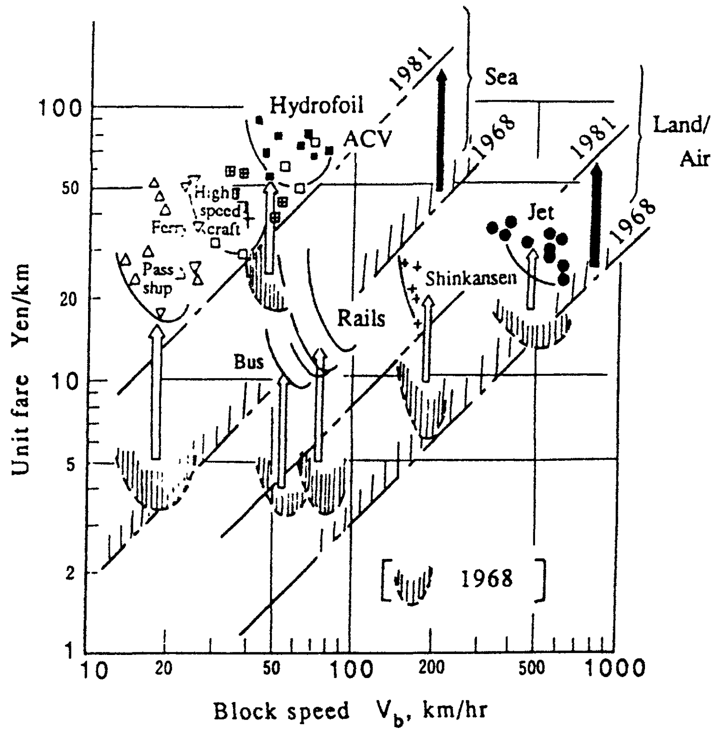


Figure 3.4 Unit Fares of Various Passenger Transport Systems

would fall under the "Triangle of sky and sea " area. It should be mentioned here, that a great influence on the required speed of transportation is imposed by the type of goods transported, as well as by the value of the time for the transported goods. This is especially true for passengers. People traveling for business demand much higher speeds of transportation than people traveling for pleasure.

It should be noted that the total traveling time of any vessel depends of some secondary factors, others than average cruising speed and sailing distance.

In brief, the total time on a given voyage depends on:

- The Sailing Distance (L)
- The Cruising Speed (vi)

- The Number of Stops/Calls en Route
- The Time of Maneuvering to and from Berths
- Changing speed due to Imposed Limits
- Boarding and Embarking of the Passengers
- Accelerating

With an estimated maneuvering time to or from the berth of 2 minutes, an acceleration time to cruising speed of 2 minutes and a slowing down time of 1 minute, it was found that for a fast-ferry traveling at 35 knots, the traveling time to cover a route 10 nautical miles long is 21 minutes. It takes 72.5 minutes for the same vessel to cover a distance four times as long. Table 3.1, demonstrates the effect of the secondary delaying factors, and their effect on an HSW vessel's efficiency. From this Table it is clear that HSW ships loose the high speed advantage when they are called to cover short distances or a long distance with many stops.

From the previous example it could be seen that if the same vessel was asked to cover the 40-mile route with four calls en-route, it would need 4x12.5 minutes, or 84 minutes . Hence the fast ship would loose 15% of its efficiency, or else it would arrive at the 40th mile at the same time with a slower vessel cruising at 30 knots which most likely would charge much lower fares. This effect is particularly obvious at longer routes. In a service operated by a 38.8-meter, Surface Effect Ship catamaran, between the ports of Bergen and Selje, the total sea time is 266 minutes. In a distance of 126 nautical miles, with the vessel cruising at 36 knots, the actual steaming time is only 210 minutes. The rest 56 minutes (20% of total sea time) is spent at the eight calls in Bergen (24 minutes) and maneuvering during these calls (32 minutes). The same effect of the number of stops en route to the efficiency and performance of an HSW vessel can be shown by Table(3.2), which demonstrates that the shorter the route the lower the average speed of the ship. In order to reduce these losses, the designers of HSW vessels try to ensure fast embarkation and disembarkation of the passengers. Assuming that the vessel would spent one extra minute per call for embarkation reasons, in order to make up for the lost time it would have to increase its speed by 1.4 knots per hour, or a 9.5% increase in Horsepower. Similar would be the benefits in the case of lost time reduction by one minute.

3.2.2 The Effect of a HSW Service on the Route Served

When considering the establishment of a new HSW service, which would either replace a conventional liner service or would compete among other means of transportation, a very important factor to consider is the effect of either service in the development of the areas served by that service. The effect of a HSW service can be either relieving or constructive. In the case of the San Francisco fast mono-hull service, it was the increasing traffic of the Golden Gate Bridge that was relieved. On the other hand, HSW services have led to the development of can increasing number of locations for commuting. In countries as different, in both geography and people's routines, as Norway and Japan, HSW services have turned trips with unpleasant and inconvenient operating hours, that usually required overnight accommodations into pleasant commuting routes. Traveling time in Norway has been reduced by up to 70% compared with the traditional shipping services. Thus, realistic commuting opportunities have risen for locations along the Norwegian coast. Hence the fast-ferry services provide a necessary condition for continuing settlement in many coastal areas.[15] In the same manner, weekly trips for supplies from remote island locations in Japan, that also required planning and accommodations, now have become daily, inexpensive and efficient, while the vessels remain simpler in terms of accommodations that are not required any more.

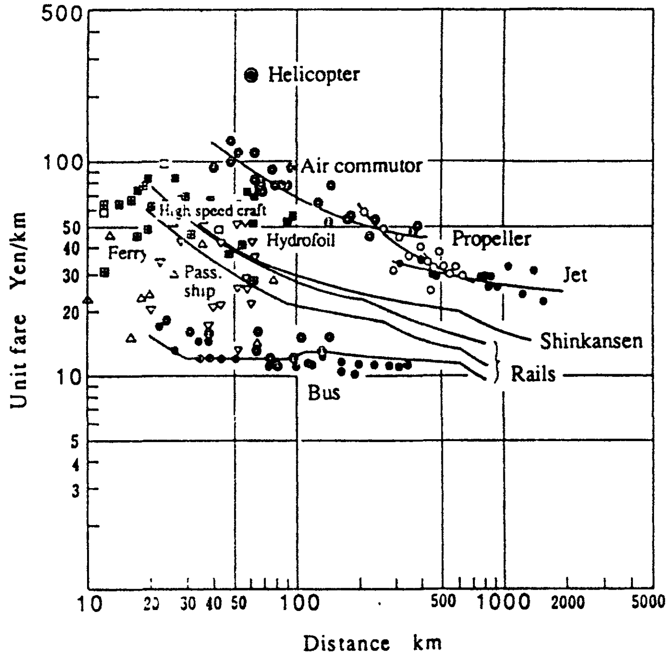


Figure 3.5 Unit Fares of Different Transport Systems as Affected by the Distance of the Trip

3.2.3 Economic Comparison of HSW Services with Other Modes of Transportation Based on a Shared Route

In order for someone to better understand the need for a high-speed, low-cost mode of transportation, it would be wise to compare competitive means of transportation on a unit-cost basis as this relates to the speed and the distance of the trip. The demand for speed as shown in Figure 3.3, can highly vary from one transport system to another. The demand is different between passenger transport and cargo transport, between business trips and recreational trips and it is highly affected by the value of passenger time. The time value of an investment banker commuting to his office is much higher than the value of time of a visitor to Martha's Vineyard, just like perishable goods have higher value of time when transported than coal cargoes. Both investment bankers and perishable goods require higher speeds and are willing to pay more for it. Agagi [4], in 1991 gave unit fares for various passenger transport systems in Japan. which are representative of global trends. These fares as shown in Figure 3.4 are noticeably higher for fast marine transporters. The fares of these vessels drop significantly with the distance of travel. From Figure 3.5 it is clear that HSW crafts are more cost effective in distances around 60 kilometers when the unit fares of some high-speed crafts is more competitive than the conventional ships and even the high-speed rail. For much longer distances the airplane becomes more competitive. High-speed rails remain always competitive transport modes, assuming that they do not have to follow a circuitous and longer route in order to serve the same sites.

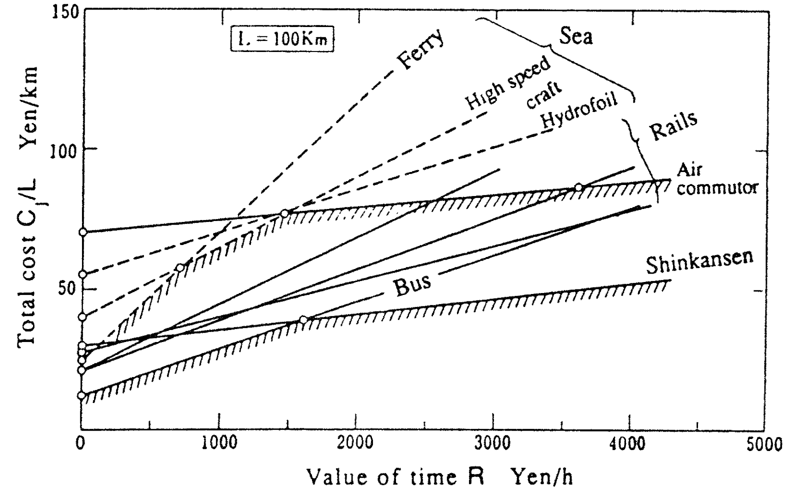


Figure 3.6 Total Cost Cj of Various Transport Systems as a Function of Passenger Value of Time

From the aforementioned two graphs, it should be noted that the unit cost (fare) increases with speed for any mode of transportation. This cost is reduced depending on the vehicle used and the distance covered. In routes of very long distances where the airplanes become more efficient, the conventional ships can not compete, mainly due to lack of speed. This fact underlines the need for HSW crafts in certain areas, where the gap of speed between the ships and the airplane will be somehow bridged.

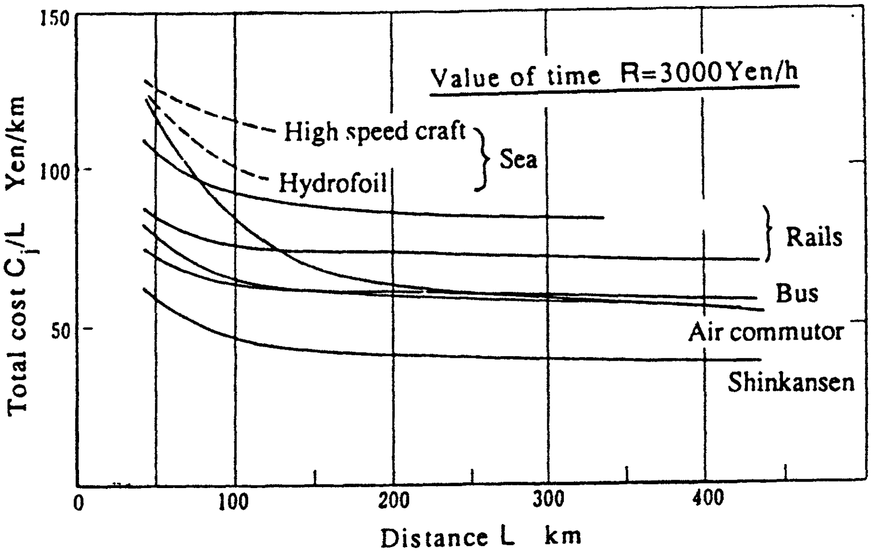


Figure 3.7 Total Cost Cj of Different Transport Systems with Respect to Distance for A Value of Passenger Time R=3,000 (yen/hr)

A very useful way of determining the competitiveness of a transportation is based on the total cost of traveling, related to the route's characteristics, the vessel's speed and the unit fare. By accounting the value of time, the total cost of traveling, based on the above transport fares, is:

$$Cj = R \times (L/Vj) + aj \times L \qquad (3.1)$$

where,

- **Cj is total cost of traveling per person with mode j**
- **R is the value of time for an average passenger**

- L is the distance of the trip
- vj is the speed of mode j
- aj is the unit fare for mode j

  and
- j is the index of each mode

An ideal transport system would be the one that, for a given route, would minimize the cost of traveling Cj.

Figures 3.6 and 3.7 show the comparison of various modes of transportation. The results are based on variation of the constituents of Formula (3.1). Figure 3.6 shows the total cost of different transport systems while varying R, for a route with a travel distance L of 100Km . In a similar manner Figure 3.7 shows the total cost of the same transport systems with respect to the travel distance, when the value of time, R, is kept constant at 3,000 yen/h. From these graphs, it is clear that for the given travel distance L=100 Km, the land based modes are more competitive, while high-speed crafts and air-commuters are considered by some passengers (R>>3,000). On the other hand, for an average passenger (R=3,000) the high-speed train is the most attractive mode of transportation, for small to average distances, while the sea going vehicles are the least desirable.

Nevertheless, from Figure 3.8, it is clear that as these vehicles become faster with less additional cost for every unit of higher service speed, they take a greater share of the market, and thus, HSW services become as attractive and competitive as the airplanes. If the designs of the HSW crafts follow the same trends that they followed until now, we will see more of them entering everyday life. Such a fact is lately shown by the improving transport efficiencies of the latest hybrid HSW vessels, an issue visited in a later chapter of this thesis.

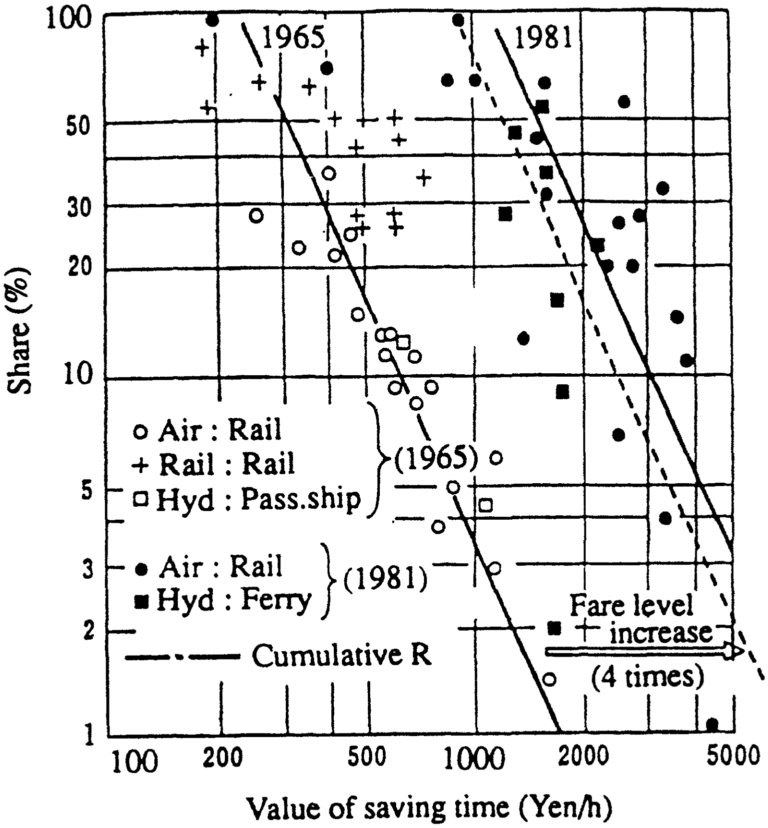


Figure 3.8 Share of Different Transport Systems Operating in the same Route as Affected by R

After the competitiveness of the HSW service has been determined for the specified area, a forecast of the future demand for such an HSW service should complete a preliminary determination of the feasibility of such a service.

This analysis should be repeated in a spiral format, and the final iteration should determine the number of vessels required and the market share that the proposed service will achieve. One should not forget that the HSW route and facilities should not impact environmentally sensitive areas such as wetlands and population centers.

Chapter 4

Craft Selection Based on Vessel Performance

4.1 Introduction

The design practices of the HSW crafts have been driven by some major rules and modern trends. The most predominant one is the reduction of wave induced drag by lifting the bulk of the volume of the vessel away from the waterline. This shift is achieved either with the use of dynamic lift generated by the hydrofoils or by the use of floaters that carry most of the displacement of the vessel (SWATH). More recently vessels are built based on the principle of function separation in the design and construction of the vessel (Agagi, 1991).

These two design principles lead to a completely new breed of vessels in which the cargo carrying section of the vessel is separate from the section providing the buoyancy of the craft. This would serve in better meeting the reasons behind developing and purchasing an HSW craft. Of these reasons it is worth mentioning high speed, good seakeeping, ease of loading-unloading, better safety for the passengers and the environment, better onboard accommodations, as well as a better and more cost effective construction. All of these characteristics would serve towards a more competitive and appealing appearance of the HSW crafts in the transportation arena.

Before anyone could propose crafts that could become potential candidates for any particular transportation service, some criteria and operational limitations should be placed, which would better define the service that the vessel will be deployed for and narrow down the selection of the vessel. Of the factors that must be considered in selecting a vessel for a given HSW service, other than design limitations, major importance should be given to these related to the passengers safety and comfort. These features will make a vessel attractive or repelling and can lead to the success or failure of even the most wisely selected site and service. Of these performance factors, the most important one is seakeeping; the way a vessel behaves in rough seas. Other criteria involved in the vessel selection are dictated by the route served. Whether accommodations or refueling are required for a trip are unique characteristics of each service, that nevertheless reduce the number of candidate vessels. Finally, cost characteristics such as maintenance, frequency of failure and consumption narrow the selection process to fewer vessels.

A very careful analysis is needed to determine the proper craft for the intended route. The range of the available crafts, which vary in type, characteristics and cost, should be addressed. Such information must be considered before a craft is selected.

4.2 Design Limitations

Design limitations imposed by the route are easy to evaluate and function as a quick tool for reducing the number of vessel appropriate for a service. After a route has been selected, evaluated and characterized as a cost effective service for the operation of an HSW craft, design constrains are placed by the physical characteristics of the route and the environment of operation. These are speed, length, beam, draft or maneuvering constrains that sometimes do not allow the use of the most cost effective vessel for the route. The maximum draft to be considered is the operational displacement draft. This is the off-cushion draft for SESs while for hydrofoils is the draft of the foils when these are lowered. For water-jet propelled vessels five additional feet should be added to the draft of the vessel for clean operation. Also, there are certain facilities, terminals and infrastructure that each ferry-boat (as well as any other means of transportation) requires. It might be more attractive to enter another market, or the same market at another site, than to construct all the necessary facilities required for the operation of the vessel.

Then, there are limitations to the required vessel's performance imposed by the route served. The use of an HSW craft is attractive under certain terms. Mainly these terms have more to do with the operational cost and the speed of the craft. If a vessel can not cover the required distance in a certain time, then the service might not be attractive to the public. Also, if a vessel has high operational cost in order to achieve the required service speed, it will reflect to the break even fare. In that case if it is very expensive to use a new technology vessel, another transportation mode should be considered.

4.3 Wave Handling

Several factors related to the vessel's performance must be considered in the selection of an HSW vessel. Although in calm water the ships performance is limited mainly by the available horsepower, in seaway, the vessel's performance consists of its speed through the waves, its motions and its structural integrity. Since an HSW vessel would have to operate in a variety of wave conditions, a number of factors can dictate its top speed. The structural forces that these vessels encounter are of principle interest, as they can cause disastrous accidents. It is the knowledge and the experience of the captain that plays an important role. Based on his judgment, the captain should reduce the speed accordingly. Stability and maneuverability are also affected by the sea-state. A good candidate vessel should be able to maintain these two features at the highest possible level. Seaway characteristics and the craft's responses in maneuvering can broadly vary.

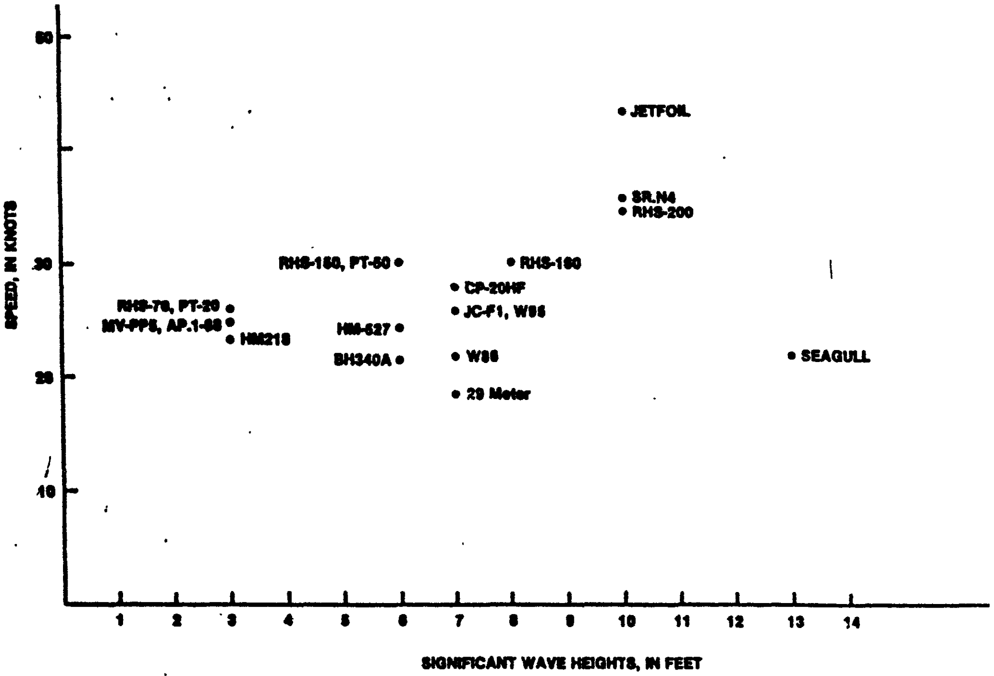


Figure 4.1 Highest Waves and Operating Speeds for Passenger Comfort

Major limitation on any ocean-going, public-transportation vehicle is imposed by the ability of the vessel to perform well in various sea-states. Fast boat designers all desire to design vessels which will give the smoothest possible ride. As a baseline for comparison is used the ride quality of a jet plane. Although in general fast ships travel in rough seas at reasonable quality, yet, there is no available technology that will generate the smooth ride of a jet plane, when aboard a fast ship, at a reasonable cost. Seakeeping quality in conventional vessels has been evaluated by examining the vertical acceleration of the vessel at its longitudinal center of gravity. If the RMS value of the acceleration is less than 0.2g, the seakeeping of the vessel was considered adequate. Nevertheless, high-speed vessel have demonstrated more complicated responses in waves, especially in following seas, that make the prediction of their seakeeping inadequate by simply estimating their vertical acceleration in waves. Critical aspects of the seakeeping of these boats are the natural heave, roll and pitch frequencies. Primarily, the seakeeping quality of the fast vessels is assessed in terms of motion sickness incidence (MSI). The techniques used are based on a frequency weighting of the seakeeping performance. When any of the primary motion frequencies gets close to the frequency of encounter with waves, the vessel is synchronized resulting to amplified motions that cause discomfort and motion sickness. Although the conditions of synchronism vary from one vessel to another, most fast vessel will encounter it at some time of their ride through ocean waves. Synchronism depends primarily on the vessel's relative heading of encounter and speed, as well as the seastate.

Hercus [17], used results of a series of full size trials in order to compare the performance of a wave piercer to a conventional catamaran in the same sea states. Both vessels had an approximate DWT capacity of 35 tones and a service speed of about 25 knots. Figures 4.2-4.4 show the results of the comparison.

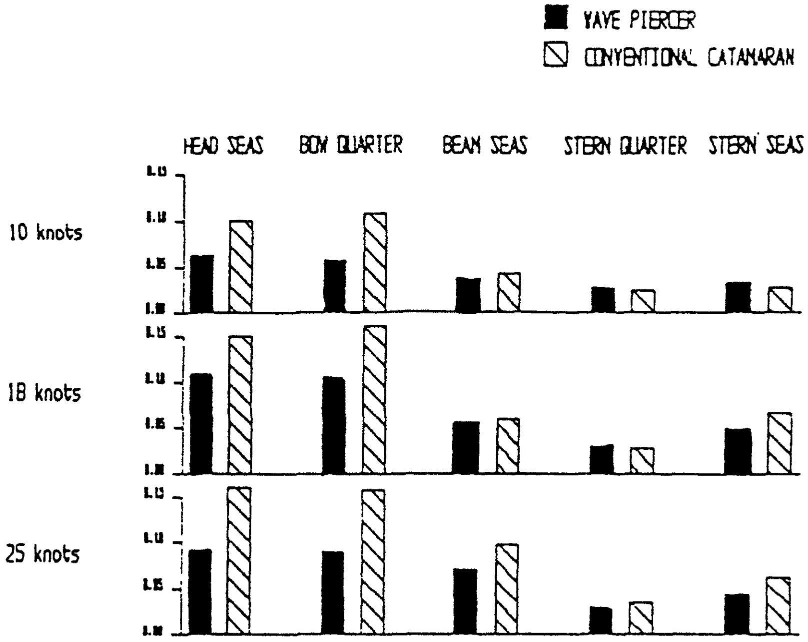


Figure 4.2 Comparison of Heave Acceleration of two HSW Crafts at the Same Sea State, Various Speeds and Relative Headings of Encounter with Waves

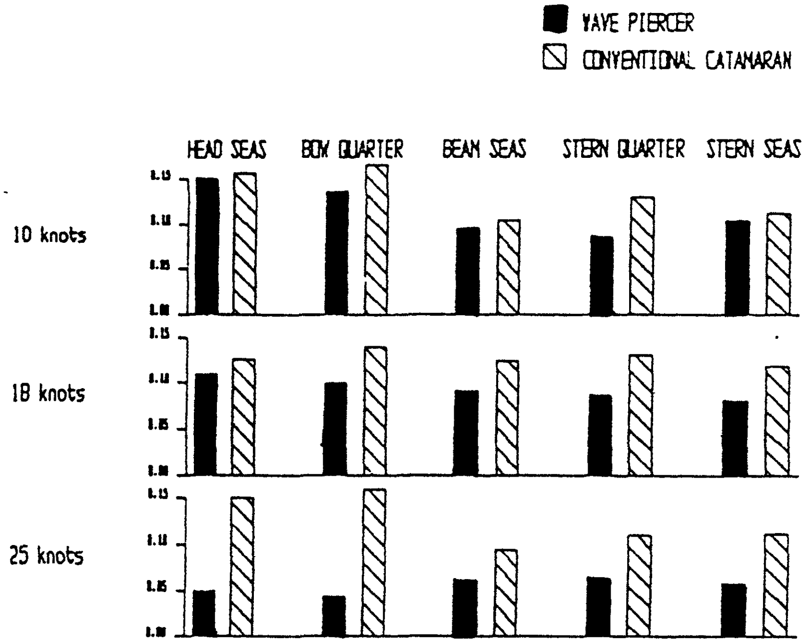


Figure 4.3 Comparison of Pitch Acceleration of two HSW Crafts at the Same Sea State, Various Speeds and Relative Headings of Encounter with Waves

The performance of the two vessels was evaluated at different speeds and relative headings of encounter with waves, demonstrating the effect of the two major factors upon which the seakeeping of the HSW crafts depends. The three graphs also show how a different approach (Piercer vs. Conventional) to the same design concept (Catamaran) affects performance.

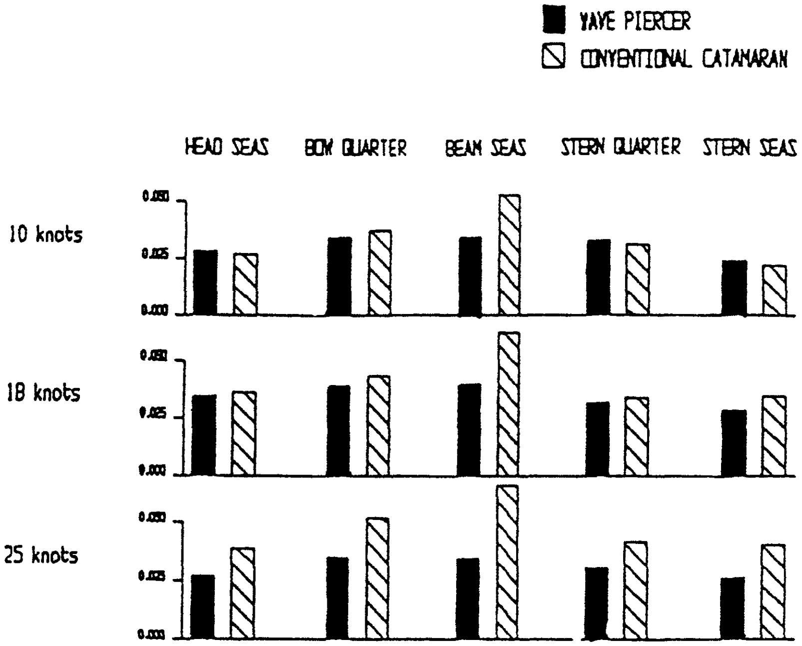


Figure 4.4 Comparison of Roll Acceleration of two HSW Crafts at the Same Sea State, Various Speeds and Relative Headings of Encounter with Waves

On the other hand, the effect of the third major factor affecting the performance of HSW vessels of different design concepts, seastate, is shown in Figure 4.5. Although there is limited performance data for the HSW crafts, seven high speed crafts were compared to a monohull. It is very significant to compare vessels of similar size and speeds as these two characteristics can greatly affect seakeeping. The eight vessels compared here are of 75 tones DWT capacity, cruising at an average service speed of 33 knots. The results are presented in percentage of MSI aboard the eight vessels at different frequencies of encounter. The significant wave height was kept constant at 2 meters, while of the data found, only head seas response is presented. As shown from the graph, the MSI in 6-second waves is higher than both 9 and 3-second waves. The data presented was taken from several sources found in [17]. These figures show clearly that some designs like the wave piercer catamaran are unconditionally superior than others. On the other hand, some vessels (SWATH vs. Monohull) may perform better in certain sea states (6 second waves), while perform worse in others (9 second waves).

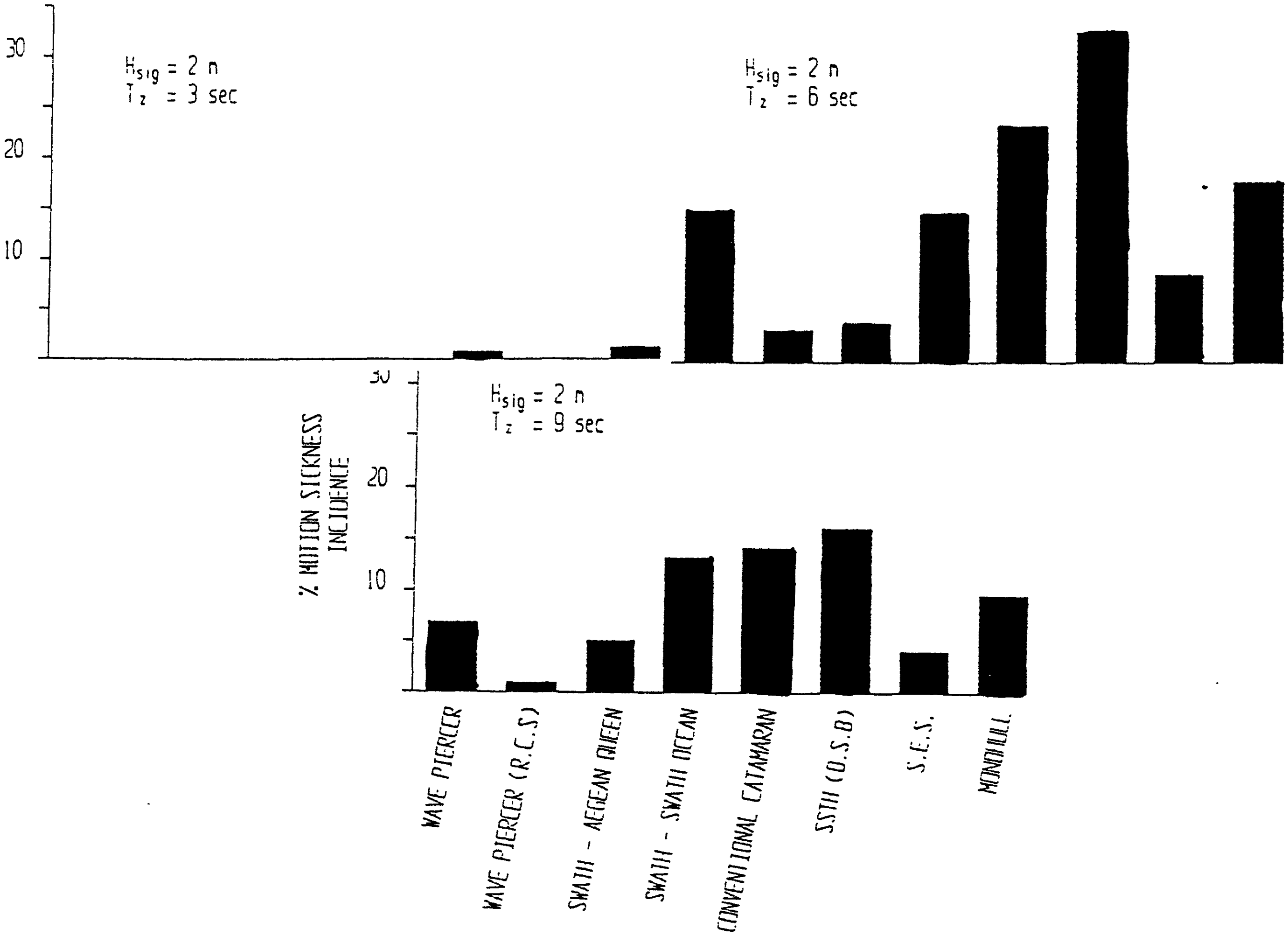


Figure 4.5 Calculated Motion Sickness Incidence for Various Vessels of 75 Tones DWT Capacity of the Same Speed but Different Sea States

Considerations of ride quality and the comfort of passengers are particularly important in imposing limits on speed in waves. The highest sea-state or wave-height that a vessel can operate, while providing passenger comfort, is a limiting factor, and for the shake of the smoothness of the ride, the vessel might have to slow down. As mentioned above such a trade-off could take the operation of the vessel outside its cost efficient operational limits and make it an unattractive candidate.

The percentage of the vessel's operational life spent under the various sea-states could redefine the effectiveness of its use in a certain service. Figure 4.1 indicates the maximum wave-height that some HSW crafts can operate under, while providing comfort to their passengers. Also, for each craft, its maximum speed at this maximum wave-height is shown. Again, these are not the limiting operational conditions for the safety of the vessel, but rather for the comfort of the passengers. A good rule of thumb for selecting a vessel under this criterion would be to reject a vessel for a certain route, if it would operate more than 15% of its service-time in waves of higher than the limiting wave-height shown in Figure 4.1.

The seakeeping of these vessels is not influenced only by the wave amplitude, the heading of the vessel with respect to the predominant direction of the waves and the frequency of encounter. The steepness of the waves, along with some slamming noise, that is disturbing and sometimes alerting to the passengers, without greatly altering the seakeeping of HSW vessels, may change the public's perception when compared to the conventional mono-hulls.

Nevertheless, large, conventional ferries could be threatened by other new technologies. In Italy, the operation of the most advanced, super-fast mono-hull, GUIZZO, sets new standards for fast ferries. In a route between Italy and Sardinia, it covers most of the 124 miles trip at its top speed which exceeds 43 knots, while loaded with 450 passengers and 126 vehicles. The cost of traveling is only 15% higher than that ridding a conventional mono-hull ferry. Similar is the price difference between the conventional monohulls and the wave piercing catamarans operating in the route between England and France. In both services, although different in nature, there is a significant preference over the conventional, but yet slower crafts.

Most operators of HSW crafts have only one type of vessel, usually built by the same builder. Of those having more than one type of crafts, a relatively high percentage is usually in a transition period of replacing one type with another. Hydrofoils that might remain very efficient carriers for short routes that are not greatly affected by the weather, as they approach the end of their economic life , are going to be replaced by other types of HSW crafts of newer technology.

Independent of the seakeeping quality of the vessel, all vessel can improve their ride comfort by altering course without greatly affecting their travel time. Also, alterations of the hull forms may provide additional improvement by altering the natural pitching frequency. Of the most common alterations is the addition of flat damping surfaces that reduce pitching. Nevertheless, synchronism is not eliminated, but only shifted to another frequency of encounter. In this manner, a vessel's hull form can be tuned to perform better at sea states and wave frequencies usually met at the site that the vessel is selected to serve. On the other hand such vessels can be terrible candidates if later transferred to another site. A step further from the simple passive flat surfaces is the use of active ride control. In this case, the surfaces are not stable. Rather they are movable fins controlled by a computer which reacts to the on the vessel's motion which is supplied by sensors fitted around the vessel. Thus, the vessel can ride smoothly in any adverse sea state with an average speed reduction of only 2 knots, due to the additional drag of the fins and the weight of the overall controlling mechanism. This reduction is minimal compared to the improvement of ride quality that such active ride control mechanisms offer. Although the seakeeping of the HSW crafts is an area of refinement and research, it should always be kept in mind that Motion Sickness Incidents are related to the interior appearance of the vessel, the space distribution, several environmental conditions such as temperature and air quality, as well as the passengers' general physical and psychological condition.

4.4 Other Limiting Factors

Other factors that restrict the speed of operation, include the wetness of the deck, spray generation, in-harbor speed limits, waterborne traffic, ice, fog and, in resort areas, water skiers or wind surfers. Another limitation to the selection of an HSW craft can be the port facilities required and used by such a craft. The selection of the proper site to use is driven by the availability of the appropriate facilities. Special considerations for terminal facilities include proximity to other transportation services, particularly to overland systems.

Limitations or conditions associated with the operation on a certain route can also be speed limits imposed by the Coast Guard, or the Port Authorities, clearances for bridges and locks, navigational draft which can dictate the need for retractable struts and foils, or the propulsion by water-jets instead of propellers, corrosion, debris etc.

4.5 Concluding on Vessel Performance

In making the final determination of the vessel to be selected for a particular route and readership, all the factors just mentioned above have to be considered in great detail. Some of them may not be adaptable to any methodical evaluation. Craft availability and financing are two additional ones. Based on the assessment of the route characteristics, craft specifications can be established for the serving speed, passenger and/or car capacities, the maximum draft, vertical height and the desired seakeeping capability. When these conditions are defined, potential candidate crafts for a particular route can be selected. Even though some vessels can be eliminated because of one of these factors, one should consult with the builders in the case of a vessel being of superior characteristics in any other respect, for possible modifications. Table 4.1 shows the ranking of some HSW crafts after they were compared in five different categories.

Design Type	**Speed**	**Payload in Med. Waves**		**Cost at Speed**		**Ease of Cargo/Pass Handling**	**Wave Handling/Comfort Depending on Weather Coastal or Open Seas**			
		Low	**High**	**Low**	**High**		**Good**	**Bad**	**Good**	**Bad**
SES	1	7	1	6	1	3	3	1	9	8
Displacement Monohull	10	1	10	1	10	4	4	6	5	5
Planing Monohull	4	5	5	5	8	4	5	7	5	7
SWATH	9	2	9	2	9	7	1	2	3	1
Techno-Liner TLS-A	6	6	3	9	3	9	1	3	1	1
Wavepiercer	7	2	6	3	5	8	6	4	4	4
Catamaran	7	2	6	3	5	1	6	4	4	5
Hydrofoils	5	10	8	10	3	9	-	-	1	1
Planing Catamaran	3	9	4	7	7	2	-	-	6	9
ACV	1	8	2	8	2	6	-	-	10	10

Table 4.1 Relative Comparison of several HSW Crafts. The Data was got from AMSA Inc. [2]

Once the vessel has been selected, its operational hours can be estimated, which will lead to the scheduling patterns that will ideally utilize the vessel given the seasonality of the route, the vessel's performance and loading/unloading times and patterns. Lately, methods similar to those used by the airline industry are employed by the HSW services for developing scheduling patterns that will maximize the profits of the service.

Chapter 5

Economic Comparison of HSW Vessels

5.1 Introduction

After the preliminary selection process has identified acceptable candidates for the route under consideration, an economic comparison of the vessels is required. Total cost for a vessel is the summation of Operating, Capital and Fixed costs. Operating costs can be broken into several constituents such as crew wages, fuel consumption, maintenance, and insurance. In addition, for an amortized vessel there is the vessel's interest and depreciation as well as the terminal's interest and depreciation. Fixed costs for the operation of the vessel include all the general and administrative costs.

Table 5.2, gives the necessary cost data for an initial evaluation of operating costs. Insurance can be estimated at three percent of the initial purchase cost of the craft for liability and marine coverage. Also the number of annual hours of operation must be estimated.

Table 5.1, contains the initial costs of the various vessels. For the shake of a more consistent analysis and due to lack of current data for most of the vessels,1982-1983 figures are used in Table 5.1. Since design and manufacturing procedures change, not only a present value (PV) adjustment is required, but also a check of these values with the builders is needed. Additionally, it would be necessary to check new safety and communication practices as they may affect the initial cost of a vessel.

Craft Designation	Crew Size	Crew Cost ($/year)	Cruise Speed (Knots)	Fuel Cost ($/Oper. Hr.)	Maintenance Cost ($/Oper. Hr.)	Initial* Cost (Millions $)
HYDROFOILS						
PT-20 Mk II	3	83,000	32	47.10	22.00	1.5
PT-50 Mk II	4	101,800	32	101.40	44.00	2.5
RHS-70	3	83,800	32.4	50.30	26.00	2.0
RHS-150	6	152,200	32.5	116.30	53.00	4.0
RHS-160	6	152,200	35	157.10	72.00	5.0
RHS-200	7	170,200	35	250.00	94.00	7.0
Jetfoil	7	170,000	43	485.00	260.00	15.0
AIR CUSHION VEHICLES						
MV-PP5 Mk II	3	83,800	45	100.00	92.00	3.8
AP.1-88	3	83,800	40	91.00	74.00	2.0
SR.N4 Mk 3	18	402,400	60	1,312.00	1,085.00	35.0
SURFACE EFFECT SHIPS (SES)						
BH-340A	6	152,200	27	160.00	135.00	4.5
HM-218	3	83,800	32	50.50	62.00	1.2
HM-527	5	119,800	33	150.00	138.00	4.6
CATAMARANS						
W-86D	4	101,800	26	98.20	46.00	1.6
W-95D	5	119,800	29	160.00	74.00	2.1
CP-20HF	5	119,800	30	236.00	99.00	5.1
JC-F1	5	119,800	30	160.00	74.00	3.3
29 Meter	5	119,800	24	70.00	34.00	1.65
SMALL WATEPLANE AREA TWIN HULLED SHIP (SWATH)						
Seagull	7	170,200	25	384.00	162.00	8.1

Table 5.1 Vehicle Cost Data for Several HSW Vessels

Terminal costs to be capitalized must also be estimated. Terminals are considered to include maintenance facilities, and can vary in size and services. The terminal costs are greatly affected by the type of purchase or lease, and the extend of repairs to be carried there. Also, the availability of the required facilities will determine whether existing terminals are going to be used, or new ones should be built.

Having all the above information, the interest rate and loan duration must be established. Furthermore, the method of depreciation must be established along with the determination of the salvage value. Sample values could be a 12% interest rate for both the vessel and the terminal, a 10-year loan duration for the craft's loan and a 20-year duration for the terminal's loan. With a salvage value being 20% of the craft's acquisition price, and with a 10-year depreciation period, the terminal's salvage value could be estimated at about the same percentage of the terminal's acquisition price, but with a 20-year depreciation period. Whenever a vessel or/and a terminal are used for more than one routes, the capital costs should be divided among these routes.

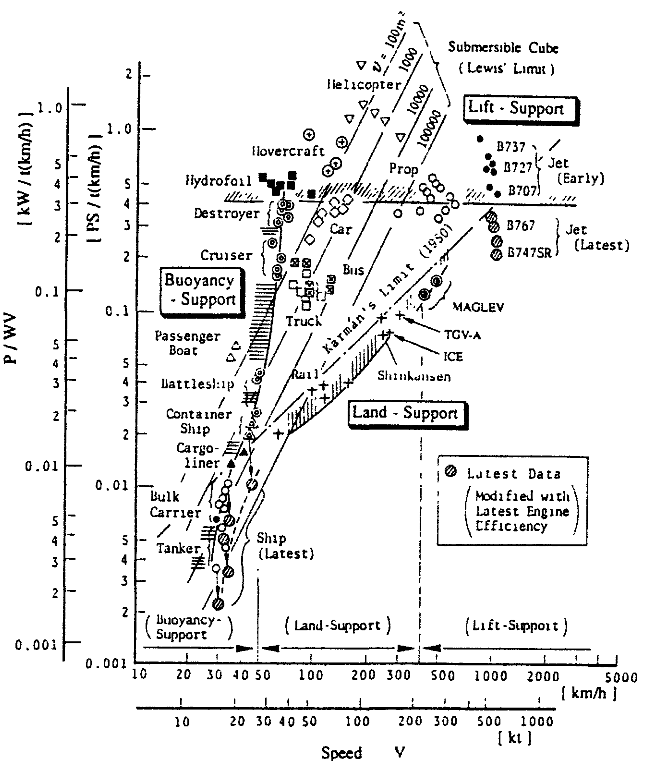


Figure 5.1 Karman-Gabrielli diagramModified with the Recent Data

Fixed costs include all the business expenses related to running the transportation system that are not included in either operating or capital costs. They primarily include the salary and benefits of the staff-support to maintain the system. They also cover legal costs, accounting costs, supplies, licenses and fees, taxes, tickets, and travel-agency fees.

5.2 Transport Efficiency and Optimum Fare

The fare charged by any vehicle is based on the cost structure of the vehicle, which reflects its capital and the operating costs. It is how efficiently or costly a transport system can carry a unit of payload at an extra unit of speed, that determines its economic viability based on its fare basis. This is called the transport efficiency of the vehicle. The two major contributors to the shape of a mode's transport efficiency are are the capital cost and the operating cost.

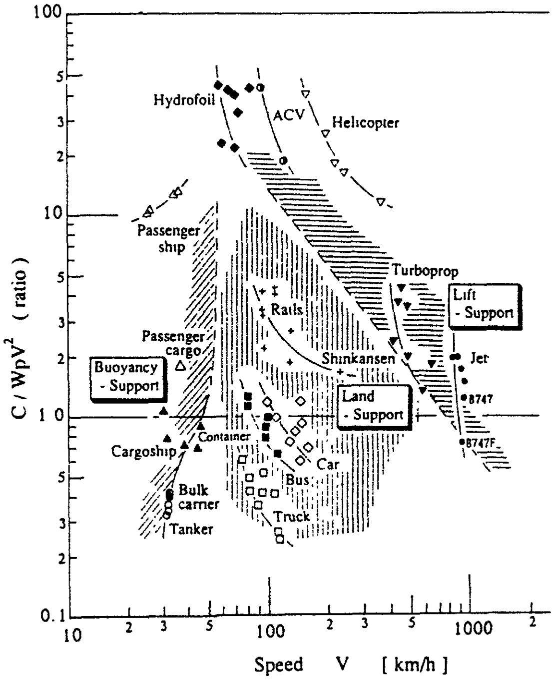


Figure 5.2 Karman-Gabrielli Diagram Reflecting the Operation Cost of Different Vehicles

The capital cost reflects the conceptual design (conventional, advanced, hybrid, etc.), the technology (propellers vs. waterjets, mechanical vs. Electric transmission etc.) and the available power of the vessel. It is measured by the power required to transport a unit of payload at an additional unit of speed. If P is the power required, Wp the payload carried and V the speed, then the relation of the capital cost to the vessel's speed is shown in Figure 5.1 as it was plotted by Gabrielli and Karman in 1950, using empirical data. The G-K plots are very useful in methodically comparisons of different transport efficiencies. Figure 5.1 shows the ratio P/WV as a function of speed V for several transport modes, where W is the overall weight of the vessel. Adjustments to the original data was performed by Agagi in 1971 and 1991 in order to include the modern crafts, while Lewis in 1963 estimated the absolute technical limit of the conventional buoyancy supported ship. As it is clear from this graph, the ships are very efficient in the lower speed range, while the required power increases sharply for speeds over 18 knots. Conventional ships show an increase of the order of 1,000 when speed changes from 15 to 30 knots. For a similar increase in speed, ground vehicles tend to require less additional power. On the other hand, hydrofoils seem to require the same additional power independently of speed. Also their required power values are comparable to the airplane, which means that for a hydrofoil to have similar transport efficient to that of the airplane it should travel at much higher speeds.

The operational cost can be expressed in a similar manner. If C is the unit price of the transport mode, the operational Cost can be expressed as C/WpV^2. Another Gabrielli-Karman diagram for the operating cost is shown in Figure 5.2. From this graph, the marine vehicles seem to have the least economically competitive power. Nevertheless, this pictures seems to be changing with the introduction of the hybrid technologies, which combine more than one advanced design concepts. Although limited data has been published on those vessels, two studies performed by Ozawa-Yamashita in 1981 and Miyata in 1987 show that a hybrid air cushion catamaran and aa hydrofoil catamaran have improved power requirements. Figure 5.3 reproduces the Karman diagram for these two vehicles next to the conventional ship data. By varying the ratio of the two supporting forces ξ,(buoyancy vs. Air cushion and buoyancy vs. Dynamic lift), the P/WV ratio becomes minimum at higher speeds. The air cushion catamaran outperforms the hydrofoil catamaran. In Table 5.2 a sample calculation of three different HSW craft's costs and revenues is shown for comparison purposes, based on the foregoing approach for total cost estimation.

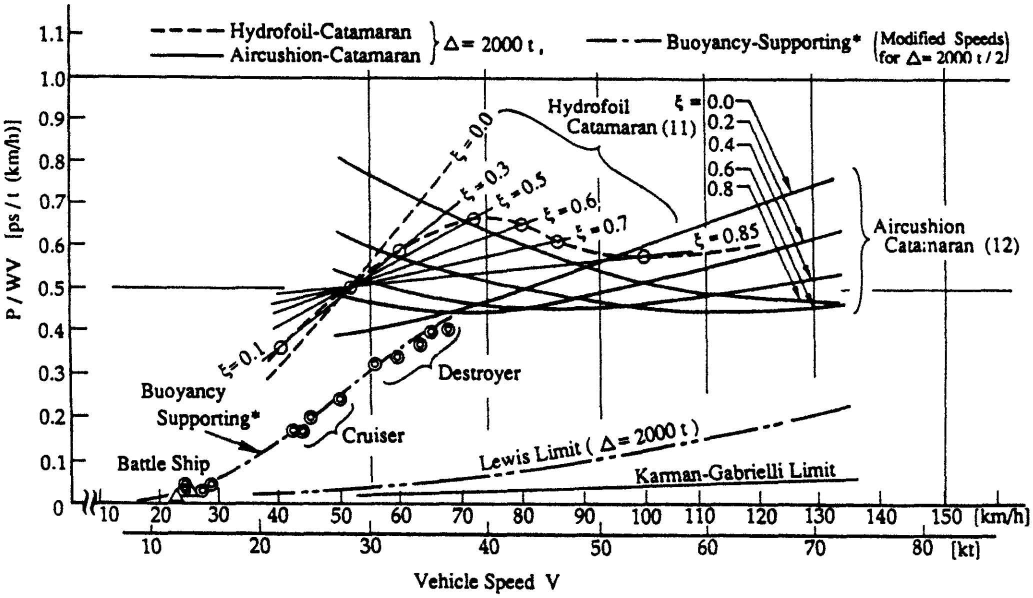


Figure 5.3 Karman-Gabrielli Diagram for theTransport Efficiency of Hybrid Marine Vehicles

5.2.1 Optimum Fare and Market Capture Estimation

Once the final selection of an HSW craft is completed, it would be wise to check whether this vessel could actually compete with a conventional one, which is currently operating on the same route. In the following paragraph, a sample comparison is presented, between an HSW vessel and a conventional ship, which for the shake of reference it was named vessel A. Such an example will facilitate the presentation of a more analytical method for such an economic comparison.

Suppose that A has a fare of \$P' for a certain route, which takes T'-hours to travel. Assuming that the number of passengers, s, is known for the conventional ship, the operator of the HSW craft cares to estimate the fare that would maximize his profits. In order to find the fare that would maximize the income from the HSW craft, the following relationship (Lioukas, 1982) that gives the total income for the HSW vessel needs to be applied;

$$\mathbf{Income = P \times s} \qquad (5.1)$$

$$\mathbf{Income = P \times \frac{\exp[-L\times(P+VOT\times T)]}{\{\exp[-L\times(P+VOT\times T)] + \exp[-L\times(P'+VOT\times T')]\}}},$$

where,

- P is the fare for the HSW craft,
- T is the time of the HSW craft
- s is the market share for the HSW craft
- VOT is the value of time
- L is the flexibility in demand (constant) and
- P', T' are the fare and time of the conventional vessel

In order to find the maximum value of the above function, which would represent the highest revenues from the vessel's operation, the derivative of the expression needs to be taken. The resulting value would be the most profitable fare for this vessel operating at the specified route.

Thus the expression could take the form of:

$$\mathbf{P^* = \frac{1}{L(I-s)}}. \qquad (5.2)$$

For a conventional vessel that takes 2 hours to get to a destination and charges **$6** per person, the corresponding fare for an HSW craft would be **$11**, assuming a flexibility in demand **L=0.0006**, a value of time **VOT=$3** and a market share capture of **s=40.2%** for the HSW vessel. This result is greatly affected by L. For a slightly different flexibility in demand of value L=0,0007 the corresponding fare reduces to $10.

Inter-City/Inter-Island Route						
CRAFT	Size of Fleet	Daily Trips	Daily Patronage	Fare $	Ridership $	Revenue $
Jetfoil	2	2	280	45	198,800	8,946
RHS-200	2	2	270	45	191,700	8,627
Seagull	2	2	245	45	173,590	7,828
CRAFT	Size of Fleet	Daily Trips	Daily Patronage	Fare	Capital / Fixed	Operating Cost
Jetfoil	2	2	280	45	4,837/150	3,088
RHS-200	2	2	270	45	2,322/150	1,978
Seagull	2	2	245	45	2,667/150	3,325
CRAFT	Size of Fleet	Daily Trips	Daily Patronage	Fare	Total	Annual Net
Jetfoil	2	2	280	45	8,072	874
RHS-200	2	2	270	45	4,450	4,177
Seagull	2	2	245	45	6,142	1,686

Table 5.2 Summary of Fleet Characteristics in Comparison. All the Revenues and Costs are in Thousands USD $

At this point, the operator should have all the information needed to determine if the proposed service is profitable or if it is breaking even, before a more detailed analysis takes place. Such an analysis would require market surveys, travel modeling and break-even analysis. A very helpful tool for estimating the per unit fare is the required freight rate which is used very successfully by the cargo transport industry. The ratio RFR, combines the aforementioned transport efficiency and per unit operational cost in one formula:

$$RFR = Y/C + (CR \times P)/C \qquad (5.3)$$

where,

- Y is the annual operating cost,
- P is the capital investment,
- CR is the capital recovery factor and
- C is the annual transport capacity.

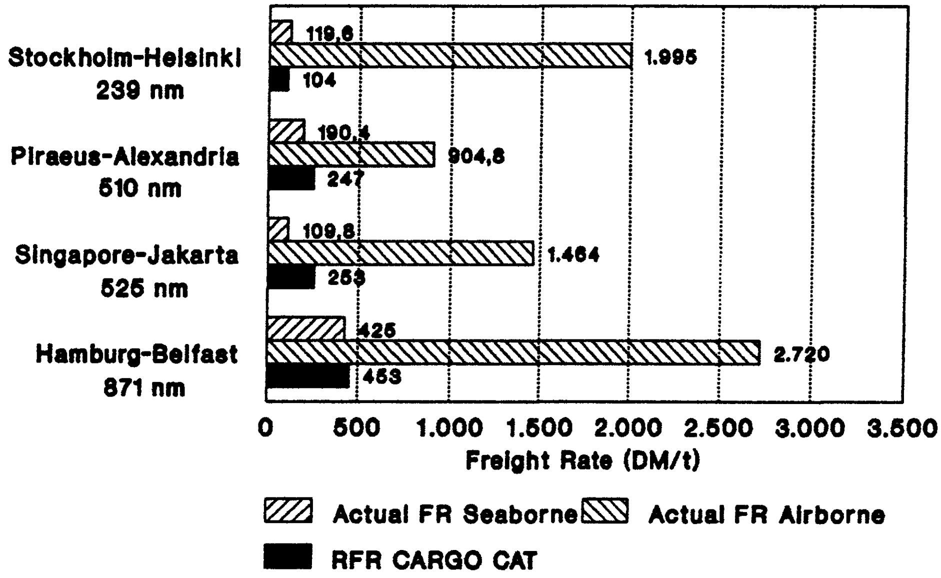


Figure 5.4 The Required Freight Rate of a Conceptual Cargo Catamaran Compared with Actual Freight Rates of Competing Transport Modes for 4 Different Routes

C, would be more accurate if it would be the market captured by the vehicle. A new high-speed conceptual cargo transport systems when compared with both conventional container ships and airplanes [18], using the RFR approach, was found very competitive with both the other modes.

Figure 3.4 shows the results of this comparison. From this graph it is clear that the cargo catamaran is competing with the freight rate of the airplane, while it is competing with both the price and the transport time of the conventional containership.

The economic viability of an HSW craft is influenced by the routing schedule and the seasonality of the operation of the vessel. Parametric studies that were done in the past can verify this fact. The demand of the vessel and the Return on Investment (R0I) can also influence the unit fare for the same trip.

Chapter 6

Application

So far, all the factors involved in the assessment and composition of a High Speed Waterborne service have been presented and analyzed. In this chapter, all the foregoing discussion and theory are implemented in the form of a model for selecting an HSW service. While the methodology would be synthesized of all the steps outlined in the previous sections for the route assessment and the vessel selection, an existing route that is served by High Speed Vessels is used as an application.

The site selected is highly seasonal. It is one of the busiest along the current services in the Greek Islands, of strategic importance for both the Hellenic Ministry of Tourism and the ship owners operating vessels in the route. It should be clarified that in the case of this site, ship owning and vessel operation coincide. The route has also commuting and supplying importance to the small population of the islands served, but with very high volumes of passengers transported throughout the summer months. The service would be considered of the Island category as it connects one or more islands to the mainland, as well as to other islands. The route is 72 nautical miles long, located at the Aegean Sea in the Eastern Mediterranean, and connects the island of Mykonos with the port of Rafina which is one of the two ports serving Athens, the capital of Greece. This site was selected for this application due to the familiarity of the author with the services currently offered in the area, the overall market served and the access to data for the existing services. The site is currently served by three conventional mono-hulls while a High-Speed Waterborne (HSW) service that is under consideration runs temporarily on a trial basis.

6.1 Baseline Establishment

Before proceeding with the model and the application, a baseline should be established for comparison reasons. For this baseline one of the mono-hull vessels was selected. This is an 118 meters long, 1,029 tones DWT ferry boat, with a maximum capacity of 2,380 passengers and 260 cars. This vessel named "Superferry II" was selected because it is the fastest mono-hull serving the route at a speed of 19 knots. The fare charged per passenger on this vessel is $14 for the economy class, which includes seats at all free decks and some selected stations, and $27 for the first class, which guarantees a seat, for each passenger holding such ticket, in air-conditioned stations similar to those of an HSW vessel. Thus, from now on, whenever referring to the baseline, it will be the first-class service of the “Superferry II”. The “Superferry II” covers the distance in 3 hours and 49 minutes when it is not serving any other island. In the case of other islands being served, two stops are performed at equal number of islands that can be served without any diversion. The first island to be approached, Andros, is 35 nautical miles from the mainland port of Rafina, which takes the “Superferry II” 1 hour and 51 minutes to cover. The island of Tinos is 63 nautical miles away from Rafina and is the second island to be reached before the final destination of Mykonos. The distance between Andros and Tinos is covered in 1 hour and 29 minutes, while the rest 9 nautical miles between Tinos and Mykonos are covered in just 29 minutes by the “Superferry II”. Although the total cruising time is the same as without any stops, with an average estimated time, of decelerating to and accelerating from each port, as well as loading and unloading, of 30 minutes, the overall traveling time increases to 4 hours and 49 minutes.

6.2 Application and Analysis

In assessing an alternative High-Speed Waterborne service in the same site, a surface-piercing hydrofoil was selected for a very good reason. A new company, which already owns this vessel is considering to enter this market. It will be of great value to be able to compare the results of this model to the results of the company’s analysis. The vessel is 102 feet long, with a maximum passenger capacity of 205 passengers and a service speed of 35 knots. The vessel is Model RHS-160 of the Rodriquez Cantiere Navale, built in Sicily, Italy. The specifications of the vessel are reproduced in Appendix A.

Although the vessel was pre-selected the methodology will evaluated with the same criteria as if there was no candidate selected for the HSW service.

This application will proceed through all the foregoing sections and steps presented in this thesis, in order to achieve an effective economic analysis for one, two and three stop services of the aforementioned route. Also the effect of the number of stops for a different sub-route of shorter distance, but in the same market will be examined.

Starting with the route, as it was already mentioned, the route is of the Island category. Typical passengers consist of a 70% tourists and 30% locals either visiting the islands or Athens. Most of the passengers are transported between the months of June and September which is the peak season of tourism in Greece. The market is defined as the population of the greater metropolitan area of Athens, people traveling from the rest of Greece and tourists arriving in Athens by another mode of transportation. The number of trips is estimated to be 540 yearly, assuming an 8-month operating period, doing two trips daily.

Since the islands are not connected with the mainland or with each other by bridges or tunnels, the only two competitors to a possible HSW service would be conventional ships and propjet airplanes. Access times to either the airport or the port is considered equal and hence it is not taken into consideration. The airplane serving the route Athens to Mykonos are small 8-20 seat propjets that cover the distance in 45 minutes. With a significant 15-minute average delay observed in the Athens airport and a transportation time of 15 minutes from Mykonos airport to the city of Mykonos, the total airplane travel time is 1 hour and 15 minutes. The air-fair is $92. The times and costs of the mono-hull vessel were established as a baseline in the previous section.

Considering now the hydrofoil, if it will cover the distance with only one stop at the final port of destination, it will take 2 hours and 6 minutes. For this calculation it was assumed a 2 minute maneuvering time, a 2 minute accelerating time and an one minute slowing down time. With the hydrofoils doing two or three stops, the corresponding times increase to 2 hours, 18 minutes and 2 hours, 30 minutes, assuming a 7 minute delay for passenger embarkation and disembarkation at each stop. From Aggagi's formula it was found that the two modes have a cost of traveling ratio of 2.8, meaning that the airplane is 2.8 times more expensive than the hydrofoil, and 3.4 times more expensive than the "Superferry II" mono-hull. Thus for this route the HSW crafts are better than the conventional monohull and the Airplane. This position becomes even stronger when considering the cost involved for purchasing any of the three vessels. The hydrofoil with a $5-million acquisition price and the minimum crew required becomes an even better candidate for a profitable service. Even in the case of the three-stop service the hydrofoil is still favorable to the monohull, while the competition with the airplane gets tighter. Finally, using equations (5.1) and (5.2), it is estimated that the hydrofoil has to charge an average fare of $18 in order to compete with the economy class of the monohull, which carries the bulk of the market to the islands, while the fare competing with the first class could be up to $44. Such a fare basis would guarantee a market capture of 39% for the hydrofoil. Thus, it could be expected that such a cupture is realistic, given the space allowed by the HSW service's operator to charge a lower fare. Confirming the result of the model, the price given by the company considering the HSW service in the route is $30.15 per passenger, which gives a 3.05 cost ratio between the hydrofoil and the airplane, eventhough the company considers only a three-stop service which makes it less appealing. Hence, the result of the foregoing methodology is very reasonable.

In the case of a shorter route, that between the ports of Rafina and Andros, a 35 nautical miles route the number of stops play a more significant role. In this case the only competing modes of transportation would be the monohull and the hydrofoil, since there is no airport in Andros. The monohull covers the distance in 1 hour and 51 minutes, while the hydrofoil would cover it in 1 hour. This time would alter to 1 hour and 12 minutes or 1 hour and 24 minutes for 2 or 3-stop services accordingly. The fair charged by the monohull is $15 while that of the hydrofoil $17.

It is clear then that the shorter the distance, the greater the effect of the stops on the value of the extra money charged by an HSW vessel, which in a longer distance are covered by the greater savings in time spent on the vessel.

Chapter 7

Financing of an HSW Craft

An HSW craft (or service) can be operated under either a public organization or a private enterprise.

Potential public operators of HSW services could be any public transportation authority. There are such agencies that are currently operating conventional passenger and car-ferry services. Local and Federal programs can provide sources of financing for an HSW service. In Massachusetts such a potentially significant source of capital funding for the local market is the Urban Mass Transportation Administration's Section 3 Discretionary Grant Program, and the Section 9 Formula Assistance Program. These sources could provide up to 80 percent of the capital cost. Although only public organizations are eligible to apply for this type of funding, these two agencies could also help private organizations to provide necessary service.

As far as a private enterprises are concerned, financing can be obtained with various methods. The most common one would be a debt issue from commercial banks. It may not be easy to strike a favorable deal on a loan for an HSW craft, since these vessels are fairly new to banks, and the collateral represented by the vessel may not provide a sufficient basis for funding an enterprise. Another way would be the issue of private or public placement. This alternative has significant transaction-costs and may have serious limitations provided that the public's exposure to equity financing of shipping companies is limited and with an unstable track record.

There are many other funding opportunities which correspond to the magnitude of investment necessary to establish HSW transportation services. Of these, it is worth mentioning venture capital and government sources. Due to the higher capital investment required for the acquisition of a High Speed Waterborne vessel, operators are forced to charge a significantly higher fare. Eventhough these fares get even higher for the additional risk of such investment, fast-ferry services, have to be heavily subsidized by the public sector and the transportation authorities. With fares getting up to 50% higher that those of the conventional ships, it is not uncommon to observe subsidies ranging between 60 and 80% of the cost of running the service.[15]

Before financing of an HSW vessel is considered, one should develop a business plan. The plan should include a detailed market analysis, a cost analysis of the potential candidate vessels, some financial projections, the proposed corporate structure and an operational plan. Additionally, it should demonstrate that all regulatory considerations have been taken into account. The business plan should address the form of the legal entity both in terms of launching the HSW venture and operating the service.

The market and cost analysis have been covered in previous sections of this report. As for the financial projections, they should be based on the market and cost analyses. Any projection should cover the useful life of the vessel.

The operations plan should include information on fleet characteristics, service schedules, maintenance schedules, crew requirements and should tie into the market analysis, cost analysis and financial projections. Also, the service schedules should be developed to satisfy the demand projections in the market analysis.

Finally, an investment in an HSW transportation service could offer favorable tax considerations.

Chapter 8

Conclusion

The motivation for the demand of speed in transport is usually explained from the issue of saving both time and money for travel. However the speed is the essential function of transport systems, which has been pursued since early times. As highways become more congested, the HSW crafts regain momentum as an increasingly used mode of transportation. The Scandinavians and the Australians, followed by the Japanese have looked more closely at moving people on water, fast.

The original designs have been followed by a new breed of crafts that incorporates the latest technologies, including elements from SES and SWATH, foils and ACV's. The result is the steady increase in both speed and the combined cargo/passenger capacity, with a decrease in unwanted motion.

Lately, the so called exotic materials have entered the game. Sandwich constructions and carbon fibers make the vessels even lighter. The concerns for safety also increase. Technologies from fast naval vehicles and performance boats, such as waterjets and gas turbines, are lately common practice in the designs of the HSW crafts. Typical constructions take 15 months to complete. The forecasts for future demand demonstrate that more of these vessels are going to enter the markets , replacing the so called conventional mono-hulls as well as other means of transportation.

Although all of these results are encouraging, the production costs remain high and increases with the maximum and operational speed of the vessel. Furthermore, high sea-states, that still create a rough ride, prevent these vessels from been used in other than the "time is money" routes.

Today, High Speed Waterborne services are being operated in areas considered unlikely fifteen to twenty years ago.[15] With the potential of the fast vessel to serve a community very efficiently, new areas are being developed, new commuting patterns have been established and waterways have being steadily gaining momentum as the means of transportation, especially now that the limited traffic potential of the vessels has been eliminated.

Interestingly, high speed vessels have been gaining momentum on the Pacific Coast, although the design and development of the commercial passenger vessels of the future are taking place overseas. San Francisco Bay has the largest fleet of fast passenger-only vessels for actual commuter work on the Pacific Coast. Other U.S. markets that are currently involved, or that have potential for HSW operations include Boston, Hawaii, Lake Michigan, New York, Providence, Seattle, the Virgin Islands and Washington D.C.

One operator after the other shifts in these fast ferries while others, like the Japanese are more daring. They have purchased such advanced vessels that they claim to be able and travel in waves 12 feet high and still maintain a speed of 45 knots.

An HSW transportation service is a relatively low-cost investment. Depending on the vessel, an initial capital investment of $5 to $10 millions could start a venture. Eventhough in previous years revenue was constrained by vessel size, lately, with the introduction of the largest HSW crafts the return on the investment has increased. And although it may still be lower than in other modes of transportation, for some routes, the higher speeds and the introduction of more efficient technologies make these vessels more attractive.

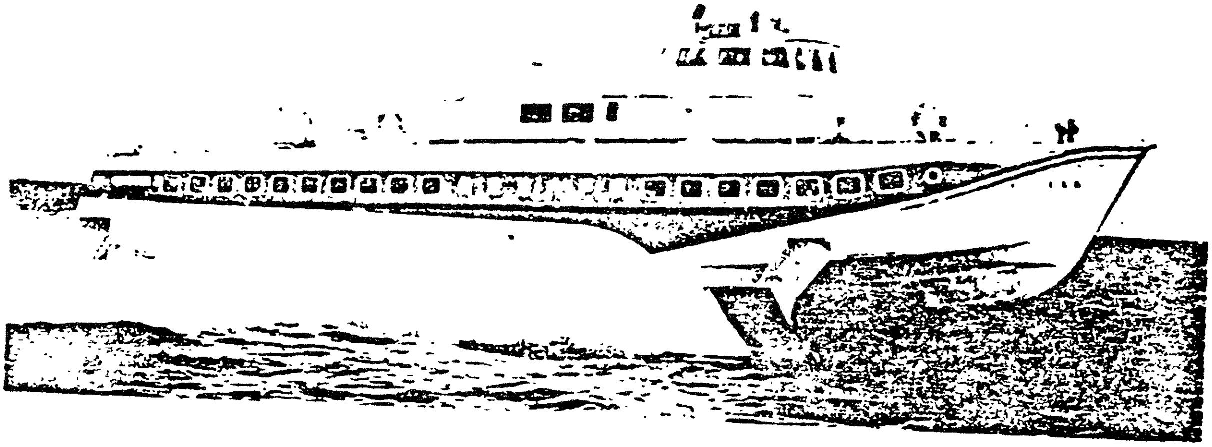
In conclusion, HSW investments have several advantages. Their market-share is relatively stable; at low to moderate load factors, a small increase in market penetration or passenger ridership can result in significant increases in revenue, with **only** marginal increases in operating costs.

The HSW operators provide reliable services. On average, 95 percent of the scheduled trips are safely completed. Since these vessels take the design practices to the limit, sometimes they demonstrate some unreliability in their early trips. Problems such as fatigue cracks due to slamming on waves at high speeds, breaking of blades in the water-jets, or superstructure and deformations that were inherent in the original prototypes have been eliminated from the newer designs. Also environmental awareness has put more stringent rules in the construction of such vessels, making them even more reliable, comfortable and safer.

Furthermore, a political willingness to provide more efficient services to old or new routes, has always raised the capital to pay for the extra cost involved. There are only a limited number of services that are being operated from private enterprises without any financial support from the authorities.

Appendix A

Vessel Specifications



Model PT-50 Mk II

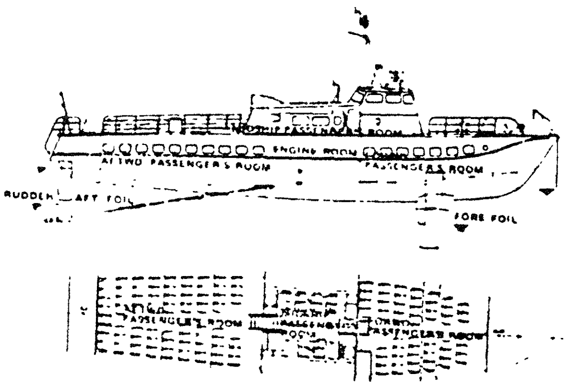
SURFACE PIERCING HYDROFOIL

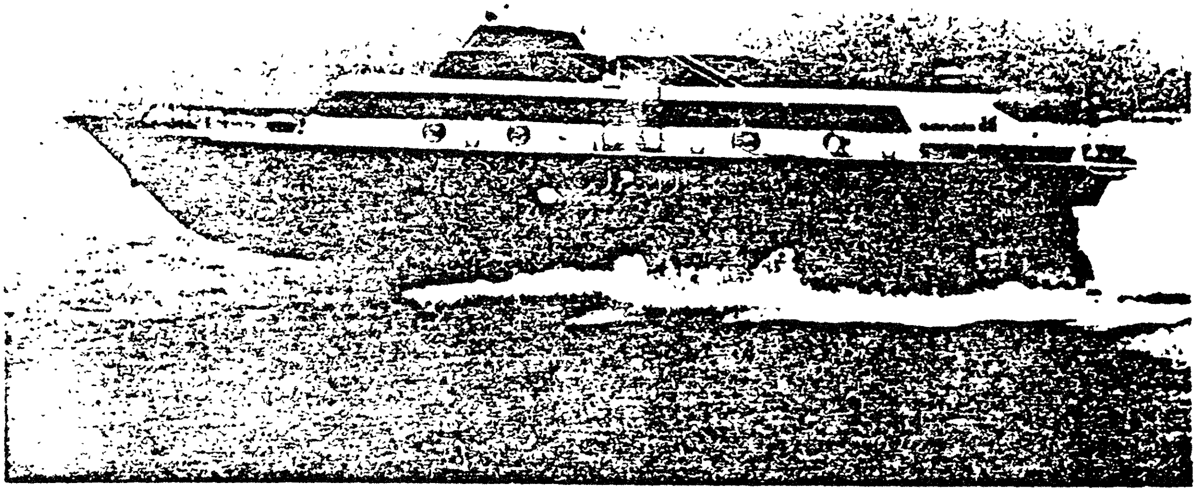
Hitachi Zosen, Osaka Japan

Dimensions:	
Length, over all	91'
Beam, Hull	17' 10"
Draft, off foils	11' 8"
Draft, on foils	5' 1"
Displacement:	63.3 tons
Gross Reg. Tonnage:	129 tons
Speed, Maximum:	36.5 Kts
Cruise:	32 Kts
Passenger Cap'y, Max:	130
Range:	300 NM

Propulsion Plant:
2 × MTU-IKEGAI MB820 Db
Marine Diesels
2 × fixed pitch propellers

Electrical Plant:
1 × 6.5 kVA diesel driven
generator





Model RHS-200 SURFACE PIERCING HYDROFOIL

Rodriquez Cantiere Navale, Messina, Sicily, Italy

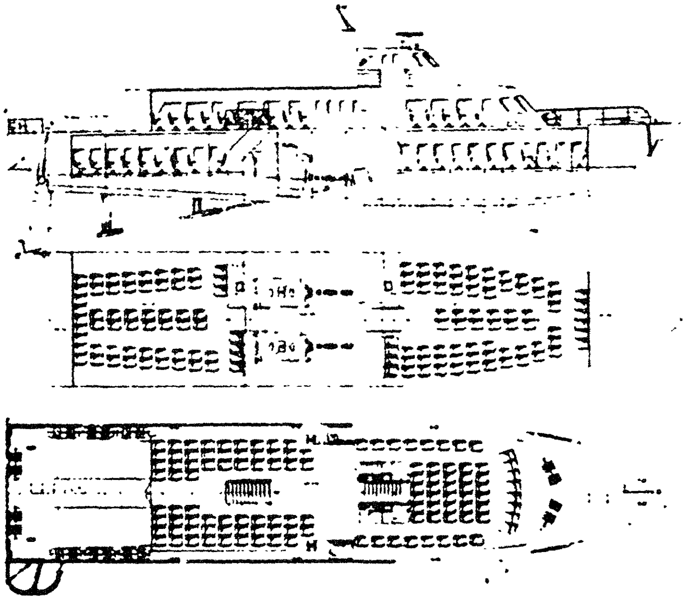
Dimensions:	
Length, over all	117' 6"
Beam, Hull	23'
Draft, off foils	14' 10"
Draft, on foils	6' 9"
Displacement:	120 tons
Gross Reg. Tonnage:	263 tons
Speed, Maximum:	41 Kts
Cruise:	35 Kts
Passenger Cap'y, Max:	300
Range:	200 NM

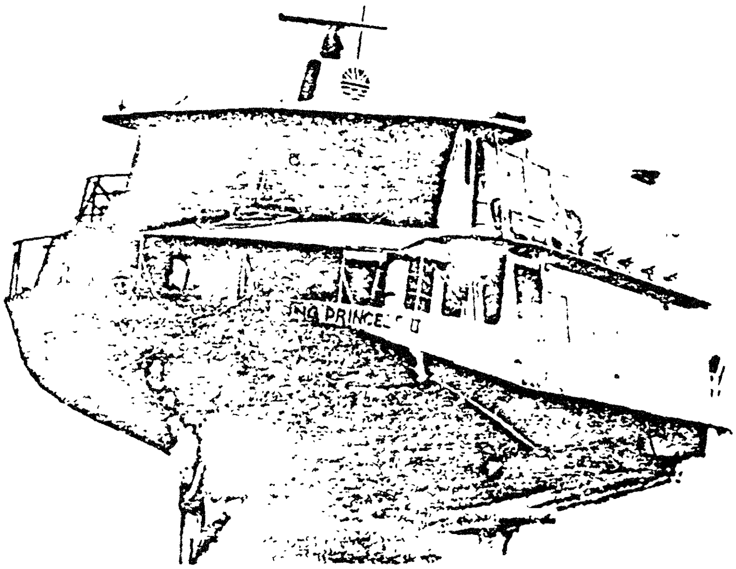
Propulsion Plant:

2 × MTU MB 16V 652 TB71
Marine Diesels
2 × supercavitating, controllable pitch
propellers

Electrical Plant:

2 × 55 kVA diesel driven
generators





Model 929-115 "JETFOIL" FULLY SUBMERGED HYDROFOIL

Boeing Marine Systems, Seattle, Washington

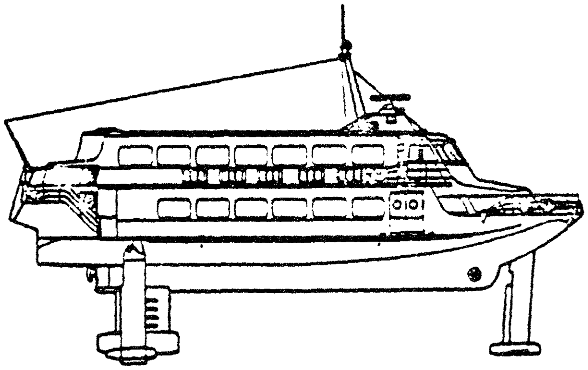
Dimensions:	
Length, over all	90'
Beam, Hull	31
Draft, off foils	17'
Draft, on foils	5'6"
Displacement:	115 tons
Gross Reg. Tonnage:	95 tons
Speed, Maximum:	50 Kts
Cruise:	43 Kts
Passenger Cap'y, Max:	423
Range:	170 NM

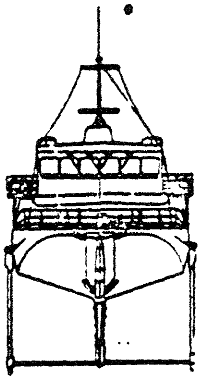
Propulsion Plant:

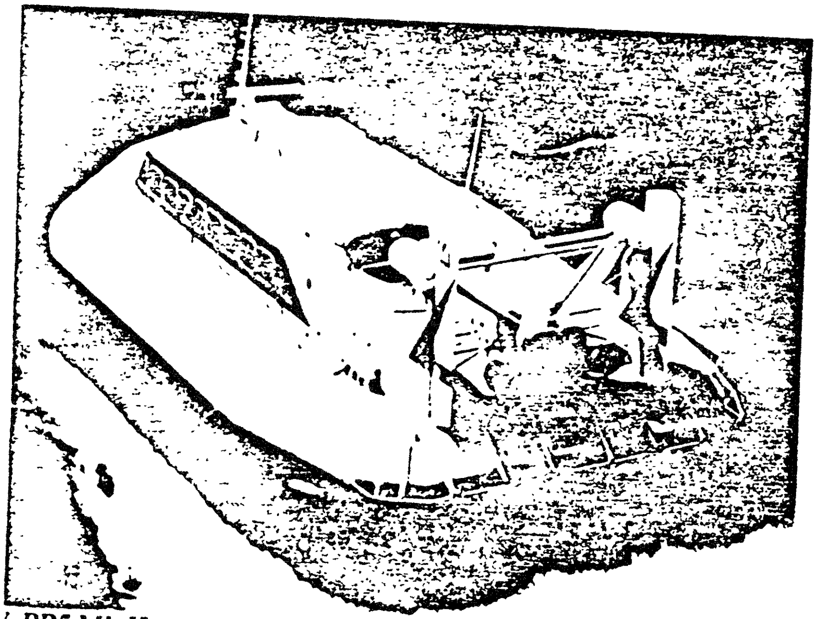
2 × Detroit Diesel Allison
501-K20A Marine Gas Turbines
2 × Rocketdyne
waterjet pumps

Electrical Plant:

2 × 62.5 kVA diesel driven
generators







Model MV-PP5 Mk II

AIR CUSHION VEHICLE (AMPHIBIOUS)

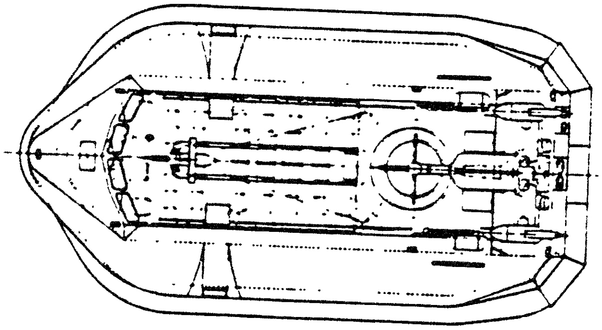
Mitsui Engineering & Shipbuilding Co., Tokyo, Japan

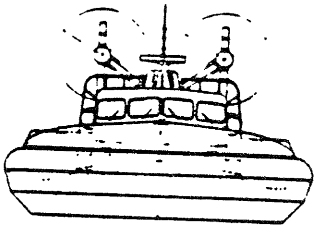
Dimensions:	
Length, over all	59'7"
Beam, Hull	28'4"
Draft, off cushion	N/A
Draft, on cushion	N/A
Displacement:	19.3 tons
Gross Reg. Tonnage:	29 tons
Speed, Maximum:	52 Kts
Cruise:	45 Kts
Passenger Cap'y, Max:	47
Range:	180 NM

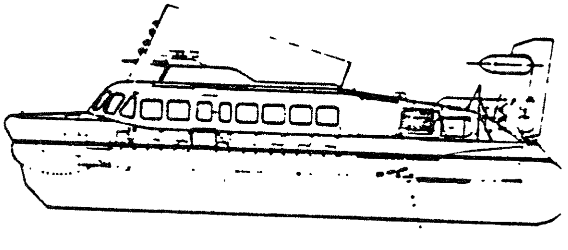
Propulsion Plant:
1 × General Electric LM-100
Marine Gas Turbine
2 × controllable pitch airscrew propellers

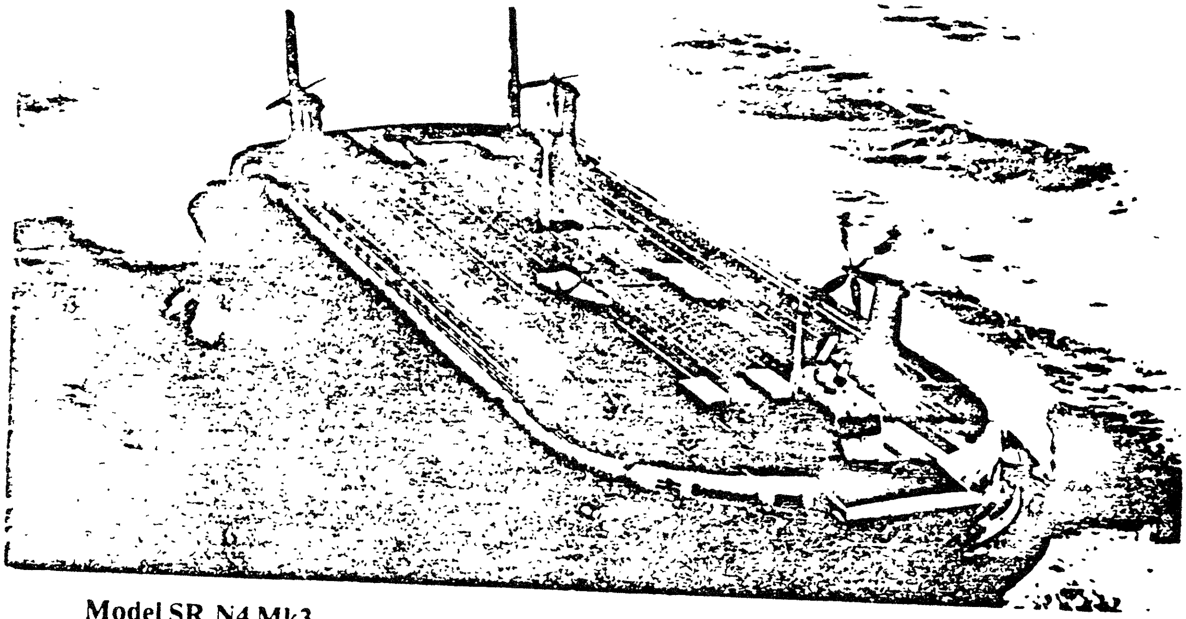
Lift Power Plant:
Integral with propulsion
engines

Electrical Plant:
2 × 2 kW belt driven
generators









Model SR.N4 Mk3 **AIR CUSHION VEHICLE (AMPHIBIOUS)**

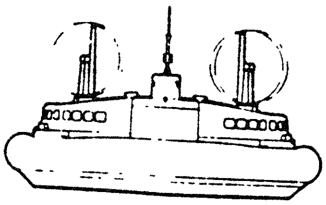
British Hovercraft Corporation, Cowes, I.O.W., England

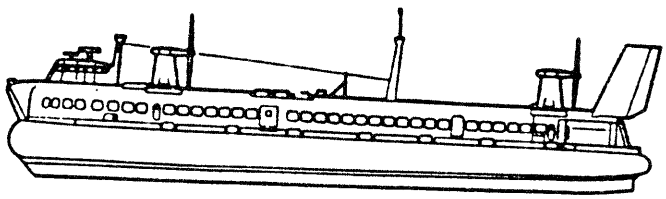
Dimensions:	
Length, over all	185'
Beam, Hull	76'
Draft, off cushion	N/A
Draft, on cushion	N/A
Displacement:	320 tons
Gross Reg. Tonnage:	808 tons
Speed, Maximum:	070 Kts
Cruise:	60 Kts
Passenger Cap'y, Max:	344/46 cars
Range:	250 NM

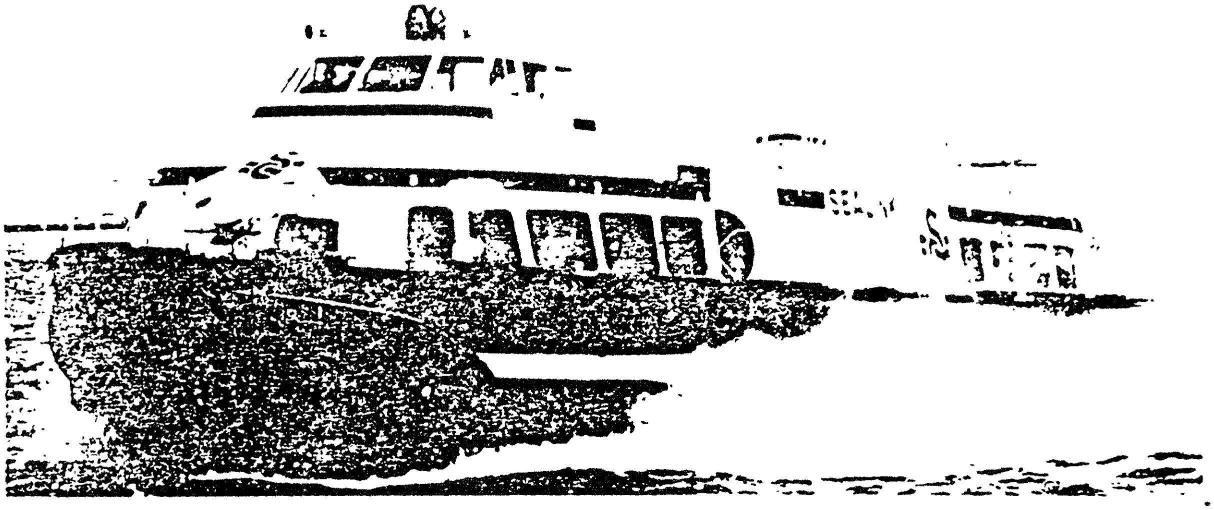
Propulsion Plant:
4 × Rolls Royce Proteus type 15M/529 gas turbines
4 × controllable reversible airscrew propellers

Lift Power Plant:
Integral with propulsion engines

Electrical Plant:
2 55 kVA generators driven by Lucas gas turbines





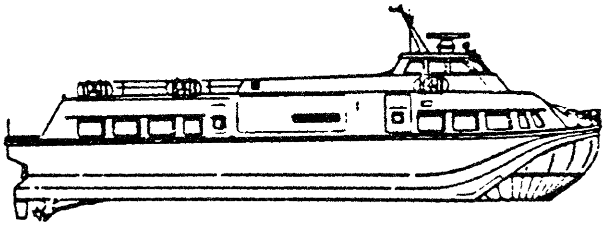


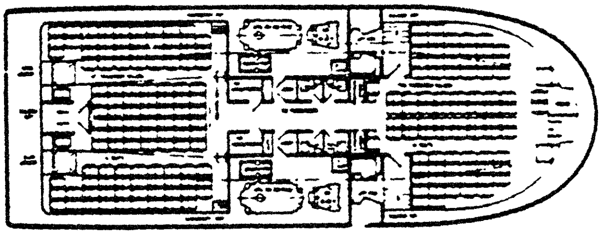
Model HM-527 SURFACE EFFECT SHIP

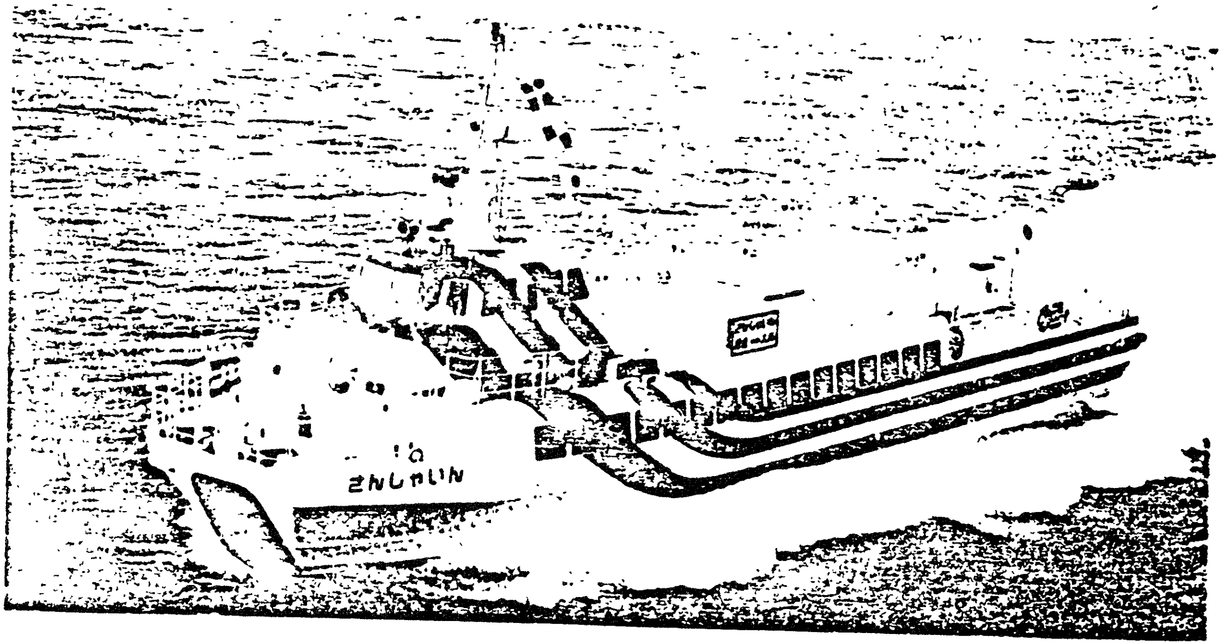
Vosper Hovermarine Ltd., Southhampton, England

Dimensions.	
Length, over all	89'
Beam, Hull	33'6"
Draft, off cushion	8'6"
Draft, on cushion	4'6"
Displacement:	87 tons
Gross Reg. Tonnage:	<100 tons
Speed, Maximum:	35 Kts
Cruise:	33 Kts
Passenger Cap'y, Max.	260
Range:	200 NM

Propulsion Plant:
2 × MTU 12V 396 TB83
Marine Diesels
2 × fixed pitch propellers
Lift Power Plant:
2 × General Motors type
8V92T1 Marine Diesels
Electrical Plant:
2 × 27 2 kW diesel driven
generators







Model CP-20-HF

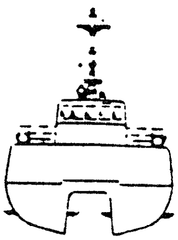
CATAMARAN*

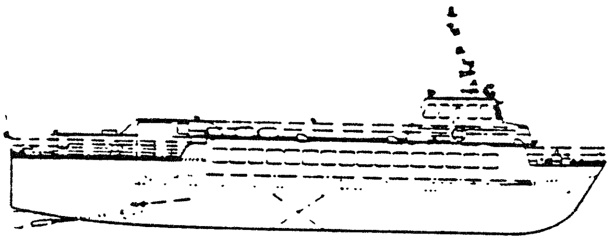
Mitsui Engineering & Shipbuilding Co., Tokyo, Japan

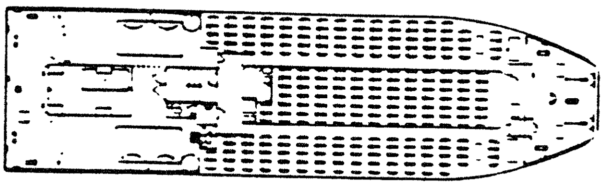
Dimensions:	
Length, over all	107'8"
Beam, Hull	30'2"
Draft	4'
Displacement:	115 tons
Gross Reg. Tonnage:	250 tons
Speed, Maximum:	30.8 Kts
Cruise:	30 Kts
Passenger Cap'y, Max:	232

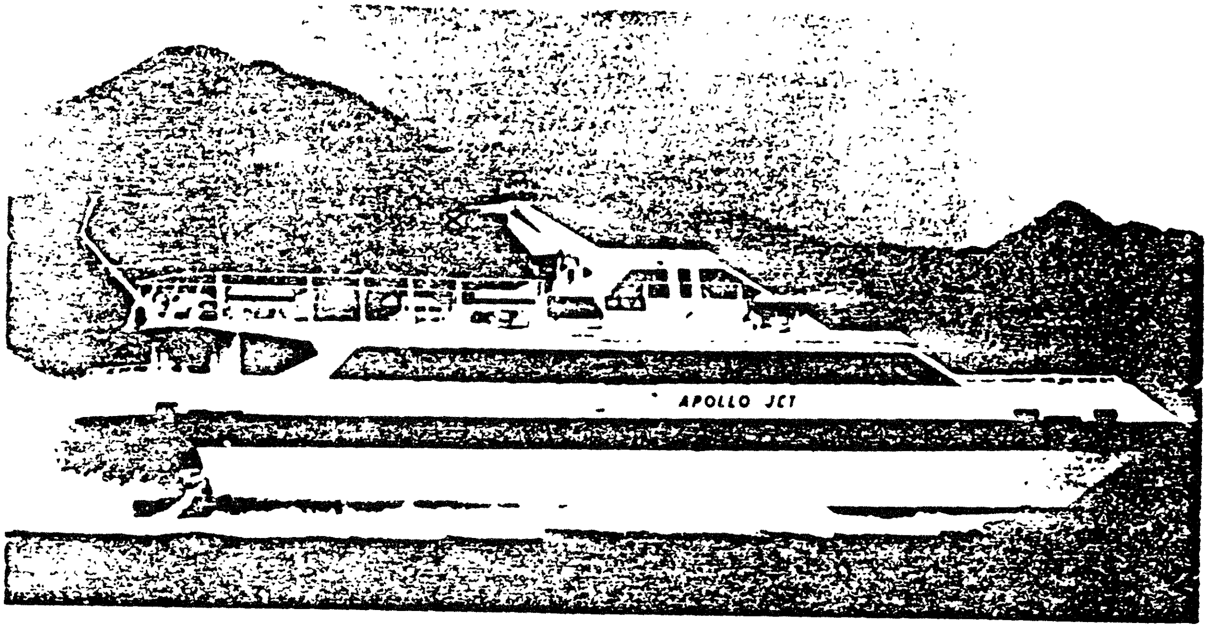
Propulsion Plant:
2 × Fuji Pielstick type
16PA4 V18 5VG Marine Diesels
2 × fixed pitch propellers

Electrical Plant:
1 × 50 kVA diesel driven
generators









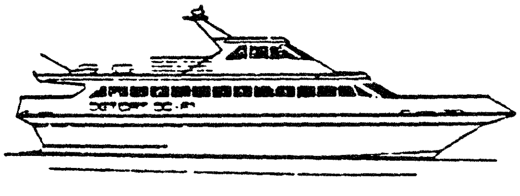
Model JC-F1 **CATAMARAN**

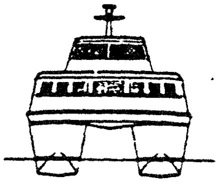
Marineteknik Verkstads A/B, Sweden

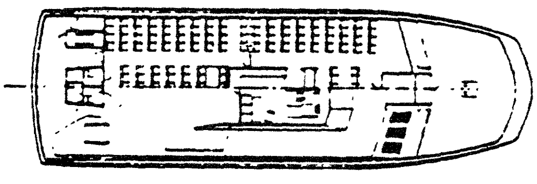
Dimensions.	
Length, over all	97' 9"
Beam, Hull	30' 11"
Draft	3' 10"
Displacement:	84 tons
Gross Reg. Tonnage:	118 tons
Speed, Maximum:	36 Kts
Cruise:	30 Kts
Passenger Cap'y, Max.	215

Propulsion Plant:
2 × MTU 12V 396 TB83
Marine Diesels
2 × KaMeWa type 60/S62-6
waterjet pumps

Electrical Plant:
2 × 24 kW diesel driven
generators



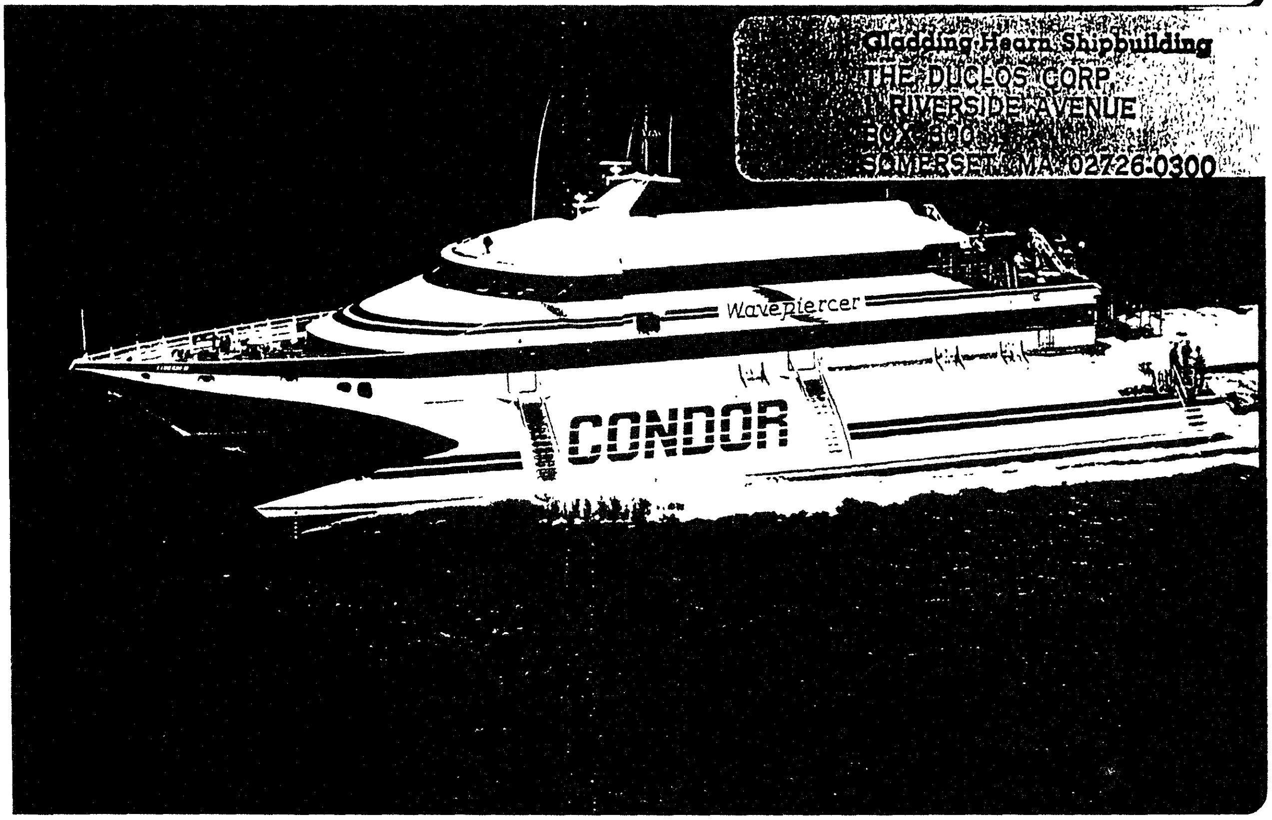




INCAT DESIGNS – SYDNEY

Specification Sheet

Condor 9



49 Metre Wave Piercer Ferry

Length (over jets)	48.7 metres	Passenger capacity	450
Beam (excl fenders)	18.2 metres	Speed – Maximum	42 knots
Beam (Hull)	3.0 metres	Cruising	36 knots
Draft	1.5 metres	Classification	Det Norske Veritas
Fuel Capacity	2 x 7,200 litres	Class	+ 1A1 Light Craft (CAT) R45
Fresh Water	2 x 1,000 litres		
Power	4 x 1680kW	Survey	Dept of Transport, UK
Engines	4 x MWM TBD604B V16	Waterjets	4 x MJP J650R-DD

International Catamaran Designs Pty. Ltd.
1 Mafeking Avenue, Lane Cove, Sydney, Australia. Tel: (02) 427 2822 (International 612 427 2822)
Fax: (02) 427 7238 (International 612 427 7238)

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