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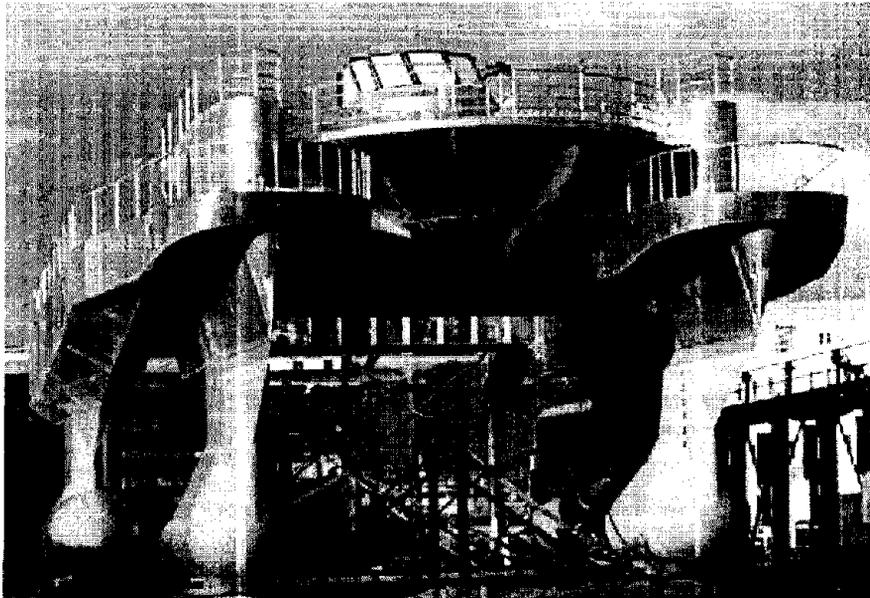
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High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

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DOT-VNTSC-ONR-01-01, Final Report

High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

Michael G. Dyer
Robert J. Armstrong
Krishna V. Jain

September, 2001

Prepared by

U.S. Department of Transportation
Research and Special Programs Administration
John A. Volpe National Transportation Systems Center
Technology Applications and Deployment Division and Economic Analysis Division

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Fast Ferry International, Tenterden, Kent, United Kingdom: Giles Clark

Panelists

Bank of America: Jeff Krupa

Boston Harbor Cruises: Rick Nolan

Dakota Creek Industries, Anacortes, Washington: Steve Nordtvedt

Navatek Ships Ltd., Honolulu, Hawaii: Eric Schiff

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Executive Summary

The Volpe National Transportation Systems Center conducted this high speed craft markets study under a program funded the U.S. Navy Office of Naval Research (ONR). The program's intent is to determine the "dual applications" potential of deep multi-hull displacement craft ("small waterplane area twin hull" or SWATH) and other SWATH types developed by the Navy since the 1970s. These include the "SLICE", a SWATH variant hull type including four or more displacement pods, co-developed by the Navy and the private sector, and one of the subjects of the study due to Congressional dual application requirements for military research and development products.

The SWATH family of hull forms provides excellent stability and seakeeping characteristics in rough seas and may offer high speed service opportunities outside the capabilities of the catamarans and high speed monohulls now dominating the world market.

Main Points of the Study

The Volpe Center chose to study several existing catamarans and high speed monohulls in comparison to representative SWATH family craft, including the SLICE 400 (passenger) and SLICE 600 (passenger/90 car) variants, the former similar in size and performance to both the SLICE "demonstrator" and SLICE 250. The demonstrator is the only SLICE that has been built and the 400 and 600 concept designs were judged the best available for commercial purposes at the time of the report's preparation. It should be pointed out that, at the completion of this report, improved and more detailed commercial service SLICE designs had been completed; none, however, has proceeded to the newbuilding stage.

The analysis proceeded following field study of several high speed operations in the United States, acquisition and organization of market data, and organizing and conducting a session titled "To Buy or not to Buy: The Operator's Fast Ferry Decision" at the Fast Ferry International Conference (Boston, Massachusetts).

The main point was to determine which high speed types can demonstrate appreciable performance and economic advantage relative to the competition. An essential component therefore was a comparative performance study, whose focus was seakeeping and passenger comfort, powering and fuel consumption, and principal particulars as they relate to practical matters of navigation and infrastructure.

The resulting high speed vessel data bases were the foundation of a service needs assessment whose aim was to identify the best opportunities for SWATH/SLICE in the current market. The main finding of this assessment was that people are the highest value, and most universally available, "commodity" for any high speed operation, which come with high capital and operating costs regardless of the vessel employed.

The approach called for regional and metropolitan market case studies. The emphasis was placed on itinerant common carrier ferry services (five case studies) because of the importance of schedule reliability, relative likelihood of year round service requirements, and the new impetus for fast ferry services provided by the Transportation Act for the 21st Century (TEA 21) recently passed by Congress. Two additional case studies were selected: (1) crew boat for offshore oil rig personnel; and (2) a high revenue excursion boat, i.e., offshore gaming service.

The common carrier case studies were selected following development of a comprehensive North American ferry services data base and application of several screening criteria, meant primarily to eliminate short routes, shallow draft operating areas, and seasonal operations. The data base was provided to the Federal Highway Administration (FHWA), which is charged by the Transportation Equity Act for the 21st Century (TEA 21) with studying the matter of high speed ferries, and was also made available to the industry as a whole. It later formed

the basis of the National Ferry Database, prepared by the Volpe Center for the FHWA in response to a mandate under the TEA 21.

Findings

Market Scan

The North American market for high speed vessels has lagged behind Asia and Europe, but is now fast maturing. Most potential markets and services are being examined, if not exploited, for start up with fully integrated commercial high speed craft designs, especially catamaran types. There are few commercial SWATH services at this point.

Meanwhile, American shipyards are now building small and medium sized high speed craft (30-70 meters), catering to precisely the classes of service potentially offered by known SLICE concept and detail designs, and are doing so mostly under license to foreign companies. Except for some international service to Canada, whatever potential demand there may be for large high speed vessels ($L > 85$ meters) has not yet been exploited. There is not, however, a SLICE concept design in this size range yet.

SLICE Performance

SWATH and SLICE are excellent seakeeping vessels, better than all other high speed types it was compared to. A comparative seakeeping analysis on computer, judging kinetosis (motion sickness) effects at sea states 4 and 5, showed that both SLICE 400 and 600 are superior at service speed even when compared to SWATH, whereas the subject catamarans and high speed monohulls failed to meet the ISO 2631 kinetosis standard. The advantage holds at slow speeds and the hove to condition, although the others tested performed much better here than at their service speeds. This analysis proved the effectiveness of the deep displacement concept in rough seas performance.

SLICE's deep draft displacement pods and small waterplane area combine to effect a very favorable wake and wash signature. The pods are at sufficient depth to minimize surface interactions and the four struts produce smaller waves than monohull or dual hull forms. An independent study found that the SLICE wake and wash signature peaks at intermediate speeds and is reduced as it approaches service speed, as with most high speed craft. At 15-16 knots (Froude number = 0.6), SLICE's wash height, measured at 300 meters distance, peaks at approximately 52 centimeters and then drops with increasing vessel speed. The SLICE demonstrator meets the Washington State Ferry standard of 30 centimeters maximum height at speeds above 26 knots. Wash and wave energy is the critical value for assessing potential impact to sensitive shoreline areas or nearby vessels. SLICE only slightly exceeds the Washington State Ferry standard of 4,500 joules/meter at its maximum wavemaking speed of 15 knots, just meets the standard at about 21 knots, and drops well below it at service speeds (23-27 knots). SLICE wash energy at service speed was reported to be well below those of other high speed craft.

SLICE even at its claimed service speed of 30 knots is slow relative to most of the high speed craft coming into the market today, and requires more power than most, because of the large wetted area associated with its deep draft displacement. Its proponents claim that the design of the short hulls results in high Froude numbers and reduced wavemaking resistance. The power and resistance data provided indicate a competitive disadvantage, however. The "transportation efficiency" number, measuring payload and speed against required power, shows that the three concept SLICE craft considered (250, 400, and 600 variants) have the lowest range of numbers relative to groups of catamarans, wave piercers, SWATH, and high speed monohulls.

The SLICE power plant presents two significant conflicting design requirements: the limited space within the displacement pods for machinery arrangements and the need for higher powered engines relative to other high speed craft. The resulting design concepts have included pod-mounted gas turbines, because of their more compact geometry, and deck mounted marine diesels geared to the propeller by Z drives. Capital, fuel, and maintenance costs are in both cases likely higher than the conventional marine diesel configurations found on most

high speed craft. The limited space and access also raise a question as to the ease of routine maintenance and repair for pod-mounted engines.

The SWATH/SLICE family may pose more complexity in construction and maintenance than do other high speed types because of the depth and shape of the displacement hulls and the length and loading of the connecting struts, although production of significant numbers of these craft would probably reduce this disadvantage. Both SLICE and, to a lesser extent, SWATH draw much more water than other high speed types. Draft proved to be a severe limitation for the SLICE design variants considered, which would draw from 14.0' to 28.5' (the designers emphasize that these were scaled up geosims of the prototype with no consideration of draft limitations). This would eliminate SLICE from many inland and nearshore waterways where channel and docking depths will not suffice. In addition, these deep drafts are unsuitable for most Coast Guard missions (except the deep water cutter service now provided by the 378' Hamilton class) where maximum access to coastal waters is necessary. SLICE proponents have stated that more recent design proposals include drafts reduced to approximately 9 feet and service speeds of up to 35 knots; the draft is still much deeper than other high speed types and potentially problematic in many services. The project team was not provided with the particulars of these designs; there is, therefore no analysis and no discussion of the design tradeoffs (e.g., the effects of reduced draft on seakeeping, wake/wash signature, speed, and fuel consumption) inherent therein.

Market Case Studies

SLICE failed to show advantageous economic performance relative to its competition in all the ferry market case studies, and, in all but narrowly defined circumstances, in the crew boat and excursion services. The projected high capital and operating expenses of SLICE are the critical cost drivers. Construction cost analysis indicates that SLICE would be slightly more expensive than SWATH and well above the newbuilding cost of comparable high speed monohulls and catamarans. In addition, its relatively slow speed adds operating hours and, therefore, higher fuel consumption (both due to additional hours and its high fuel consumption per hour), personnel, and maintenance costs.

The seakeeping and ride quality advantage was factored in as extra passengers in the ferry service relative to other craft (based from local sea spectra data and ISO kinetosis standards), but did not result in significantly higher revenue. Hypothetical revenue and avoided cost factors in the gaming boat and crew boat studies indicate some potential economic advantage, but do not imply an overall advantage for SLICE. SWATH craft also offer excellent stability and seakeeping performance in high sea states, as well as speeds which in some cases now exceed 30 knots, at least equaling SLICE's design service speed. They are in fact SLICE's closest competitors, and the minimal practical advantages in U.S. passenger services of seakeeping and stability are reflected in the limited market penetration that SWATH has thus far achieved.

Southeast Alaska (Juneau to Skagway)

Of the mainline Alaska Marine Highway (AMHS) southeast route segments, the SLICE 600 would be best suited for the Juneau to Skagway route, which is well patronized, experiences relatively difficult sea states despite its location protected from the open ocean, and has fewer navigational issues related to controlling depths of channels and at berths than some of the other route segments in southeast Alaska. Although most channel depths in the area are suitable for the SLICE 600, the controlling depths along side of 26 feet at Juneau (Auke Bay), 23 to 25 feet at Haines, and 17 feet at Skagway are marginal with respect to the SLICE 600, but would be more than adequate for the 78 meter wave piercing catamaran (WPC) or other WPC designs being evaluated by AMHS. In addition to draft constraints, operational difficulties are also likely to be encountered with the SLICE 600 because of the deck heights at the existing ferry terminals throughout southeast Alaska, which allow a maximum freeboard height at the main vehicle deck entrance/exit of 8 feet. The SLICE 600 main vehicle deck freeboard height of 21.5 feet would be incompatible with existing southeast Alaska ferry terminal facilities. Although the 78 meter WPC returns an economic performance that is superior to the SLICE 600, both the 78 meter WPC and the SLICE 600 would require an increase in financial support from the state of Alaska, which does not meet the stated goal of the AMHS and the state of Alaska to reduce the system's financial burden upon the state.

Bay of Fundy (Saint John to Digby)

The Canadian federal government would not meet its goal of reducing and phasing out the current subsidy on this route with the SLICE 600, or the other high speed vessels analyzed. SLICE 600's draft would likely impose operational constraints in both prospective terminals at Saint John and Digby. Freeboard height would also be problematic at the existing ferry terminals, which are approximately 10 feet lower than the SLICE 600 vehicle deck freeboard. Sea conditions here are the worst among the case studies, but SLICE's revenue advantage here would be insignificant relative to other cost factors. Tractor trailers are not accommodated on either the SLICE 600 or the other high speed vessels examined, likely a politically unacceptable drawback. All the high speed craft examined would lose money in this service, with SLICE 600's deficits twice those of its competitors.

Hawaii

The difficult wave climate of the Hawaiian Islands is well suited to the application of SLICE vessels, providing SLICE ample opportunity to improve ride quality and passenger comfort for a substantial number of vessel operating hours annually relative to other vessel designs. Projected income before interest expense and taxes for Phase A of the inter-island SLICE ferry are conservatively estimated to be \$1.7 million during the first year of operation and \$2.4 million annually thereafter.

Lake Michigan (Milwaukee to Muskegon)

The SLICE 600 did not project profitable returns under any of the scenarios considered, including those in which the vessel would be repositioned in the off-season. SLICE would accrue little added ridership due to its superior seakeeping, because of relatively benign local sea state conditions. None of the craft considered could accommodate tractor trailers, a serious political disadvantage. Operating speed restrictions in Milwaukee and Muskegon Harbors limit the speed advantage of SLICE's competitors. Both the Incat 72 meter and AMD K50 (two of each) outperformed the single SLICE 600 financially in all six scenarios examined. SLICE 600's draft would result in unacceptable or marginally acceptable operating conditions at both termini.

Florida Keys (Miami to Key West)

The SLICE 600 does not project as a profitable option for any of the scenarios considered, due to higher direct operating costs, and much longer transit times. SLICE 400 appears to be better suited for this market, with more optimal passenger capacity for this market and lower operating costs. SLICE 400 falls between the more profitable AMD K50 in all scenarios considered and the 74 meter Incat WPC in all scenarios considered. Superior weather reliability and ride quality would benefit SLICE little in this service and its transit time of nearly 6 hours each way would limit the possibility of "day trip" travel, which prospect is only slightly better for the faster craft. SLICE 600's draft would also result in marginally acceptable operating conditions in both Key West Harbor and the Port of Miami at certain berths and in certain channels.

Caribbean

The economic, transportation, and wave/climate data proved very difficult to obtain for this route and a full analysis was not completed. It may be inferred, however, that SLICE would have difficulty competing against other high speed craft here. The service would be characterized as passenger only in relatively benign sea spectra, with route lengths of 44 to 100 nautical miles. It may be inferred from the results of the other cases that the SLICE seakeeping advantage would be minimal at best and its lower speed, particularly over the longer routes, would result in several categories of higher operating costs.

Excursion (Gaming Boat) Service

Excursion service may offer services where SLICE has an appreciable advantage, although such niches are likely to be quite small and narrowly defined. Only under circumstances where a high end service (large per passenger expenditure) must operate reliably year round in demanding sea conditions can SLICE offer inducement to the operator relative to the high speed competition today. The model for this study gives great weight to seakeeping and ride quality aspects, despite which the SLICE 400 could demonstrate only a narrow financial advantage under the worst of five sets of sea spectra for the different regions examined.

Crew Boat

The SLICE and SWATH vessels do not appear to offer significant advantages over less expensive, more fuel efficient and faster monohull and catamaran crew boats. High purchase price and lower cruise speed appear to be the biggest drivers of SLICE's overall costs. A faster, relatively cheap monohull would seem to offer operating and ownership costs low enough to offset the occasional sea state caused delay. Better information on the actual operating practices of crew boat owners in response to high sea states might shed more insight into the oil industry valuation of kinetosis prevention and timeliness of rig crew delivery.

SLICE Outlook

SLICE must have a substantial advantage in service to entice commercial buyers. This has proven difficult to demonstrate except for a very narrowly defined set of circumstances: high revenue service, and intensive year round schedule where sea states are consistently high. It must compete in this niche against SWATH, a similarly constrained design, and do so with two disadvantages: (1) it is at this time still considered a novel concept and is probably more expensive to build; and (2) it is draft limited to a worse extent than SWATH.

Analysis of Army Corps of Engineers sea state data for American waters indicates that very few areas have a profile conducive to SLICE's advantage in rough conditions. These exist mostly offshore, especially on the Pacific coast, whereas passenger services are overwhelmingly in inshore, more protected waters.

The results of the market case studies preclude any recommendations of a marketing type. The narrow definition of a viable market niche in the excursion service appears to fit the demands of the tourist economy and sea conditions in Hawaii, the very type of service under consideration by Pacific Marine, Inc. There are two successful SWATH services there now, although the present tepid condition of the Hawaiian tourism economy probably would not support a new SLICE start-up. One or two SLICE craft could, at some point in the future, be built to enter this service, although this is not a sufficient number for a long shipyard production run.

There are indications that technical improvements would enhance SLICE's performance and marketability. Advanced propulsion components and innovative arrangement, as well as upgraded and more effective ride control, would improve speed and ride quality (although in the latter case, SLICE is already superior in its class). The major drawbacks noted herein—relatively high fuel consumption and low speed and extremely deep draft—will, even if marginally mitigated, remain. Radical changes such as reduction of draft and wetted area to improve speed, economy, and operability in shallow waterways might seriously degrade SLICE's signature feature, superior seakeeping.

There is possible success in the future for SLICE as transportation system congestion forces the utilization of more modal alternatives, including ocean transport in exposed waters with challenging wave spectra. Although indications are that the right combination and waterway do not currently exist in North America, population growth and modernizing economies overseas may result in favorable market conditions in the future. SLICE's proponents will have a greater chance for success if they are prepared with fully realized commercial designs and cost estimates.

Chapter 1: Introduction

1.1 Project Background

The United States Navy Office of Naval Research (ONR) tasked the Volpe National Transportation Systems Center (Volpe Center) to evaluate the potential of "SLICE" for commercial application and non-military Government missions. SLICE is an advanced high speed hull form, derivative of the "small waterplane area twin hull" (SWATH) craft developed by the Navy in the 1970s. SLICE was designed and developed by Lockheed Martin Incorporated and Pacific Marine Incorporated (Honolulu, Hawaii) with the financial and technical support of ONR. At present, a SLICE "demonstrator" is operated by Pacific Marine from Honolulu, primarily as a workboat in support of Navy component testing requirements. Lockheed also developed concept designs known as SLICE 250 (similar in size to the demonstrator), SLICE 400 (a larger passenger only craft), and SLICE 600 (the largest, designed for passengers and vehicles). Until recently, there have been no commercial variant designs or contracts; Lockheed developed a design for a 400 passenger only ferry as a proposal for the Washington State Ferry System in the summer of 1999 which is not considered in the analysis herein.

The project's purpose is to ascertain the potential commercial aspect of its "dual use" purpose envisioned in the development of SLICE and required by Congressionally mandated Department of Defense policy. ONR tasked the Volpe Center to prepare a commercial and non-military government mission viability study, for which the Volpe Center commenced work after approval of a reimbursable agreement with ONR, effective May 1, 1998 through June 30, 1999. The program's period of performance was later extended further extended to accommodate schedule modifications, by modifications to the RA.

1.2 Objectives of Report

The objectives of the project are: (1) determine the potential of SLICE in commercial and non-military government applications, (2) investigate the implications of relevant marine safety and environmental protection regulations, and (3) ascertain the potential for future SLICE production work at United States shipyards. The first two objectives are addressed through an analysis of SLICE's performance characteristics and comparison to those of competing high speed craft types, and regional market case studies, identified following a service needs assessment and a characterization of the national commercial ferry market. The case studies focus on services and markets where SLICE's performance characteristics offer the greatest potential advantages. The potential for domestic shipbuilding production benefits is treated briefly thereafter.

The approach places the greatest emphasis on the commercial market, particularly the common carrier ferry sector. The reasoning is threefold: (1) high value capital acquisitions such as SLICE must carry high value cargo to succeed and people are not only the highest value cargo, but are also a high volume cargo; (2) the most highly capitalized part of the ferry market appears to be common carrier ferry service; and (3) as a corollary to (2), public financing, to the extent available, is the most available for scheduled common carrier service. The early stages of project research and analysis were therefore focused on characterization of this market, and identification of specific common carrier opportunity areas and services for SLICE, followed by acquisition of technical and performance data, analysis of other opportunity service options, and selection of market case studies.

1.3 Organization of Report

This report follows logically from general considerations to particular analyses. Background and project methodology (Chapters 2 and 3) precede a technical treatment of SLICE, a performance comparison relative to competing high speed types, and a treetop assessment of service needs and SLICE capabilities (Chapters 4, 5, and 6). The case studies follow.

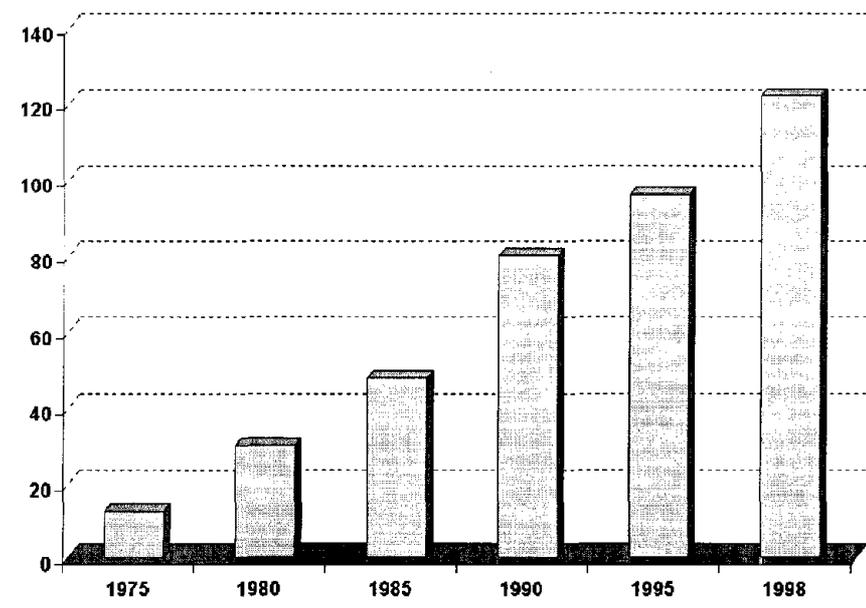
First, the results of the North American common carrier ferry market analysis and subsequent case study selection process and results are presented (Chapter 7), and details of the overall case study methodology are reviewed (Chapter 8). This is followed by specific ferry case studies (Chapters 9 through 13), which include a brief recapitulation of previous studies of the Hawaii market. Chapters 14 and 15 are case studies selected from the other services examined in Chapter 6; these turn out to be for crew boat and gaming excursion boat. The report concludes with findings and recommendations (Chapter 16).

Chapter 2: Background

2.1 High Speed Craft Environment and Trends

The high speed craft sector is the fastest growing of the marine industry, driven by several new technologies and improved producibility, and brought to an international market where demand and expectations have grown steadily since 1975. Figure 2-1 illustrates the upward trend of worldwide deliveries, which some in the industry feel will move toward a more constant rate. Designs have progressed toward larger and faster high speed craft, particularly catamaran and monohull types.

FIGURE 2-1: WORLD HIGH SPEED CRAFT DELIVERIES



Northern Europe and east Asia have been the major market areas, while Australia has dominated the high speed shipbuilding industry. The Australian commitment to the catamaran concept, principally by the Incat and Austal firms, began with small designs and has since resulted in a succession of larger and faster craft, now up to 120 meters in length with speeds in the mid to upper 40 knots range, with accompanying larger payloads. Several European companies, notably the Italian shipyards, have concentrated on high speed monohull designs. There is presently a design for a 142 meter long, 37 knot, 1,500 passenger, 425 car monohull, indicating a similar trend towards larger craft of that type.¹

The market in North America, in particular the United States, has lagged behind that elsewhere in the world, in part due to the strictures of the Jones Act. This picture has changed in recent years, however, as several U.S. shipyards have entered into licensing agreements with overseas firms to build high speed craft. After a period during which small to mid-sized craft have been built exclusively, the trend is now towards larger vessels, e.g.,

¹ Phillips, Stephen J., editor. *Jane's High-Speed Marine Transportation*. Thirty-first Edition. 1998-99. Jane's Information Group Limited.

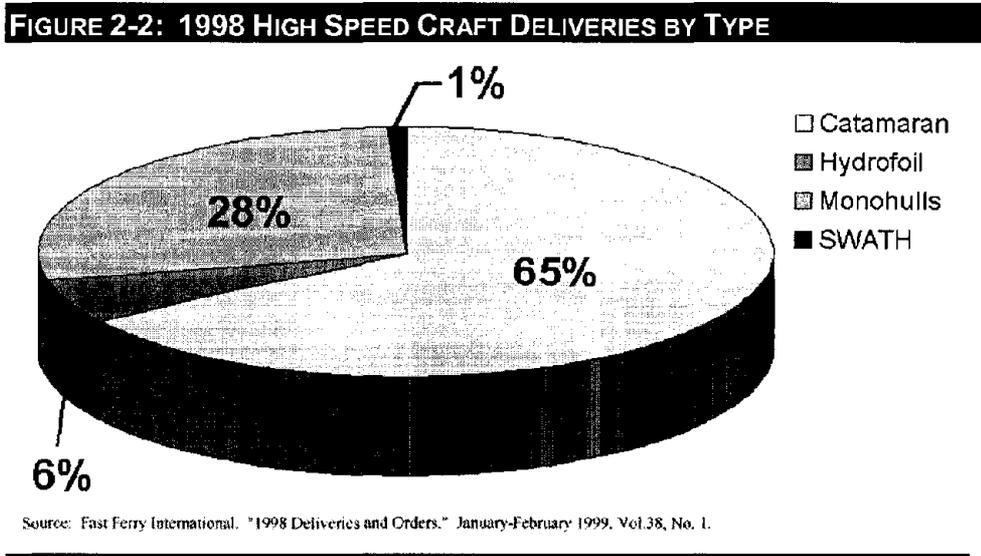
contract negotiations between Gladding-Hearn and Hydrolink (a venture proposing high speed ferry service between Milwaukee, Wisconsin and Muskegon, Michigan) call for one or two 72 meter Incat designed RoPax catamarans.

Island and commuter ferry services provide the bulk of the demand for the new craft, particularly the latter. Transportation planners are looking to waterborne transport options to alleviate road congestion and the TEA 21 legislation directs study of and provides funding for this emerging sector.

2.1.1 Technology

Several technologies have enabled the progression of successful high speed craft designs and construction, as well as the reliable and safe operation of the craft. These include waterjet propulsors with thrust reversing “buckets” for emergency stopping, advances in welding, fabrication, and metallurgy of aluminum structure, improved radar and electronic navigation, proliferation of multi-hull forms, and the advent of ride control systems. In addition, the continued progress in the power and sophistication of computer hardware and software has vastly improved the tools available to both designer and operator.

The result has been a proliferation of high speed types and sizes, dominated by catamarans and, to a lesser extent, monohulls (see Figure 2-2). The intent here is not to undertake a detailed comparison of these vessel types (a comparative analysis of representative class samples appears later in the report), but to point out that each has its strengths and weaknesses, depending on size, service, and operating conditions. The foreword to the 1998-99 *Jane’s High-Speed Marine Transportation* points out that the argument is far from decided and that each particular situation, with its particular shipbuilder, ship owner, and operating requirements, dictates the outcome.



2.1.2 Environmental Concerns

The growth of the high speed marine sector has brought with it increased attention to environmental impact, in particular noise, air emissions, and wake and wash effects. National and local statutes have been seen to drive technological improvements, for example catalytic converters for the engines of a new Corsair 11500 to meet the NOx emission standards in its operating area in Sweden.

The impact of wake and wash on sensitive shoreline receptors has been the foremost environmental issue in the United States. Waves propagated by high speed craft are themselves faster than those from conventional craft and increase in height as they enter shallow water. Their height and energy can pose a greater threat relative to conventional vessels and therefore have drawn the attention of citizens and public officials alike. A prominent example is the lawsuit against Washington State Ferries for its operation of an Advanced Multi Hull (AMD) design through Rich Passage on its Seattle-Bremerton service. Tests conducted showed that the vessel meets the local criteria for wave height and energy, but the plaintiffs contend that the operation is nonetheless damaging ecological features of the shoreline.

Noise and emissions have not yet achieved this sort of notoriety but there are indications that they may. A recent report indicates that environmental groups in San Francisco are contending that harmful diesel engine emissions from ferries are ten times those of cars and 23 times those of buses per passenger mile. Proponents respond that cleaner burning engines and alternative fuels could limit the emissions.² The expansion of high speed services, especially in the public transit sector, will certainly magnify the importance of this issue and designers and operators will have to respond, much as in the case of the Swedish service previously mentioned.

2.2 SLICE History

SLICE was originally developed under a cooperative agreement between ONR and the Lockheed Martin Company. The SLICE hull form is an evolution of Small Waterplane Area Twin Hull (SWATH) technology. SWATH was originally developed for the U.S Navy in the 1970s as a platform for oceanographic research, anti-submarine warfare, and other missions suited to its excellent seakeeping and stability characteristics. The SWATH's twin hulls (port and starboard separated by an ample beam dimension) provide displacement and lift at deep draft, connected to the working platform by relatively thin struts. The hulls lie below the waterplane, which is intercepted only by the struts; ship motion resulting from wave action is thus minimized. SWATH designs are now found in the Navy (T-AGOS 19 and 23 vessels) and in commercial operation. The latter includes two "Navatek" excursion vessels in Hawaii, the *Patria* operating passenger service in Europe, and recent new-buildings *Stillwater River* (crew boat) and *Cloud X* (gaming excursion).

The SLICE concept takes SWATH hull design a step further by separating the deep draft displacement units on each side, port and starboard, into two or more tapered pods. The aims are 1) to improve speed and resistance performance by a reduction of wetted surface and wavemaking resistance and an improved lift to drag ratio, and 2) to further improve on the seakeeping performance of the SWATH. Launched three years ago in November 1996, the demonstrator was built at Pacific Marine in Honolulu, Hawaii, who operated the craft until recently returning it to Lockheed. SLICE revenue service has been mostly in work boat missions for test and evaluation of military electronics systems. The owners have also engaged the craft in marketing activities with potential military and commercial customers, as well as additional technical evaluations such as the wake wash tests conducted in the spring of 1999.

Lockheed has undertaken the development of commercial concept designs for larger displacement SLICE vehicles, the SLICE 400 and SLICE 600. These designs are scaled up "geosims" of the original and were not subject to any limitations of water or air draft. The essential technical parameters for these craft are complete, but Lockheed has, at this writing, not produced an integrated commercial design with detailed builders drawings or an accurate estimate of the cost to build either the SLICE 400 or SLICE 600. A detailed SLICE ferry proposal for Washington State Ferries (WSF) was prepared and submitted in the summer of 1999, but was not available to the Volpe Center.

² Marine Digest and Transportation News, "Ferries pollute more than cars, Bay environmentalists say," August 1999. The reader should note that the data and analytical techniques employed by the "Bluewater Coalition" are a matter of some dispute with industry representatives.

High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

Pacific Marine has studied the potential for commercial SLICE service, including reports on international markets by Nigel Gee and Associates^{3,4}, U.S. markets by Art Anderson Associates⁵, and an internally prepared business planning document for inter-island service in Hawaii.⁶

³ Nigel Gee and Associates, Ltd.. *Sea SLICE Marketing Study for Pacific Marine. Volume 2 - Stena HSS Case Study.* June 1995.

⁴ Nigel Gee and Associates, Ltd.. *Sea SLICE Marketing Study for Pacific Marine. Volume 3 - Route Studies.* June 1995.

⁵ Art Anderson Associates. *Study of Marketing Possibilities for Two Variants of the SLICE Design.* June 1995.

⁶ Pacific Marine & Supply Company, Ltd. *Hawaii Inter-Island Ferry Business Plan. Phase A.* July 1995.

Chapter 3: Methodology

3.1 General

SLICE is a unique high speed prototype craft and an unproven commercial product whose novel features and performance characteristics have not yet resulted in commercial orders. Its potential to enter the market depends on opening new routes and services where other high speed types are not likely to succeed, or in demonstrating a clear competitive advantage over those craft on certain attractive routes and services. Case studies of individual markets screened for high success potential are the chosen method for the assessment of SLICE's commercial potential.

The commercial feasibility analysis of SLICE involves the integration of three data sets and analyses, resulting in a complete picture for each of a number of selected case market studies. These are: (1) economic and demand parameters; (2) comparative high speed craft performance measures; and (3) characterizations of the operating environment. Each case study will therefore present a thorough analysis of the market, including technical and performance data not typically found in many commercial business plans.

The technical aspect of this approach goes beyond what most in the industry and finance sectors normally expect. SLICE's purported advantage of stable, seakindly operation in rough weather and its benign wash and wake characteristics must therefore be quantitatively defined by a valid technical and economic comparison to other high speed vessels. The performance analysis of the SLICE and a comparison to that of other high speed craft is essential to determining whether SLICE's unique features suffice to make it attractive to some operators. The aim of this assessment is to establish whether these features, in conjunction with economic parameters, will gain SLICE entry into the burgeoning North American high speed marine sector. Therefore, a thorough quantitative analysis is undertaken to compare economic and performance, particularly seakeeping, characteristics of the SLICE and the high speed craft family.

The definition of the universe of competing high speed vessels starts with the recognition of three categories: Design, Build, and Commercial. The working assumption is that all craft in the concept and design phases, as well as prototype or first article vessels in the build phase (e.g., HYSWAS), aren't commercially viable for technical and economic reasons. The field of competition is formidable as is, with many mature craft types up and operating. This approach confers commercial status to SLICE beyond the reality of the sole prototype craft in operation.

3.1.1 *SLICE Candidate Market Boundary*

The initial assessment of the world market concluded that a successful SLICE service would probably be in one of three venues: (1) in the United States; (2) in countries without their own subsidized (direct or indirect) ship-building industries; or (3) as a design licensed to shipyards throughout the world. Companies operating in countries with their own subsidized ship-building industries will tend to buy their boats from local shipbuilders; SLICE is, for these purposes, ruled out of the market in France, Great Britain, Japan, Australia, Germany, Sweden, Italy, South Korea, Singapore, and Norway, although the design could be locally licensed in the future.

The Gee study of overseas markets characterizes European and Asian prospects clearly, i.e., serious difficulties in Europe and better prospects in certain Asian markets.^{7,8} That work was not repeated as a practical matter of project resource use and the relative difficulty of executing the work in the detail desired for overseas markets.

Furthermore, markets in the U.S. and directly influenced by the U.S are the best candidates at this time for two compelling reasons. The first is that places where high speed vessels in general and SLICE in particular might be of interest need to be fairly prosperous in order to justify the capital costs of the boat, as well as the apparent need in some cases for special or modified terminal facilities. By this logic, the U.S. and Canadian markets, as well as nearby "destination" markets (i.e., Mexico and the Caribbean Islands), are the most attractive world market. The second reason is that this part of the world has lagged considerably behind Europe and Asia in its exploitation of the high speed market; it is arguably the best opportunity area in the world at this time.

3.1.2 Approach

The initial assessment of the high speed marine market, consisting of internal consultations and review of past Volpe Center work in transportation economics, efficiency and feasibility, is that the best high value, time sensitive opportunities lie in passenger transport. Recent market developments indicate that there are opportunities for high speed craft in other services. The scope of the project includes an assessment of passenger service opportunities and an investigation of specific markets for other services as well.

The approach, then, is generally as follows:

- (1) Develop technical data base for SLICE and other high speed vessel types for purpose of identifying comparative measures for the potential service applications. This included a detailed and quantitative assessment of SLICE's performance relative to other high speed craft types. Results appear in Chapters 4 and 5.
- (2) Identify the parameters (mission, economics, range, seasons, exposure to rough seas, etc.) of other possible services, e.g., excursions, HAZMAT, and non-military government missions, and conduct an initial assessment of the efficacy of SLICE in said services. Results appear in Chapter 6.
- (3) Conduct a macro-market scan and analysis of the North American passenger transport market, defined to include the United States, Canada, Mexico, and the Caribbean. The scheduled, common carrier sector only was included, e.g., ferry services, with both existing and potential new routes examined. Excursion passenger services were excluded from this portion of the study because data on a national basis are not so readily available and because this is a highly localized and variegated market. Results appear in Chapter 7.
- (4) Select common carrier market cases by screening of descriptive data for economic, operational, and engineering requirements and limitations. Process and results appear in Chapter 8.
- (5) Conduct detailed case studies of individual metropolitan and regional common carrier ferry markets. These were identified by the output of the macro-market scan and review and input of the ONR. In addition to economic and demand analyses, the case studies treat environmental and navigational safety issues. Process description appears in Chapter 8 and results in Chapters 9 through 13.
- (6) Select and execute "other service" case studies, two in number, to determine the commercial potential of SLICE there as well. Selections appear in Chapter 6 and results in Chapters 14 and 15.

⁷ Nigel Gee and Associates, Ltd.. *Sea SLICE Marketing Study for Pacific Marine. Volume 2 - Stena HSS Case Study.* June 1995.

⁸ Nigel Gee and Associates, Ltd.. *Sea SLICE Marketing Study for Pacific Marine. Volume 3 - Route Studies.* June 1995.

3.2 Technical Analysis of High Speed Craft

It was essential to establish a basis of performance comparison among SLICE and competing high speed vessel types. Those results form, in part, the basis of the economic analysis of each case study and comprise one element of the service needs analysis. SLICE performance was thus more precisely defined for both the common carrier studies and for matching to the operating specifications, to the extent they are available, of the non-military government, cargo, and other services examined. The results of the latter analysis are the basis of the selection of case studies in addition to those undertaken for the common carrier ferry service.

3.2.1 Service Needs

Volpe Center staff conducted an industry scan and developed a roster of potential services for SLICE, outside of common carrier passenger ferry service. A matrix catalogs the needs of each service option and the benefits and drawbacks of SLICE application thereto. The detailed specifications for all service could not be accurately compiled because of the reticence on the part of some operators and builders. It should be added that none of those contacted indicated that seakeeping requirements are specified; operators and financiers have not reached that level of sophistication and confidence with the ship motion and environment characterization now available.

Project staff, with cooperation of the ONR, screened the list of candidate services and identified those that were the most viable candidates for SLICE application. These are the subject of additional case studies. In addition, a brief examination of available Coast Guard mission specifications resulted in an assessment of SLICE's suitability for those services (note that the Volpe Center did not consider the ongoing Coast Guard deep water cutter project, for which a SLICE proposal, prepared by a consortium led by Lockheed, is one of three finalists).

3.2.2 SLICE and Other High Speed Craft Capabilities

The apparently high acquisition cost and novel nature of hull form imply that SLICE's potential to enter the market depends on its opening new routes and services where other high speed types are not likely to succeed, an argument that has not been effectively made in the marketplace by SLICE's proponents. SLICE's purported advantage of stable, seakindly operation in rough weather must therefore be quantitatively defined by a valid comparison to other high speed vessels, and that advantage demonstrated in specific sets of operational criteria and conditions. For this reason, the project team developed a data base with a set of basic technical descriptors for a variety of commercial high speed craft likely to compete with SLICE. The team also acquired a catalog of motions and acceleration data, from computerized linear seakeeping programs, validated by model tests and full scale instrumentation, for SLICE and a smaller group of competing vessels of varied types.

The vessel population of interest includes catamarans (including wave piercing type), pentamarans, monohulls, and small-waterplane-area-twin hulls (SWATH). The following descriptive data are the primary points of reference for the economic and technical comparisons:

- Principal dimensions and draft
- Displacement and payload weight (includes weight of passengers, their baggage, cargo and vehicles only)
- Description of power plant (type and power rating)
- Operational speed and fuel consumption rate at service speed
- Passenger and vehicle capacities
- Service endurance
- Resistance and powering data

Chapter 5 is an analysis from the general to the particular, resulting in a clear picture of the capabilities of SLICE relative to its likely high speed craft competitors in the common carrier ferry and other service case stud-

ies. The “transportation efficiency” index is a good initial indicator of both performance and acquisition cost, relating payload and speed to installed power. More detailed comparative measures rate the field in fuel consumption, seakeeping, and other features (notably, draft).

The ship motions calculations are aimed primarily at a determination of passenger comfort, with some attention also to passenger, crew, and cargo safety criteria, with the results used in a comparative analyses of the SLICE variants and the selected competing craft. The calculations are for a variety of conditions, i.e., sea states 3, 4, 5, and 6 with outputs including ship motions (pitch, roll, heave and vertical acceleration) at specified bridge and passenger deck positions, deck wetness and slamming statistics, passenger comfort assessment for selected operational conditions, crew and passenger safety assessment for the above selected conditions using the subjective motion (e.g., Shoenberger) or other specified criteria, and cargo safety assessments for the above selected conditions using standard IMO acceleration and motion criteria.

3.2.3 SLICE Variants in this Study

Proponents of SLICE have put forward many concept variants in the aspects of size, service, number of pods, propulsion type, and others. There has also been a proposal for a “SLICE trailer”, a non-propelled platform with four pods which would be designed for towing by a powered SLICE and for carriage of large vehicles or other revenue cargo.

It was necessary to establish the study’s bounds by identifying known vessel and design data and limiting the number of variants under consideration. It was agreed via e-mail correspondence of December 7, 1998 that the SLICE “250” discussed in the Hawaii inter-island study, and the 400/600 types in the Gee studies would be sufficient. The SLICE 600 includes the passenger-vehicle capability and eliminates the need to address the unknowns of the SLICE trailer.

It turned out that the best available data from Lockheed were for the SLICE 400 and 600 variants, in “Technical Data Packages” completed in April, 1995. The size and geometry of the SLICE 400 are actually very close to both the demonstrator and the SLICE 250. It should in addition be noted that the competition in the small size range of catamarans and other high speed craft are, for the most part, carrying 350 passengers or more; the SLICE 400 therefore is a better choice than the 250 for more direct comparison. The performance results for the SLICE 400 are quite serviceable for purposes of analysis involving the smaller variants.

3.3 Common Carrier Ferry Service Case Studies

The Volpe Center adopted a case study approach for this analysis of the commercial feasibility of SLICE, wherein the technical and economic characteristics of various vessels and their operation in specific geographic markets are reviewed in some detail, allowing for conclusions to be drawn with more confidence than from a more generalized approach. This method is a hybrid of the broad brush, multi-route analysis adopted by Gee and Art Anderson Associates in their 1995 SLICE studies and the thorough-going investment grade analysis required for financing of a new or improved ferry service for a public or private provider.

The case studies here are in many ways comparable to the “real world” approach, and improve upon it in some notable respects. Each case includes a histogram of sea states during hours of operations and links those data to the seakeeping signatures of several competing vessels. The result is a determination of the projected ride quality and weather reliability performance of SLICE and other craft. These data combine with demand, ridership, and financial analysis to form an integrated picture of each case market.

3.3.1 Ferry Route Data Base

The Volpe Center developed a comprehensive ferry route inventory data base, with data on route length, service types, scheduled travel times, and other basic data elements. This tool, whose basis was a broad spectrum of public and private sector data bases, literature search, and personal contact with operators, served as the route population from which case study candidates were selected. The data base was made available on both diskette and via the Volpe Center anonymous ftp site to operators and other attendees at the Fast Ferry International Conference in February, 1999. It later formed the basis of the National Ferry Database, prepared by the Volpe Center for the Federal Highway Administration in response to a mandate under the Transportation Equity Act for the 21st Century (TEA 21).

3.3.2 Screening Process and Selection

The total population of services and routes was reduced in successive steps by the application of several selection criteria, a systematic process of elimination to screen out routes deemed unsuitable for further consideration. The primary criteria utilized were:

- Route length
- Wave climate
- Draft restrictions and controlling depth
- Existing or forecast ridership
- Service profile
- Seasonality
- Likelihood of implementation
- Sponsor and other industry stakeholder input

The result is a group of case studies logically selected on the basis of geography, demographics, and commercial environment. Optimal route length and potential operational restrictions constitute the geographic data of interest. The notably high draft values of SLICE craft designs restrict their operation in many areas because of shallow navigational channels and terminal approaches. The initial screen for channel depth was based upon the known draft of the SLICE demonstrator (the only variant whose principal dimensions were known at that stage of the project). Subsequent adoption of the SLICE 400 and 600 variants as the subject craft did not fatally flaw the assumed case study conditions but resulted in some marginal situations. Where the draft of the chosen SLICE variant is close to, or even slightly in excess of, minimum channel depths, the assumption is that it can operate without channel dredging.

Demographics and commercial environment fields provided the data for a rough determination as to whether the economic threshold for a fast ferry operation could be attained. The presence or history of ferry operations led to the choice of the SLICE variant chosen for each case. For instance, a route with a history of passenger only service would be the subject of a study of the SLICE 400 variant, while the SLICE 600 would be chosen where passenger and vehicle service is found.

Likewise, SLICE main deck freeboards are high relative to most passenger vessels. There is an assumption that no terminal modifications to accommodate deck height are necessary, although in practice such a requirement might well be necessary and quite costly.

3.3.3 Data and Analysis

Each case study represents a comparative analysis of alternative vessel types and specific operating scenarios, in common carrier ferry markets meant to be illustrative of those most likely to be suitable candidates for application of SLICE vessels. The primary elements considered for each case study analysis include the following:

- Introduction and regional overview
- Ferry market overview and operational profiles
- Related infrastructure and facilities
- Existing and/or proposed vessels
- Weather and wave climate
- Navigational considerations
- Environmental considerations
- Market forecasts and financial analysis

Economic and operational performance analyses appear in the case studies, resulting in budgetary estimates for the operator and weather reliability impact projections. The influence of the latter on the bottom line is also gauged. Further detail on the data processing and market analysis methods appears in Chapter 8.

3.4 Other Service Case Studies

Chapter 6 is a compendium of all the reasonably applicable services, other than common carrier ferries, for SLICE, and a reduction to two additional case studies. This screening process lacks the quantitative precision of the common carrier ferry case selection process because there are many different services considered, some in much smaller market sectors. The market-wide data are not available as they are for ferry services; therefore, a qualitative judgment by a group of marine professionals was undertaken, based on a thoughtful compilation of SLICE's advantages and disadvantages relative to each service. The results of the performance comparison in Chapter 5 were foremost in the minds of the group. It should, however, be pointed out that the seakeeping results do not play directly into the service needs assessment because almost all commercial and government operators fail to specify seakeeping performance. The advantage of SLICE seakeeping performance could only, therefore, be qualitatively characterized at this stage.

3.4.1 Selection and Analysis

The selection of other services case studies was the result of the best effort of the project team to logically reduce the field and best match the needs of those services to SLICE's capabilities. Performance specifications for most of the services in the matrix are not, similar to their lack of market data, available. Two cases were selected.

The analytical approach combines economic and performance modes. Estimates of the significant financial factors result in a daily operating cost for both cases and, in one case, daily revenues. The impacts of reliability and ride quality for each service route are quantified by estimating frequency of cancellations and exceedance of international motion sickness standards.

Chapter 4: SLICE Technical Profile

4.1 SLICE Description and Service History

The term "SLICE" describes a family of designs of varying size and service, one of which has been built and tested as a demonstrator. SLICE designs may be modular variants of the parent design, achieved by modifying the size and number of displacement pods. SLICE and similar craft operate on displacement pods attached by thin struts to the hull, which rides above the surface. As with SWATHs, their predecessor, SLICE's waterplane intercept is thus quite small in area, lending excellent stability and seakeeping characteristics, even in severe sea conditions.

SLICE design has allowed for an unusual performance signature: a small, relatively fast craft with excellent stability. The displacement is provided by multiple (four or more) short and relatively fat deep hulls which are at sufficient depth to reduce surface interactions. The connecting struts have relatively low wavemaking resistance, resulting in low wake and wash signature. The demonstrator has shown that it can maintain high speed in sea state 4, with only a 7% speed loss relative to calm water speed.⁹

All design variants thus far seen have four pods, which vary in size to yield a range of displacement values. Power is provided by engines in two or more of the pods; all designs, except that recently proposed to Washington State Ferries, currently share the two engines forward configuration with propellers at the aft ends of the pods. All functions save propulsion are topside on the deck, which spans the four pod struts; these include the pilot house, command and control suite, mooring and line handling components, crew accommodations, and the working or revenue spaces of the craft, e.g., helicopter deck, working deck for military test and evaluation missions, or modular units for commercial and other military missions. The modularity feature has been given some emphasis by the proponents of SLICE, who feel that the interchangeability and multi-mission capability are strong features of the craft.

The prototype SLICE ATD (Advanced Technology Demonstrator) is a 180 long ton displacement craft with minimal superstructure for command and control functions and basic day mission habitability requirements, with a large, open working deck aft. The craft was built to a limited budget and is not regarded by Lockheed or Pacific Marine as the working design for future commercial endeavors. The fiscal constraint in the prototype project limited the size of the craft and choices for propulsion. Its particulars appear below in Table 4-1, along with those of the concept designs for larger commercial service variants.

The demonstrator has been employed in a number of performance trials and several military workboat missions, mostly in Hawaiian waters. Notable among the performance trials was a comparative sea trial with two Coast Guard cutters in June of 1998. The SLICE fared quite well in sea state 3 and 4 conditions, demonstrating excellent seakeeping and ability to hold speed on all four headings in a quadrant, particularly by comparison to the Coast Guard 110' cutter. The demonstrator also visited the U.S. west coast in the spring of 1999 for military workboat missions in San Diego and marketing to transit and commercial operators in San Francisco. An evaluation of SLICE's wake and wash characteristics was also conducted at this time (synopsis of results below).

Pacific Marine, Inc., the operator of the SLICE demonstrator, are pursuing pod design modifications which they feel could significantly reduce drag and increase service speeds from 30 to 50 knots. It is not within the scope of this report to comment on the efficacy of such prospective technological improvements. The commercial vi-

⁹ Pacific Marine presentation, "The Hydrodynamics of SLICE Ships or Why Short and Fat Might Outperform Long and Slender Hulls."

ability analysis proceeds with available geometric and configuration data for the demonstrator and designs for future variants as addressed in Chapter 3.

4.1.1 Observed Performance

The Volpe Center project team visited Hawaii in June of 1998 to observe the SLICE demonstrator in a sea trial with two Coast Guard cutters. The trial was designed to compare SLICE performance at cruising speed against two Coast Guard cutters at their top speeds: the 378' CGC *Rush* and the 110' CGC *Washington*. All three were instrumented for motions and accelerations. The *Washington* was late due to a generator problem and missed two of the four quadrant runs. The *Rush* was only able to operate diesels (gas turbine problems) and could only make up to about 15 knots. The third quadrant included all three vessels at about 14 knots. The *Rush* departed prior for the final run, which went off at about 28 knots into bow quartering seas.

The trial condition was a strong sea state 3 to sea state 4, with long southerly ocean swells and easterly wind waves. The observations were:

- SLICE's worst motion was in beam waves.
- The craft exhibited excellent stability and sustained speed quite well in all seas. Generally, it performed best in head seas. Mr. Steven Loui of Pacific Marine stated that steep waves of 10-12 feet cause the worst slapping loads on the exposed under structure.
- The impression on deck was one of a stable, but somewhat rough ride. The operators stated that the ride control system was not performing as expected and should improve with experience.
- The high speed (28 knots) run with the 110' CGC was stable yet with quick minor accelerations (a "trolley ride" as described by the operators). The 110' CGC kept up speed but often labored heavily through the waves. The Coast Guard skipper ordered all personnel off decks because of heavy motion and spray. Observers on the SLICE were as comfortable as on other runs, except for the increased wind.
- Pacific Marine reports that SLICE consumes about 170 gallons of fuel per hour. The diesels are overhauled every 6000 hours, the generator sets every 15,000 hours. The prototype was built with about 75,000 man hours.
- SLICE can "crash stop" in approximately two boat lengths.
- SLICE is not a nimble craft. The "canards", moving control surfaces on the inboard sides of the aft pods, are programmed to minimize roll and will resist quick turns.

Volpe Center personnel also observed SLICE operations in San Francisco during April of 1999. The most notable event was the operation in waters just outside the Golden Gate, where sea state 5 conditions were encountered. Current and bathymetry make for steep short crested waves in this area, which the SLICE handled very well. The ride was observed to be quite stable and with a small fraction of the ship motions one would expect from a conventional vessel. Some slamming was noted when the largest waves were encountered. There was instrument recording of accelerations but the project team has not been able to obtain the data.

Instrumented trials conducted by the Naval Surface Warfare Center, Carderock Division in April, 1998 off Oahu were reported in a summary published in January, 1999.¹⁰ The Navy reported that SLICE demonstrated "SWATH-like" seakeeping characteristics and a "relatively stable ride" in sea conditions up to sea state 5, with some "slamming and shuddering" in the higher conditions.

¹⁰ Applebee, Terrence R., and Dennis A. Woolaver. *Summary of Seakeeping Trials Aboard SLICE*. Naval Surface Warfare Center, Carderock Division. Report # NSWCCD-50-TR-1999/002. January 1999.

4.2 Principal Particulars

The principal particulars of known SLICE designs appear below in Table 4-1. Source data are from Lockheed Technical Data Packages for the SLICE 400 and SLICE 600, which include data for the demonstrator and SLICE 250 variants as well. These characteristics are the key inputs for the economic and performance analyses which follow. The Technical Data Packages also contained sufficient hull form and weight distribution data for execution of the seakeeping analysis, whose results appear in Chapter 5. The reader should note that Lockheed's numbers for the demonstrator changed from the original design (descriptors WT-15 to WT-AAA), due mainly to a decision to replace the gas turbines with diesel engines, and also because of other modifications for safety and passenger vessel requirements.

TABLE 4-1: SLICE PRINCIPAL PARTICULARS

Particulars	SLICE Variant			
	SLICE Advanced Technology Demonstrator (ATD) ⁽¹⁾	SLICE 250 ⁽²⁾	SLICE 400 ⁽³⁾	SLICE 600 ⁽⁴⁾
Length Overall (LOA) (feet)	104.0	110.5	111.5	213.0
Beam (feet)	55.0	55.0	61.0	105.0
Draft (feet)	14.0	14.0	15.0	28.5
Main Passenger Deck Freeboard (feet)	11.0	11.0	11.75	31.0
Vehicle Deck Freeboard (feet)	n/a	n/a	n/a	21.5
Displacement (long tons)	180.0	180.0	220.0	1,500.0
Payload (long tons)	35.1	17.9	28.6	177.9
Passenger Capacity	n/a	250	400	600
Vehicle Capacity (AEU) ⁽⁵⁾	n/a	n/a	n/a	90
Main Engines	(2) MTU 16V 396 TB94	(2) TF40 gas turbines	(2) TF40 gas turbines	(2) RLM1600 gas turbines or equivalent
Total Power (hp)	6,850	6,800 ⁽⁶⁾	6,800	36,000
Service Speed (knots)	23 to 25 ⁽⁷⁾	30.0	30.0	30.0

n/a (not applicable)

Sources:

- (1) Lockheed Marine Systems, *SLICE ATD Weights Summary*. Also, U.S. Navy, Office of Naval Research, Industrial Programs.
- (2) Lockheed Marine Systems. Also, *Hawaii Inter-Island Ferry Business Plan Phase A*. Pacific Marine & Supply Company, Ltd. July 1995.
- (3) Lockheed Marine Systems. *400 Passenger Slice Ferry. Technical Data Package*. April 1995.
- (4) Lockheed Marine Systems. *SLICE 600 Passenger Vehicle Ferry. Technical Data Package*. April 1995.
- (5) Automobile equivalent unit (AEU), which in the case of the SLICE 600 is considered a 19' x 9' space on the vehicle deck.
- (6) No data available, but power requirements are inferred from the SLICE ATD and the SLICE 400.
- (7) Although operating speeds of 27 to 28 knots were planned for, in practice speeds of 23 to 25 knots are achieved at 85% mcr.

Several comments relative to the above data are appropriate at this stage:

- Outfit and furnishings for the demonstrator are minimal, therefore its payload is very high relative to those projected for commercial designs.
- There is no known passenger or vehicle capacity for the demonstrator.
- The chosen power plant for all variants except the demonstrator are gas turbines, probably because of space limitations in the pods. Two MTU 16V 396 TB94 marine diesel engines were installed in the demonstrator apparently because they came at very low cost, but also with a penalty of weight and speed.

- The operators of SLICE ATD report that, at 85% mcr, the craft makes approximately 23-25 knots.
- The geometry, displacement, and powering requirement of the demonstrator, SLICE 250, and SLICE 400 are quite similar, a fact which should be recalled in review of the economic and performance analysis results.

The general arrangements for the SLICE 400 are presented in Figure 4-1. The SLICE 400 is a conceptual design for an aluminum hulled 34 meter passenger-only ferry. The vessel is planned to accommodate a total of approximately 400 passengers on two decks, with the main deck accommodating 268 passengers, and the upper deck 132 passengers. The planned service speed of the SLICE 400 is 30 knots.

The general arrangements for the SLICE 600 are presented in Figure 4-2. The SLICE 600 is a conceptual design (a “geosim” of the 400, according to the designers) of a steel hulled 65 meter RoPax ferry. The vessel is planned to accommodate approximately 600 passengers and 90 automobiles, or a combination of 4 motor-coaches and 75 automobiles, with access to the vehicle deck from the stern. Passengers are accommodated on two decks, with approximately 422 in economy class seating in two separate compartments on the gallery deck, with each compartment having its own restroom and snack bar. An additional 178 passengers accommodated on the upper deck in first class or lounge type seating. The planned service speed of the SLICE 600 is 30 knots.

4.3 Safety

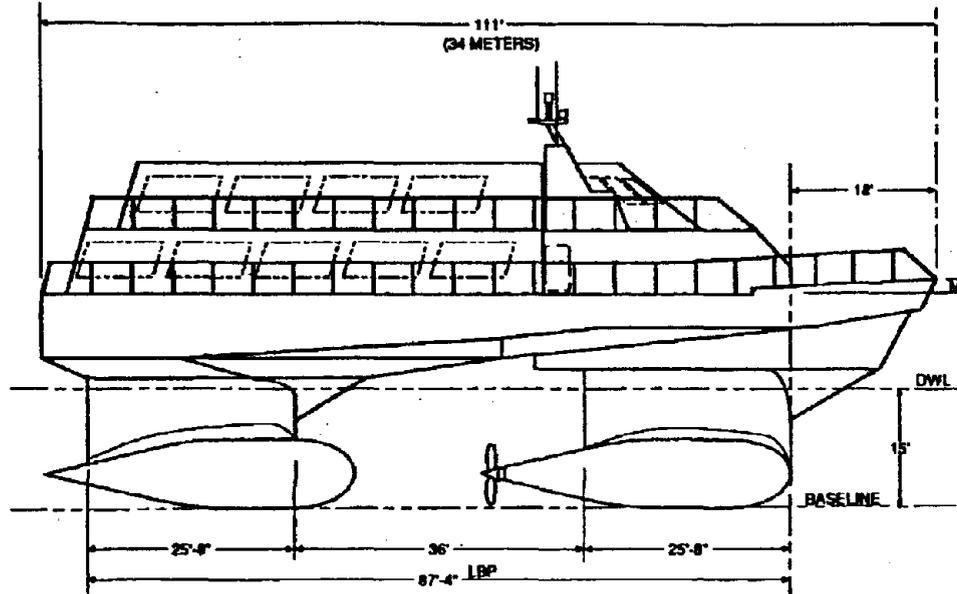
The SLICE ATD has been reviewed by the Coast Guard as a Subchapter T passenger vessel (fewer than 150 passengers, L<200’, gross tonnage<100), first by Marine Safety Office (MSO) Honolulu then by the Marine Safety Center in Washington, D.C. because of its novel aspects. The MSO Captain of the Port felt that there were no significant issues with regard to SLICE’s compliance with the relevant safety regulations. Such has been the case generally with high speed vessels, which have successfully met the engineering and safety requirements of the U.S Code of Federal Regulations (CFR) or the more stringent international High Speed Craft Code (HSC).

SLICE 400 and SLICE 600 designs also are intended to meet the relevant requirements of Title 46 of the Code of Federal Regulations, Subchapter T (parts 175-185). The designs at this stage meet the requirements for intact and damage stability for mechanically propelled ocean going passenger ships. Review at the time of certification would include approval of general arrangement and hull lines drawings, curves of form, tank capacities and draft markings, as well as the arrangement of watertight bulkheads and doors, and trunks and penetrations. Both vessels are designed to survive damage to any two adjacent compartments. They would also have to comply with fire safety, lifesaving appliances, navigation and communication, and passenger accommodation regulations.

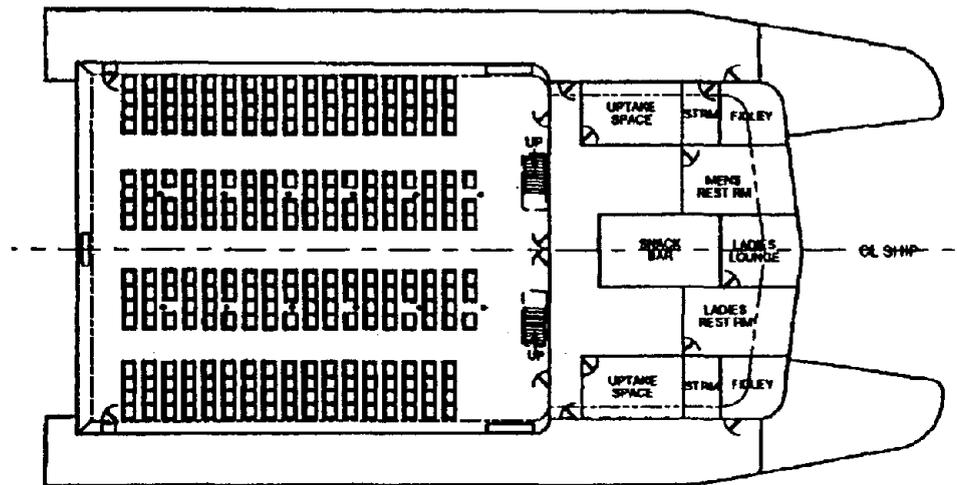
The issues that have arisen with high speed vessels are instead operational safety and environmental impact, e.g., high speed collision avoidance and wake and wave effects on adjacent shores, respectively. These concerns are waterway specific, nuanced according to local vessel traffic conditions and environmental sensitivity. They are therefore addressed in the context of the specific market case studies, which portray a variety of services and routes, whose analysis provides a clearer illumination of the issues than a general discussion.

FIGURE 4-1: SLICE 400 GENERAL ARRANGEMENTS

SLICE 400: OUTBOARD PROFILE



SLICE 400: MAIN DECK (268 passengers)



SLICE 400: UPPER PASSENGER DECK (132 passengers)

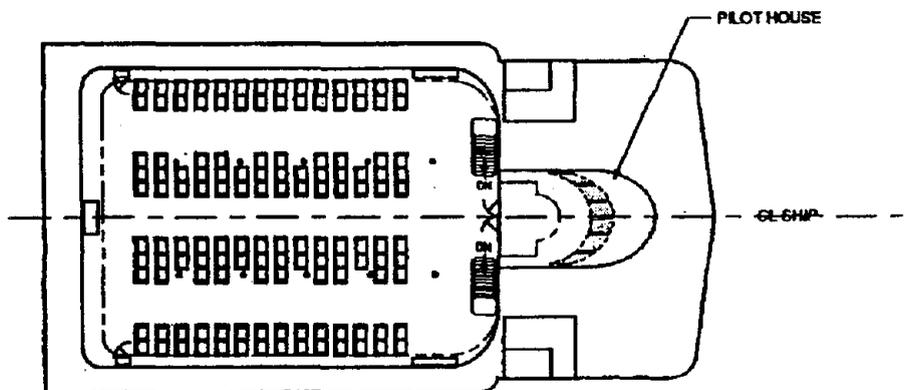
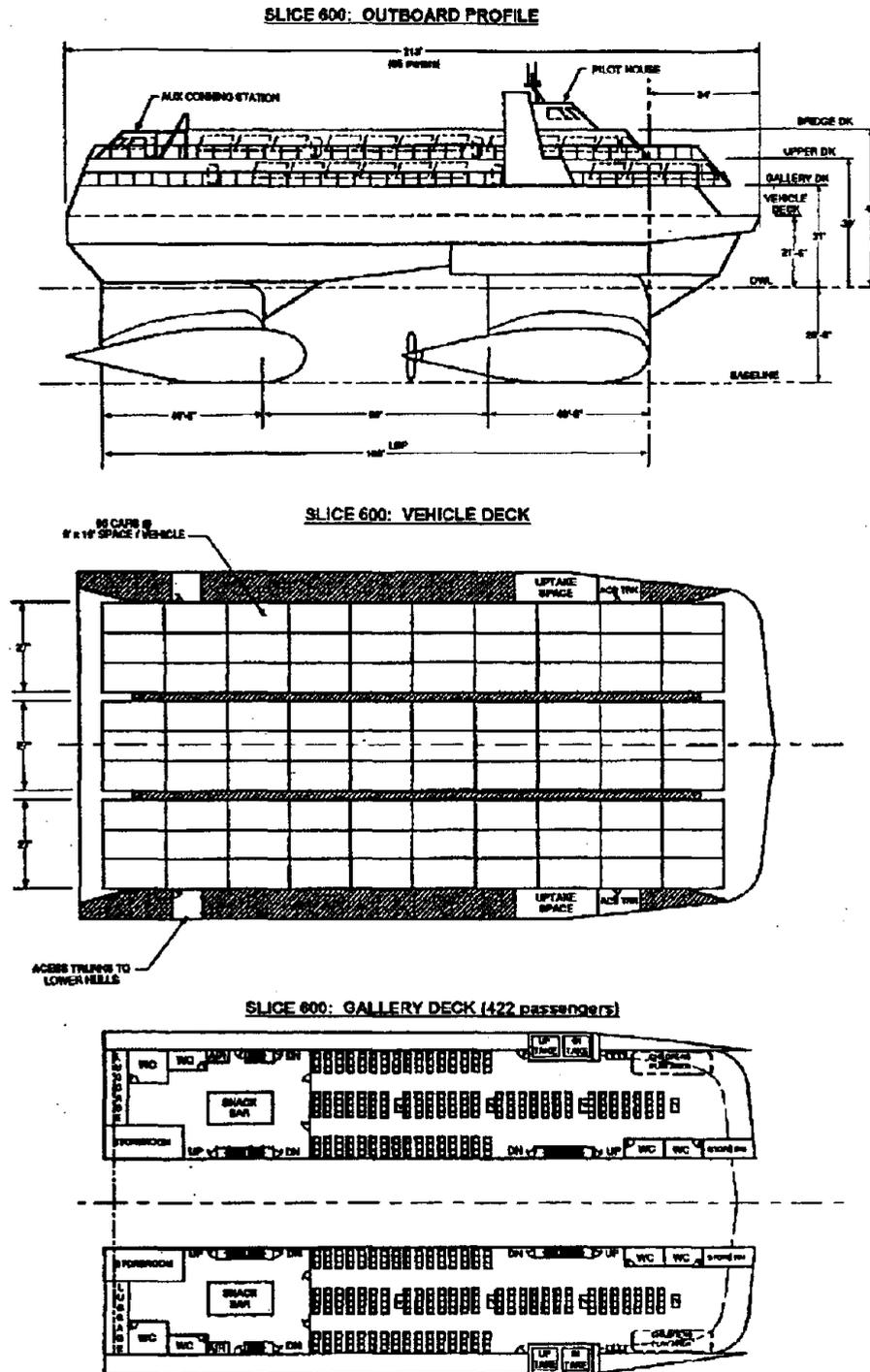


FIGURE 4-2: SLICE 600 GENERAL ARRANGEMENTS



One safety aspect which may present a problem is emergency evacuation, because of the interface between SLICE's high main deck and the decks of rescue vessels. This is particularly so for the SLICE 600 where the vehicle deck is 21' above the design waterline and the lowermost passenger deck 31.5' above it. This is likely solvable with one of the many new marine evacuation systems now available.

4.4 Power and Propulsion

The SLICE 400 and SLICE 600 Technical Data Packages both propose the use of aero-derivative marine gas turbines for power.¹¹ The powerplant for the SLICE 400 is two AlliedSignal TF40 marine gas turbines, which have a nominal maximum rating of 4,600 horsepower (3,430 kW), and a maximum continuous rating (MCR) of 4,000 horsepower (2,980 kW) but which would be derated to a MCR of 3,400 horsepower (2,530 kW) for the SLICE 400 application. The "oversizing" of the TF40 for the SLICE 400 is most likely due to the limited number of marine gas turbines available in this relatively low-power class, and has the benefit of accommodating power requirement growth. The powerplant for the SLICE 600 is two General Electric LM 1600 gas turbines, which have a peak rating of 20,000 horsepower (14,900 kW), and will be operated at a maximum continuous rating (MCR) of 18,000 horsepower (13,400 kW) to achieve the 30 knot operating speed. The SLICE 400 and 600 will both be equipped with controllable pitch propellers (CPP) driven through gearboxes by the gas turbine engines, one each located in the two forward pods. A further discussion of high speed craft propulsion is contained in Chapter 5, Section 5.2.2.

4.5 Seakeeping

SLICE's most attractive feature is its apparently superior seakeeping performance, resulting from the deep draft of its displacement pods and minimal waterplane of the four struts which minimizes surface interactions. It was essential to quantify this performance feature relative to the competition, in order to gain the perspectives of weather reliability and passenger comfort (i.e., the incidence of sea sickness).

The approach was to identify a small population of high speed craft in competition with the SLICE 400 and SLICE 600, conduct computer model (verified with model test and full scale instrumented results) seakeeping runs, and compare key outputs such as motions measured against ISO 2613 kinetosis standards, slamming, and propeller emergence. The work was carried out under a contract to Seaspeed Technology Limited, a top international high speed craft consultancy.

Seaspeed found that both SLICE variants are in this regard superior performers to the sampled craft of all types tested. SLICE easily met the ISO 2631 two hour kinetosis standard, the most stringent, in all conditions modeled up to sea state 5, both at service and low speeds. SLICE appears not to suffer from slamming at all in the modeled conditions (although Pacific Marine has found in operation that it occurs rarely), although, curiously, the SLICE 400 undergoes propeller emergence in sea state 5 beam waves. Altogether, SLICE lives up to its designers' expectations as the best seakeeping craft at high speed in heavy waves. Details of the comparative analysis may be found in Chapter 5. The complete Seaspeed report is presented as an Appendix to this report.

¹¹ Derived from aircraft engine designs, the Allied Signal/Lycoming TF40 and the General Electric F-404, respectively.

4.6 Wake and Wash

SLICE's deep draft displacement pods and small waterplane area combine to effect a very favorable wake and wash signature. The pods are at sufficient depth to minimize surface interactions and the four struts produce smaller waves than monohull or dual hull forms. Lockheed commissioned a study by Fox Associates, who designed a testing procedure in San Francisco Bay and recorded data characterizing SLICE's wake and wash.¹²

SLICE wake and wash signature peaks at intermediate speeds and is reduced as it approaches service speed, as with most high speed craft. Fox Associates reported that at 15-16 knots (Froude number = 0.6), SLICE's wash height, measured at 300 meters distance, peaks at approximately 52 centimeters and then drops with increasing vessel speed. Unlike other high speed craft, the SLICE wave period decreases at speeds above 0.6 Froude number.

This observation tracks roughly with the speed versus resistance curve developed by Lockheed indicating a maximum at about 12 knots, a minimum at 18 knots, and then a gradual increase as service speed is approached. Fox noted the curious phenomenon that the wave height and energy density peaks occur at about 4 to 6 knots higher speed than the resistance "hump". The SLICE demonstrator meets the Washington State Ferry standard of 30 centimeters maximum height at speeds above 26 knots.

Wash energy, or wave energy, is the critical value for assessing potential impact to sensitive shoreline areas or nearby vessels. The Washington State Ferry standard of 4,500 joules/meter has reportedly been exceeded by the AMD 385 Chinook now in service. The Fox analysis showed that SLICE only slightly exceeded the standard at its maximum wavemaking speed of 15 knots, just meets the standard at about 21 knots, and drops well below it at service speeds (23-27 knots). It is noteworthy that Fox reported that SLICE's wash energy at service speed is well below those of other high speed craft they have tested (catamarans and tri-catamarans). These favorable results were one of the primary features offered in Lockheed's high speed service proposal to Washington State Ferries.

The discussion of wake/wash performance comparison will not be repeated in individual case studies. Regulatory strictures as seen in Puget Sound are not in place in the regions under study (although speed limits are in some cases). This section serves as the common reference in the matter of wake/wash for the entire report.

¹² Fox Associates. *Wake Wash Measurement Trials: M/V SLICE*. Conducted for Lockheed Martin, Inc.. April 1999.

Chapter 5: High Speed Craft Comparison

This chapter is a technical brief offering a comparison of the SLICE family of craft to other high speed types. The results are the basis, in part, of the service needs assessment in Chapter 6 and the subsequent ferry, crew boat, and excursion boat case studies.

World fleet data indicate a very strong position for catamarans of all lengths and a solid showing for monohulls, particularly among the larger classes of high speed craft. Catamarans and monohulls accounted for 93% of the world market between them in 1998. Of the remaining 7%, hydrofoils accounted for 6%, leaving a 1% niche for other types. These include older technology such as air cushion and surface effect vehicles, and SWATHs. The question for SLICE, then, is whether it can compete successfully on routes served by other craft or make possible the opening of new routes which they cannot serve, in either case expanding that niche to the point where successful production of SLICE could occur.

It is therefore necessary to quantitatively compare the performance of high speed craft. The comparison includes use of conventional and readily available data such as powering and fuel consumption values, as well as seakeeping performance data. SLICE's apparent advantage is its stable and seakindly ride in heavy seaways. That advantage must be quantified relative to the competition in a technically consistent way, that is, ship motion results derived from the same analytical tools applied with the same set of conditions (Section 5.3). The results of all the foregoing give a fair picture of SLICE's place in the current environment and, furthermore, are a vital set of data for the quantified case study findings to follow.

The following sections are: (1) a tree top look at the advantages and disadvantages of several high speed types; (2) an examination of powering, payload, and efficiency; (3) a detailed comparison of seakeeping characteristics of two SLICE variants and a sampling of other high speed craft of comparable size and capacities; and (4) consideration of other operating features. Table 5-1 presents a subset of high speed craft and the SLICE variants of interest, which were used in the detailed technical and economic analyses to follow, both in this and subsequent chapters. "T.E." is the transportation efficiency, the subject of analysis in Section 5.2.1.

TABLE 5-1: HIGH SPEED CRAFT PRINCIPAL PARTICULARS

Craft Type	Payload (kg)	Service Speed (knots)	Power (kW)	T.E.	Length (m)
WPC	18,500	27.0	1,440	347	30
WPC	31,000	25.0	2,340	331	39
WPC	45,000	34.0	6,128	250	49
Catamaran	23,000	34.0	3,063	255	35
Catamaran	29,000	43.0	8,062	154	45
Catamaran	43,500	40.0	7,953	219	53
Catamaran	150,000	35.0	14,491	362	74
SWATH	41,000	30.0	3,885	317	37
SWATH	37,500	28.5	5,432	197	37
Monohull	80,000	38.0	13,422	226	70
Pent Design	33,000	65.0	19,138	112	66
Ro-Pax Cat	330,000	39.0	26,991	477	90
SLICE 250	18,500	30.0	5,250	106	34
SLICE 400	29,500	30.0	5,250	169	34
SLICE 600	181,500	30.0	25,500	214	65

5.1 High Speed Craft Overview

Table 5-2 shows the primary characteristics of the important types of high speed craft in the world today. The available technical literature serves generally as the source of this information, and an excellent summary is found in the Ferries 97 Conference presentation of Philippe Goubault (Fort Lauderdale, November 1997).

It is not intended as a definitive outlook on the benefits and drawbacks of high speed vessel types, but as an indication of current thinking in the industry. Specific designs will of course each have their own performance features. The following sections offer more specific measures of SLICE compared to particular designs of other popular high speed types.

TABLE 5-2: HIGH SPEED CRAFT PERFORMANCE FEATURES

Craft Type	Advantages	Disadvantages
Monohull	<ul style="list-style-type: none"> • Mature Technology • Large Hull Volume • Large Deadweight 	<ul style="list-style-type: none"> • High Power Requirement • Stability Limitation Relative to Beamier Types
Catamaran	<ul style="list-style-type: none"> • Good Stability • Large Deck Area • Good Powering Performance Due to Long Slender Hulls 	<ul style="list-style-type: none"> • Beam May Limit Access • High Vertical Accelerations in Head Seas • Stiff Roll Motion in Beam Seas
SWATH/SLICE	<ul style="list-style-type: none"> • Excellent Seakeeping & Stability • Low Speed Loss in Seaway • Large Deck Area 	<ul style="list-style-type: none"> • Difficult Machinery Arrangement • Limited Top Speed Due to High Wetted Area
Hydrofoil	<ul style="list-style-type: none"> • Superior Seakeeping • High Speed Capability 	<ul style="list-style-type: none"> • Limited Deadweight • Complexity of Foil Control System • Poor Operating Characteristics at Low and Medium Speeds • Expensive Aerospace Technology • Difficult Maneuvering

Source: Philippe Goubault. "Worldwide Review of Fast Ferries." Ferries 97 Conference. Fort Lauderdale, Florida. November 1997.

5.2 Power and Efficiency

5.2.1 The "Transportation Efficiency" Measure

One very effective measure of high speed craft performance is the "transportation efficiency" value, whose name may vary slightly depending on the source, but whose meaning is essentially constant: the relationship between the power plant and payload and speed it delivers. As such, transportation efficiency tells the operator, in relative terms, quite a bit about the operating costs and potential revenue of various high speed craft.

The term has been used in studies by the Alaska Marine Highway System in a 1997 Technical Memorandum entitled "Potential Implications of Technological Improvements", which rank ordered 22 high speed vessel types. Table 5-3 shows those results, which are not linked to any variable (e.g., length).

TABLE 5-3: HIGH SPEED CRAFT TRANSPORTATION EFFICIENCIES**Passenger-Only High Speed Vessels**

Rank	Vessel Type Description	T.E.
1	Foil Assisted Monohull	247
2	Surface Effect Ship	208
3	Wavepiercer	203
4	Catamaran	195
5	Surface Piercing Hydrofoil	182
6	Air Lubricated	177
7	Monohull	163
8	Air Cushion Vehicle	162
9	Foil Assisted Catamaran	159
10	Trimaran	154
11	Fully Submerged Hydrofoil	147
12	SWATH	146

Vehicle (RoRo) High Speed Vessels

Rank	Vessel Type Description	T.E.
1	Wavepiercer	441
2	Catamaran	342
3	Trimaran	336
4	Air Cushion Vehicle	315
5	Semi-SWATH	312
6	Monohull	305
7	Foil Assisted Catamaran	283
8	Surface Effect Ship	272
9	SWATH	249
10	40+ Knot Catamaran	176

Notes: T.E. = transportation efficiency.

Source: State of Alaska Department of Transportation and Public Facilities. Technical Memorandum 3: Potential Implications of Technological Improvements. Final Memorandum. Prepared by KJS Associates, Inc., in association with Art Anderson Associates and HDR Alaska. September 29, 1997. pg. 11.

Nigel Gee conducted a similar comparison for Pacific Marine in 1995, with more specific data linked to each craft, i.e., speed and length. Gee found that:

- SLICE competed poorly against most vessel types, excepting SWATHs, and in each case offered the caveat that SLICE would compete much better with the consideration of loss of speed in a seaway.
- Passenger-only monohulls (lengths up to about 50 meters) reach their maximum performance efficiency, and are the best among all craft types considered, at about 30 knots and suffer more marked power penalties at higher speeds than multi-hull craft. It is worthy of note that 30 knots is SLICE 400's intended service speed.
- The advantage shifts to catamarans in the class of larger RoPax craft. Monohulls as well as catamarans at these lengths operate at low Froude numbers and also perform well. The SLICE 600 rating was about average for a monohull and low for a catamaran.

The project team sampled the Gee data and added those for more high speed craft built since 1995. In-house calculations for craft payload were on the basis of 72.7 kg (160 pounds) per passenger (Coast Guard standard) and 1,200 kg per automobile. The Gee transportation efficiency calculations were adjusted downward because of their original selected value of 85 kg per passenger.

The results appear in two scatter diagrams (see Figure 5-1 and Figure 5-2), for passenger-only and RoPax craft, respectively. Both indicate that SLICE does not provide speed and payload comparable to most catamarans and high speed monohulls now in the market. Figure 5-1 indicates the SLICE 250 and 400 variants at the low end of the scale. The two best SWATHs appear to be competitive although not among the best performers, while the low values for three other SWATHs track well with the SLICE values.

Figure 5-2 tells much the same story for high speed RoPax craft: the SWATH types, including SLICE 600, do not compare favorably using this measure. A sampling of the craft analyzed shows that there is no clear relationship of SLICE's power to either the payload, by itself, or the speed, by itself, relative to other craft types. In each case, SLICE is in the low to middle range; the combination of the two, however, results in poor transportation efficiency performance.

FIGURE 5-1: TRANSPORTATION EFFICIENCY (PASSENGER-ONLY VESSELS)

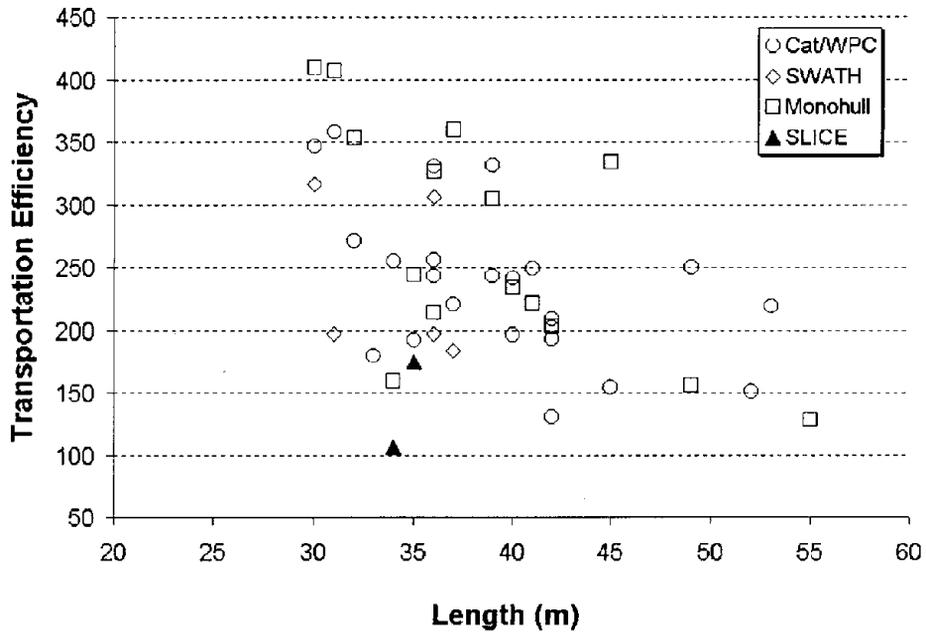
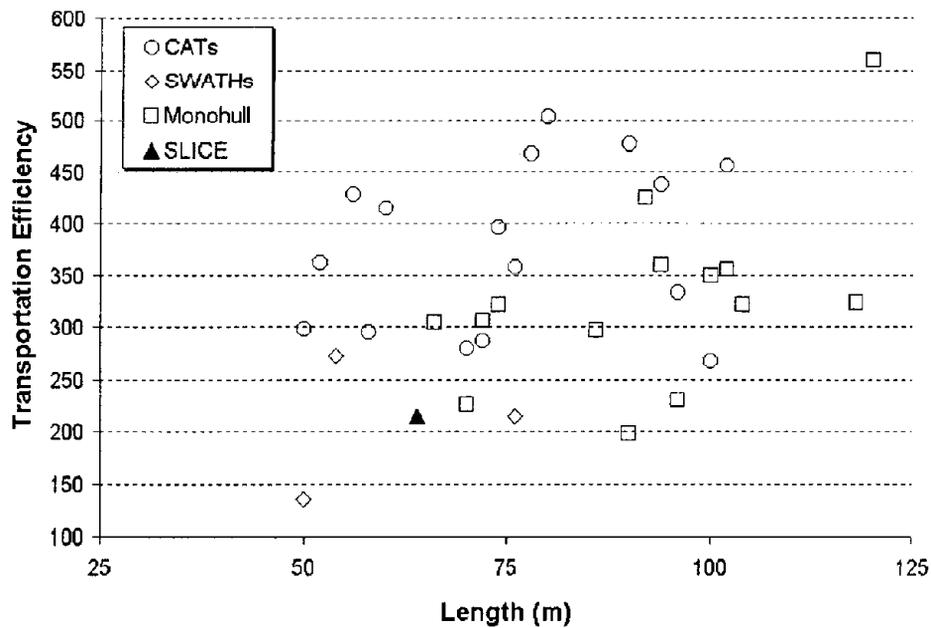


FIGURE 5-2: TRANSPORTATION EFFICIENCY (ROPAX VESSELS)



5.2.2 Power and Propulsion

The majority of high speed water craft are powered by medium and high speed 4-stroke diesel engines, usually with turbocharging for improved power density and efficiency at high power settings. These engines are almost all V-configuration engines with 12, 16 or even 20 cylinders.

Diesels have the advantage of being very efficient compared to gas turbine and spark ignition engines by virtue of their basic thermodynamic cycle. Diesels also tend towards a very flat specific fuel consumption curve versus power output, which allows flexibility in operation because relatively high efficiency can be maintained across a broad range of powers. Diesels are also considerably more compact and less complex than powerplants utilizing sophisticated cycles incorporating regeneration, or mixed cycle systems, such as steam turbines. Table 5-4 describes some of the diesels currently used in high speed craft.

TABLE 5-4: MARINE DIESEL ENGINES

Engine	Configuration	Rating (kW)	Rating (HP)	SFC (kg/kW-hr)
Caterpillar 3516	V-16	2,088	2,803	0.193
Caterpillar 3612	V-12	3,830	5,141	0.201
Caterpillar 3616	V-16	5,650	7,584	0.240
Caterpillar 3618	V-18	7,200	9,664	0.201
Detroit Diesel 16V-92TA	V-16	3,282	4,405	0.200
Duetz MWM TBD604B V8	V-8	840	1,128	0.226
MTU 16V 396 TB84	V-16	2,040	2,738	0.194
MTU 16V 396 TE74L	V-16	2,000	2,685	0.229
MTU 16V 595 TE70L	V-16	3,925	5,268	0.245
MTU 20V 1163 TB73L	V-20	6,500	8,725	0.252
Ruston 16V RK270 M	V-16	5,500	7,383	0.200
Ruston 20V RK270 M	V-20	7,080	9,503	0.248

A limited number of high speed craft, including the proposed SLICE 400 and SLICE 600, are powered by gas turbines. Gas turbines in general are not as efficient as equivalent power marine diesels, however some larger units do achieve comparable minimum specific fuel consumption levels. Unlike diesels, gas turbines generally have a narrow "flat" in their power vs. SFC curve located near the maximum continuous rating (MCR). Operation below this range tends to significantly increase specific fuel consumption. Some of the more widely used marine gas turbines are reviewed in Table 5-5.

TABLE 5-5: MARINE GAS TURBINE ENGINES

Engine	Configuration	Rating (kW)	Rating (HP)	SFC (kg/kW-hr)
ABB Stal GT35	----	17,000	22,819	0.255
Allied Signal TF40 Marine	----	3,430	4,604	0.300
Allied Signal TF50A	----	3,600	4,832	0.292
Allied Signal TF80 Marine	twin turbine	5,970	8,013	0.300
Allied Signal TF100 Marine	twin turbine	7,000	9,396	0.295
Allison 501-KF5	----	3,978	5,340	0.251
Allison 601-KF11	----	7,830	10,510	0.206
GE LM1600	----	14,913	20,017	0.226
GE LM2500	----	24,310	32,631	0.200
RR Marine Spey SM1C	----	19,500	26,174	0.252
Solar Mars 100M	----	10,280	13,799	0.218
Solar Taurus 70M	----	7,000	9,396	0.272
United Technologies MFT8	----	25,200	33,826	0.200

Gas turbines do, however, have very high power densities relative to even turbocharged marine diesels, but the weight advantage of gas turbines is offset by the added fuel weight that must be carried for all but the shortest journeys. The relative compactness of gas turbines does make them well suited for applications with space limitations due to unconventional hull forms, such as some catamarans, SWATHS or the SLICE vessels. The Pequot 45m TriCats use Caterpillar Solar Taurus gas turbines fitted within their narrow hulls for propulsion. TriCo Marine's Stillwater River SWATH vessel is another example of the requirements for high power contained within an unconventional hull form, which led to the choice of two Allison 501-K gas turbines. The location of the SLICE vessel powertrains within the two forward hull pods, combined with the high power requirements of the SLICE hullform make gas turbine power a good choice for the SLICE 400 and 600.

Medium and high speed diesels operate on a variety of light weight fuel oils, which are generally similar to kerosene. Marine gas turbines have a greater fuel flexibility than diesels, with some units such as the ABB Stahl GT35 used in the Bazan Buquebus B60 catamaran capable of operating even on heavy fuel oil. However, the gas turbine powered SLICE vessels would most likely be operating in and out of ports also served by conventional diesel powered vessels, so a specialized fuel supply for the SLICE vessels could be a logistical barrier to its introduction on these routes. Therefore, this study assumed that all vessels operate on the same fuel, which is a fuel oil with a specific gravity of 0.8.

Estimation of Vessel Power Requirements

The SLICE 400 and 600 both have relatively high power requirements when compared to similarly sized high speed vessels. The complicated hull form of the SLICE, which is in effect four short hulls instead of one or two long narrow hulls, has a high wetted area versus displacement, which causes high frictional losses. The location of the propellers on the forward pods may also cause higher form drag than for a similarly sized catamaran. Figure 5-3 illustrates the power requirements of the SLICE 400 versus a number of other high speed vessels. The fast monohull has very similar power requirements compared to the SLICE 400, but this curve represents the power required by a 925 passenger capacity monohull with twice the displacement of the 400 passenger SLICE 400.

Based on the plotted curves of Figure 5-3, simple formulas were used to estimate vessel power requirements at speeds lower than maximum cruise. These do not account for low-speed wave energy peaks, which cause a significant "bump" in power requirements, generally between the speeds of 10 knots and 20 knots, depending on the individual hull design.

For catamaran vessels, MCR power was defined as 80% of installed power:

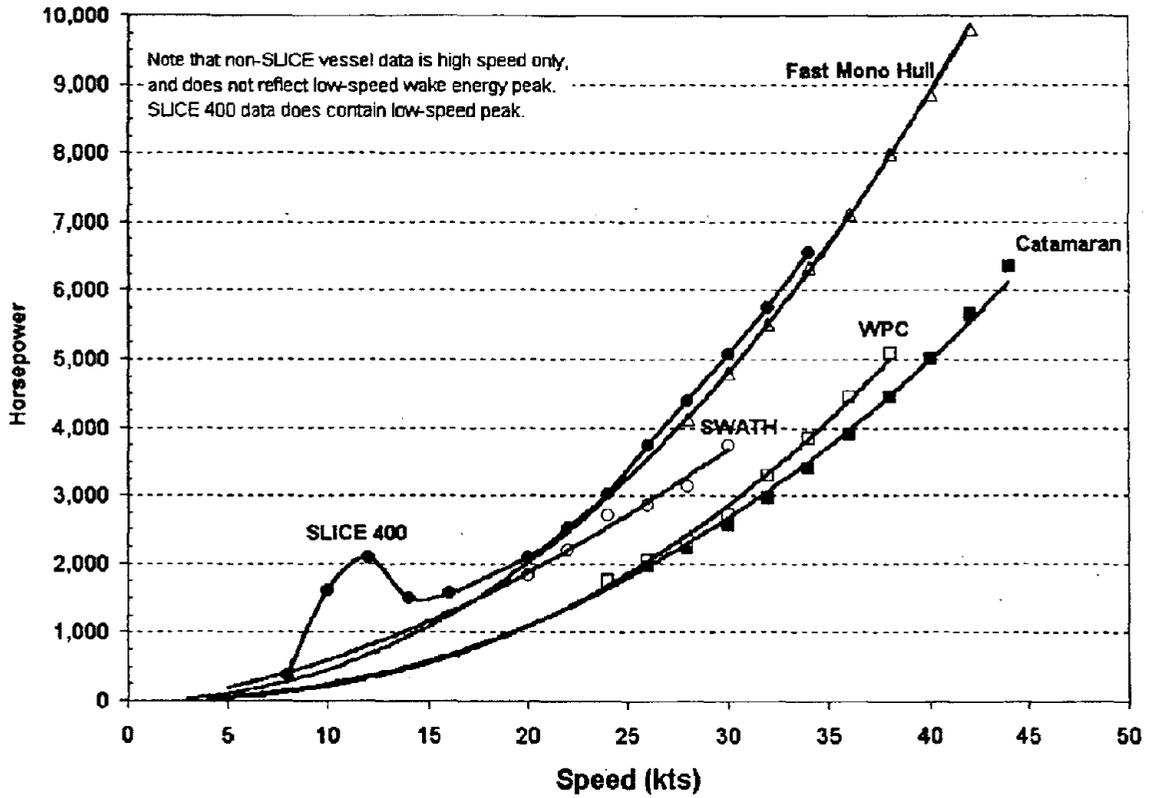
$$\mathbf{Power_{REQUIRED} = Power_{MCR} \times (V_{ACTUAL}/V_{MAXIMUM CRUISE})^{2.2}}$$

For baseline low speed monohull vessels, MCR power was defined as 80% of installed power:

$$\mathbf{Power_{REQUIRED} = Power_{MCR} \times (V_{ACTUAL}/V_{MAXIMUM CRUISE})^{2.0}}$$

For SLICE vessels, power requirements as a function of vessel speed were taken from directly LMS supplied data.

FIGURE 5-3: HIGH SPEED VESSELS - POWER VS. SPEED



Because specific fuel consumption (SFC) curves were not available for the engines powering the study vessels, and in the interest of simplifying the spreadsheet modeling involved in the route case studies, a series of speed-based multipliers were used to estimate vessel fuel consumption rates at various speeds. Published SFC values were assumed to reflect engine fuel consumption at maximum continuous rating. Table 5-6 shows the SFC multipliers used in the route case studies.

The reader should note in Table 5-6 that the SFC of the gas turbine powered SLICE vessels is assumed to rise to a much greater extent than that for the other diesel powered vessels. This reflects the poor off-design fuel consumption characteristics of gas turbines referred to previously.

TABLE 5-6: SFC MULTIPLIERS

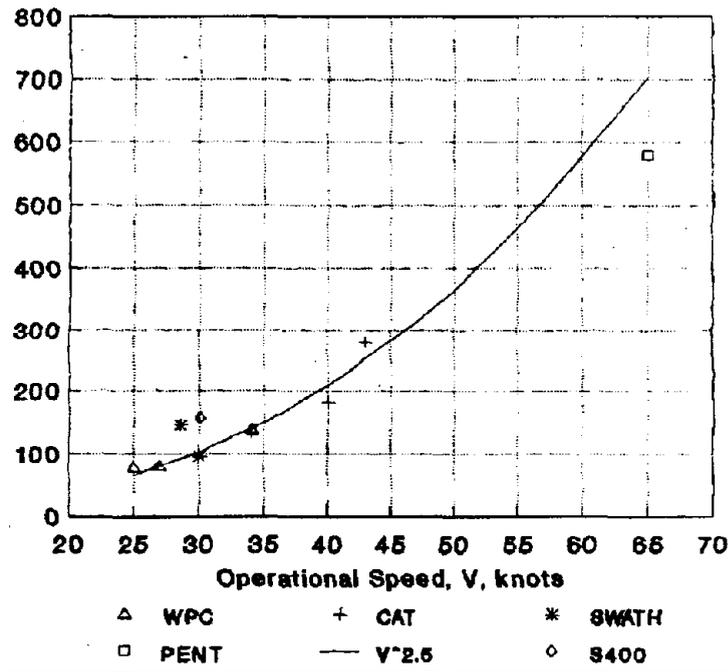
Vessel Speed	Slice 400 and 600, gas turbines	Other vessels, diesels
High Speed	MCR SFC X 1.0	MCR SFC X 1.0
Low Speed 1 (3.5 knots)	MCR SFC X 3.0	MCR SFC X 1.25
Low Speed 2 (7 knots)	MCR SFC X 3.0	MCR SFC X 1.25
Low Speed 3 (15 knots)	MCR SFC X 1.5 for SLICE 400; MCR SFC X 1.0 for SLICE 600	MCR SFC X 1.0

Basic fuel flow rates were calculated by multiplying the power required by the appropriate SFC, along with the appropriate conversion factors, to yield fuel flow rates in gallons per hour. After examining real world idle fuel flow values for diesel powered high speed vessels, it was decided that the estimated fuel flows were too low, and that a better approximation was to use real world fuel flow values (in gallons per hour) for idling fuel flows and then the sum of the idle fuel flows plus the estimated fuel flows from above for the low speed operations (in effect offsetting all the low speed fuel flows by a base idle fuel flow). The fuel flows used in the case studies then were of the form:

$$\text{Fuel} = \text{Fuel}_{\text{IDLE}} + (\text{Power}_{\text{REQUIRED}} \times \text{SFC}_{\text{MCR}} \times \text{Factor}_{\text{SFC MULTIPLIER}}) \times (\text{Units Conversion})$$

Results from SeaSpeed later validated this general approach, as the SeaSpeed study used a general formula for all high speed vessels which estimated power required to be a function of $(V_{\text{VESSEL}})^{2.5}$. To better assess the SLICE's relative power requirements, Figure 5-4 expresses vessel power requirements in terms of the power required per ton of payload.¹⁴ The SLICE 400 lies well above the curve in this plot, which translates into SLICE requiring roughly 50% more power per ton of payload relative to similarly sized high speed craft. Notice that one SWATH design has a power to payload ratio that is similar to the SLICE 400, however this represents a SWATH vessel outfitted for casino operations, and therefore with a great deal of equipment that cuts directly into the vessel's payload capacity.

FIGURE 5-4: BRAKE POWER PER PAYLOAD TONNE, KW/TONNE



¹⁴ SeaSpeed Technology Limited. *High Speed Craft Sea Performance Comparative Study for the Volpe National Transportation Systems Center*. September 1999. Page 10.

TABLE 5-7: VESSEL PARTICULARS

Particulars	PaxOnly & RoPax SLICE Variants		Other High Speed RoPax Vessels			
	SLICE 400 ⁽¹⁾	SLICE 600 ⁽²⁾	Incat 78m ⁽³⁾	Incat 74m ⁽⁴⁾	Incat 72m ⁽⁵⁾	AMD K50 ⁽⁶⁾
Vessel Designer	Lockheed Marine Systems	Lockheed Marine Systems	Incat	Incat	Incat	Advanced Multihull Designs
Vessel Type	Passenger-Only	RoPax	RoPax	RoPax	RoPax	RoPax
Hull Construction	Aluminum	Steel	Aluminum	Aluminum	Aluminum	Aluminum
Purchase Price (1997 US\$)	\$12,000,000	\$37,000,000	\$32,000,000	\$28,900,000	\$27,500,000	\$30,000,000
Principal Dimensions (feet)						
Length Overall	111.5	213.2	254.0	243.2	238.3	262.7
Beam Overall	61.0	105.0	85.3	85.3	58.4	82.3
Full Load Draft	15.0	28.5	11.5	9.5	7.2	7.1
Capacities						
Passenger Capacity	400	600	600	597	325	400
Vehicle Capacity (AEU) ⁽⁸⁾	n/a	90	150	84	75	89
Fuel Capacity (gallons)	5,837	39,087	9,858	10,087	8,981	12,680
Weights (long tons)						
Payload	28.6	177.9	207.5	154.6	120.0	138.9
Total Deadweight	47.1	355.0	252.0	199.0	151.0	174.0
Displacement	220.0	1,500.0	865.0	700.0	631.0	612.0
Propulsion						
Main Engines	(2) TF40 gas turbines	(2) RLM1800 gas turbines or equivalent	(4) Ruston 16 RK270 marine diesel engines	(4) Ruston 16 RK270 marine diesel engines	(4) MTU 16 V 595 marine diesel engines	(4) Ruston 16 RK270 marine diesel engines
Total Installed Horsepower	6,800	36,000	23,494	22,025	21,036	29,476
Service Speed (knots)	30	30	34	39	40	45
Range at Service Speed (nm)	340	620	370	390	350	390
Fuel Consumption (gallons per hour at indicated speed)						
GPH at service speed	502	1,891	898	993	1,014	1,439
GPH at 30.0 knots	502	1,891	804	557	539	590
GPH at 15.0 knots	218	1,757	310	270	269	344
GPH at 7.0 knots	142	484	176	177	180	246
GPH at 3.5 knots	120	450	144	155	158	222
GPH at idle	75	284	135	149	152	216

n/a (not applicable)

Sources:

- (1) Lockheed Marine Systems. 400 Passenger Slice Ferry. Technical Data Package. April 1995.
- (2) Lockheed Marine Systems. SLICE 600 Passenger Vehicle Ferry. Technical Data Package. April 1995.
- (3) Incat Designs. Also, *Jane's High Speed Marine Transportation 1998-1999*. Also, Volpe Center estimates for some data elements, as per discussion in Chapter 8.
- (4) Incat Designs. Also, *Jane's High Speed Marine Transportation 1998-1999*. Also, Volpe Center estimates for some data elements, as per discussion in Chapter 8.
- (5) Gladding-Hearn Shipbuilding, the Dulos Corporation. Also, Volpe Center estimates for some data elements, as per discussion in Chapter 8.
- (6) Advanced Multihull Designs. Also, *Fast Ferry International*, October 1993, pp. 21-24. Also, *Jane's High-Speed Marine Transportation, 1998-1999*. Also, Volpe Center estimates for some data elements, as per discussion in Chapter 8.
- (7) For a nominal vessel operating hours of 3,000 annually.
- (8) Automobile equivalent unit (AEU), typically a minimum of a 17' x 8.5' space on the vehicle deck.

the overall contribution to fuel consumption was not very large. Additionally, because routes in this study are generally those with long high speed cruise segments, the overall impact on fuel consumption is small.

SLICE Powerplant Layout and Maintenance Issues

Placing the SLICE powerplants and drivetrains within submerged close-fitting pods presents some servicing difficulties versus a conventional monohull engine room layout. As an example, while the AlliedSignal TF40 powerplants specified for the SLICE 400 have a major maintenance interval of 24,000 service hours, they require a scheduled inspection every 2,000 hours of service, which involves some disassembly of the engine hot section (combustor and turbine section).¹⁵ While some engine servicing can be accomplished from within a propulsor pod, any major procedures, especially those requiring removal of all or part of the engines, gearboxes, drive shafts or propellers most likely will require that the vessel be dry-docked so that the propulsor pod is no longer submerged. Based on this study's assumption of a nominal 3,000 vessel operating hours annually, this

¹⁵ *Jane's High-Speed Marine Transportation 1998-1999*. Page 339.

implies that unless the gas turbine hot sections can be accessed and disassembled from within the propulsor pods, the SLICE 400 could possibly require dry-docking roughly every 8 months.

Even with a SLICE vessel in drydock, access to the engines and rest of the powertrain is still a potential issue. The SLICE prototype vessel uses pods of a welded construction, so access to major powertrain components can only be achieved by actually cutting through the pod skin. Production vessels could conceivably be made more serviceable through use of bolt-on access hatches or split bolt-joined pods. It has also been suggested that production vessels might use modular propulsor pods which could be removed for servicing and replaced with spares, much as nacelle/engine assemblies are on commercial jet aircraft.

An alternate propulsion system layout is being explored by Lockheed for a proposed Washington State ferry, in which the engines would be located at or near deck level, with a system of drive shafts and gears, transmitting power to the propellers mounted on the two propulsor pods. Lockheed is proposing twinned diesel engines driving each of the vessel's two propellers. Using diesels in a deck level installation is possible because space constraints will not be as much of an issue as for a podded configuration, so the lower power density of diesels will not be an issue. Using diesels will also allow commonality of engines with Washington State Ferries' other diesel powered vessels, plus the diesels will most likely be more fuel efficient than the TF-40 gas turbines proposed for the SLICE 400. The drawbacks of such a system are increased mechanical complexity, which would most likely lead to increased maintenance requirements, increased weight, both due to the lower power density of the diesels and the weight of the substantial shafting and gearing required to bring power from the deck-level engines to the pod-mounted propellers, and some loss of efficiency due to mechanical losses in the drive system. A hydraulic drive system is also a possibility for such a layout. In such a system, the engines drive a hydraulic pump which transmits power through a line to hydraulically driven propellers. Hydraulic drive systems, such as those manufactured by Kamewa and Rexroth, allow flexibility in location of propellers. In some cases, the fluid flow losses in the pumping and drive system are offset by the gains in efficiency due to better positioning of the ships propellers.¹⁶

5.3 Seakeeping

The Volpe Center established two premises as the basis of the commercial viability analysis:

- SLICE's potential to enter the market depends either (1) on its opening new routes and services where other high speed types are not likely to succeed or (2) demonstrating a sufficient advantage to out compete other craft on established routes.
- SLICE's purported advantage in stable, seakindly operation in rough weather must be quantitatively defined by a valid comparison to other high speed vessels.

The quantification of performance is in two stages, of which this section recounts the first. They are:

- Seakeeping performance of a group of high speed craft compared through a controlled process, with outputs desired in terms of passenger comfort and safety.
- Application of the seakeeping results to route specific wave spectra, resulting in ride quality and weather reliability outputs.

Several craft were selected for the seakeeping analysis from the group of vessels presented earlier in Table 5-1, including three competitors for the SLICE 400 and one for the SLICE 600. This subset of craft appears in Table 5-8.

¹⁶ *Jane's High-Speed Marine Transportation 1998-1999*. Page 355.

TABLE 5-8: SEAKEEPING ANALYSIS - SUBJECT CRAFT

Passenger-Only Craft	
•	SLICE 400
•	40 meter SWATH
•	45 meter catamaran
•	50 meter wave piercing catamaran
RoRo-Passenger (RoPax) Craft	
•	SLICE 600
•	75 meter wave piercing catamaran

5.3.1 Approach, Input and Output Data Sets

The Volpe Center contracted with Seaspeed Technology Limited to execute the calculations and present findings. The approach and selection of software were validated by comparison of results to a catalog of motions and acceleration data from model tests and full scale instrumentation for a large number and variety of contemporary commercial high speed craft. The subject craft population (the group appearing in Table 5-8) includes two SLICE hulls (the 400 and 600 variants) and the selected competing high speed craft. The accuracy of the output is considered good (see comments on validation below) and certainly serves as an excellent relative measure of seakeeping performance.

The particulars of the seakeeping work are the following:

Seakeeping Analysis Input

- Relevant characteristics of SLICE 400 and three competitors, and SLICE 600 and one competitor, including hull geometry, centers, gyradii, and service speed.
- Positions onboard specified as the bridge, and two positions on the passenger deck - on the centerline at the longitudinal center of gravity (LCG), and at the transverse outermost seat at the LCG.
- Assumption of no active ride control systems.
- Long crested waves in sea states 3, 4, 5, and 6, with a limited sensitivity analysis varying crossing periods for the SLICE 400 and the 50 meter wavepiercer, both at service speeds.
- Five headings of subject craft relative to the waves: head, bow and stern quartering, beam, and stern.

The "CATMO" ship motion program generated the required motions and accelerations output, with various post-processing algorithms employed for calculations of comparative craft performance, e.g., compliance with

ISO 2631 kinetosis thresholds. CATMO is based on the strip theory approach but run in the time domain to facilitate analysis of control systems. Its accuracy relative to full scale recorded motions was satisfactorily demonstrated by comparisons presented by the contractor. In addition, the results of the analysis correspond well to the experience onboard the types of high speed craft under consideration.

Seakeeping Analysis Output

Ship motions, including peak, root mean square (rms), and standard deviation values for pitch, roll, heave, and vertical acceleration, were the basis for:

- Deck wetness and slamming statistics.
- Passenger comfort assessment for selected operational conditions using analysis of the vertical accelerations and comparison to accepted kinetosis criteria (i.e., ISO 2631).
- Crew and passenger safety assessment for the above selected conditions using the subjective motion (e.g., Shoenberger) or other specified criteria.
- Cargo safety assessments for the above selected conditions using standard IMO acceleration and motion criteria.

5.3.2 Results

The results of the seakeeping analysis comprise three data sets: (1) comparative rms values of motions and accelerations derived directly from the CATMO output; (2) a brief assessment of the subject craft motions relative to accepted limiting operational criteria for ships at sea; and (3) application of the ISO 2631 standard “Evaluation of Human Exposure to Whole-body Vibration” to compare subject craft ride quality performance.

RMS Motions and Accelerations

The seakeeping study yielded a full range of motions and accelerations data for the subject craft, all of which appear in their entirety in the tables and figures of the Seaspeed report, attached as Appendix A to this report. A representative graphic sampling appears here, as listed:

- Figure 5-5: rms roll angles of the SLICE 400 and its competitors in various headings at sea state 5.
- Figure 5-6: rms vertical accelerations of the SLICE 400 and the 50 meter wavepiercer in sea states 3, 4, and 5, with varied wave crossing periods.
- Figure 5-7 and Figure 5-8: rms pitch and roll angles of the SLICE 600 and the 75 meter wavepiercer in sea states 4, 5, and 6, at their respective service speeds.

FIGURE 5-5: ROLL ANGLE COMPARISON IN VARIOUS HEADINGS AT OPERATIONAL SPEEDS IN SS 5 (SLICE 400 AND COMPARATIVE VESSELS)

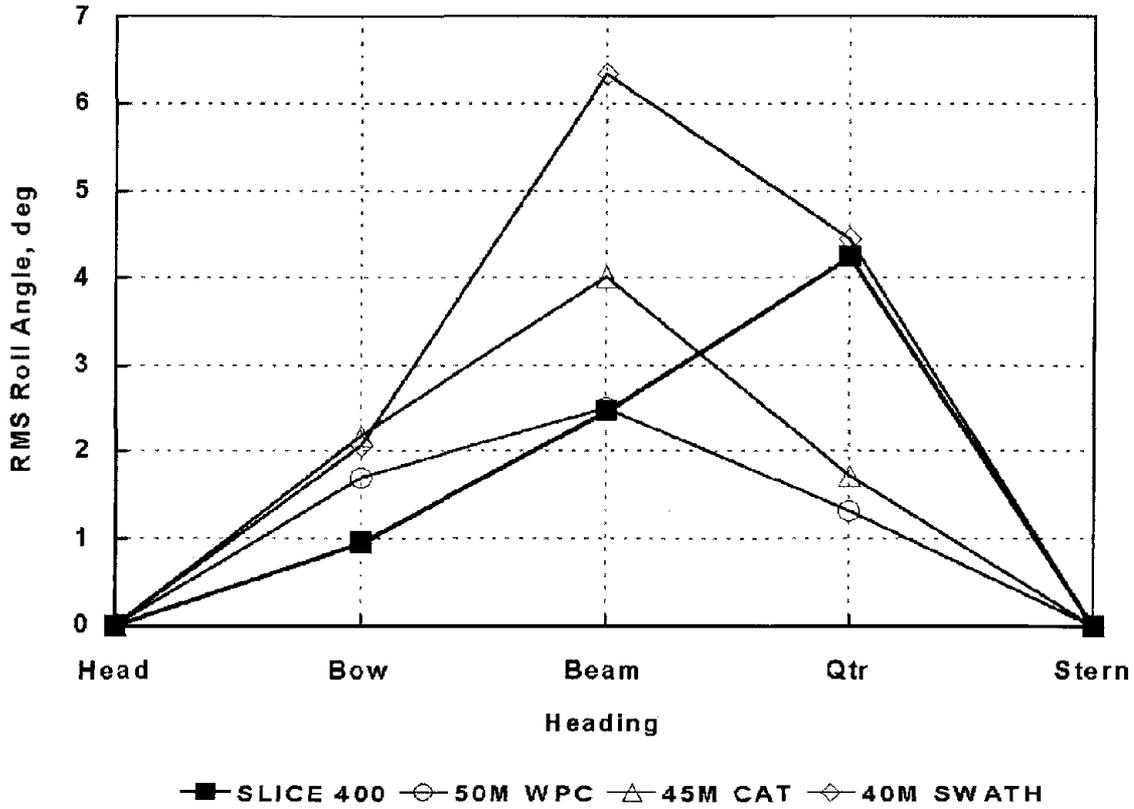


FIGURE 5-6: SLICE 400 AND 50 m WPC - MOTION SENSITIVITY TO WAVE PERIOD - COMPARISON OF VERTICAL ACCELERATION AT THE LGG

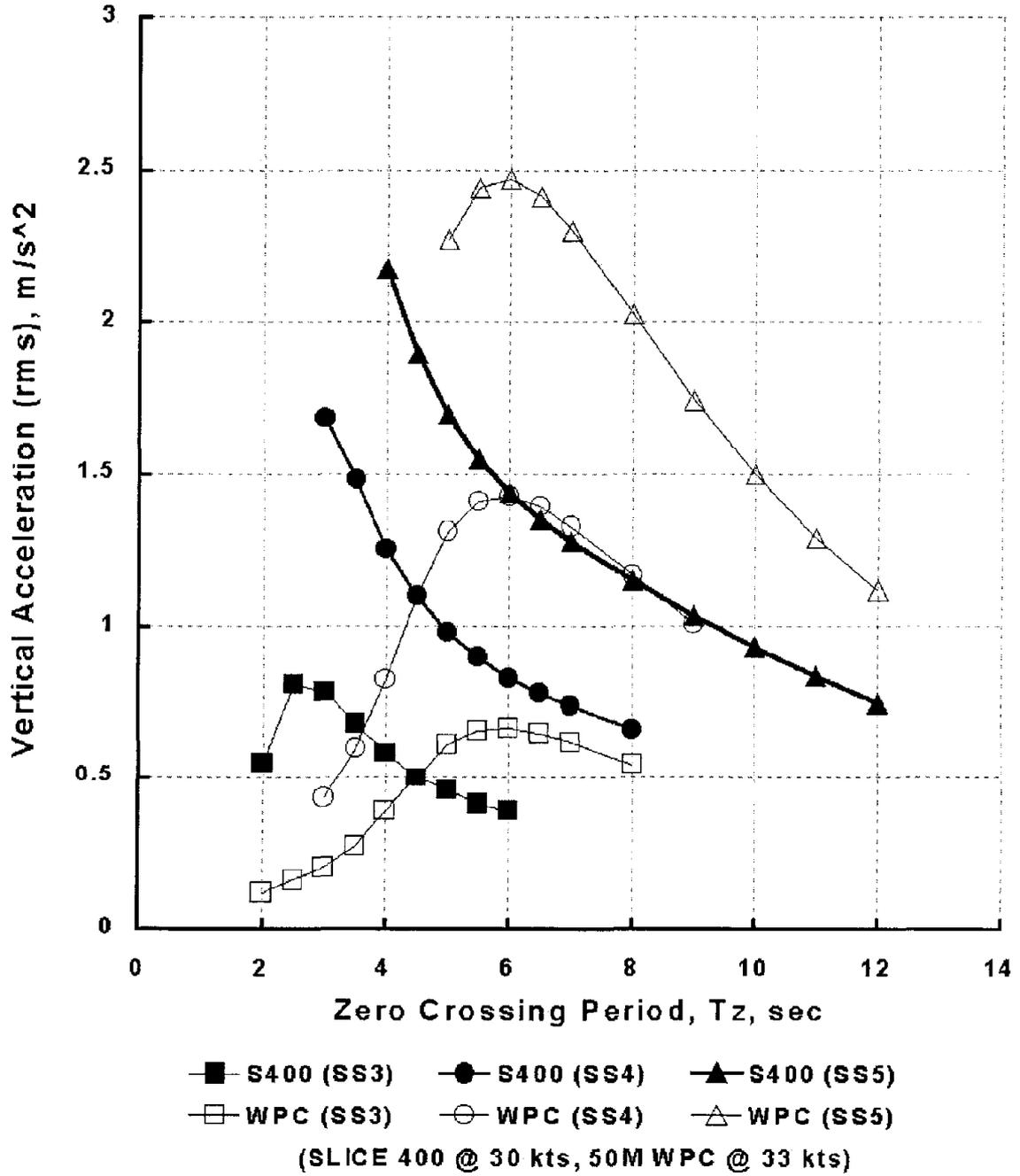


FIGURE 5-7: SLICE 600 AND 75 M WPC - PITCH ANGLE VERSUS HEADING AND SEA STATE

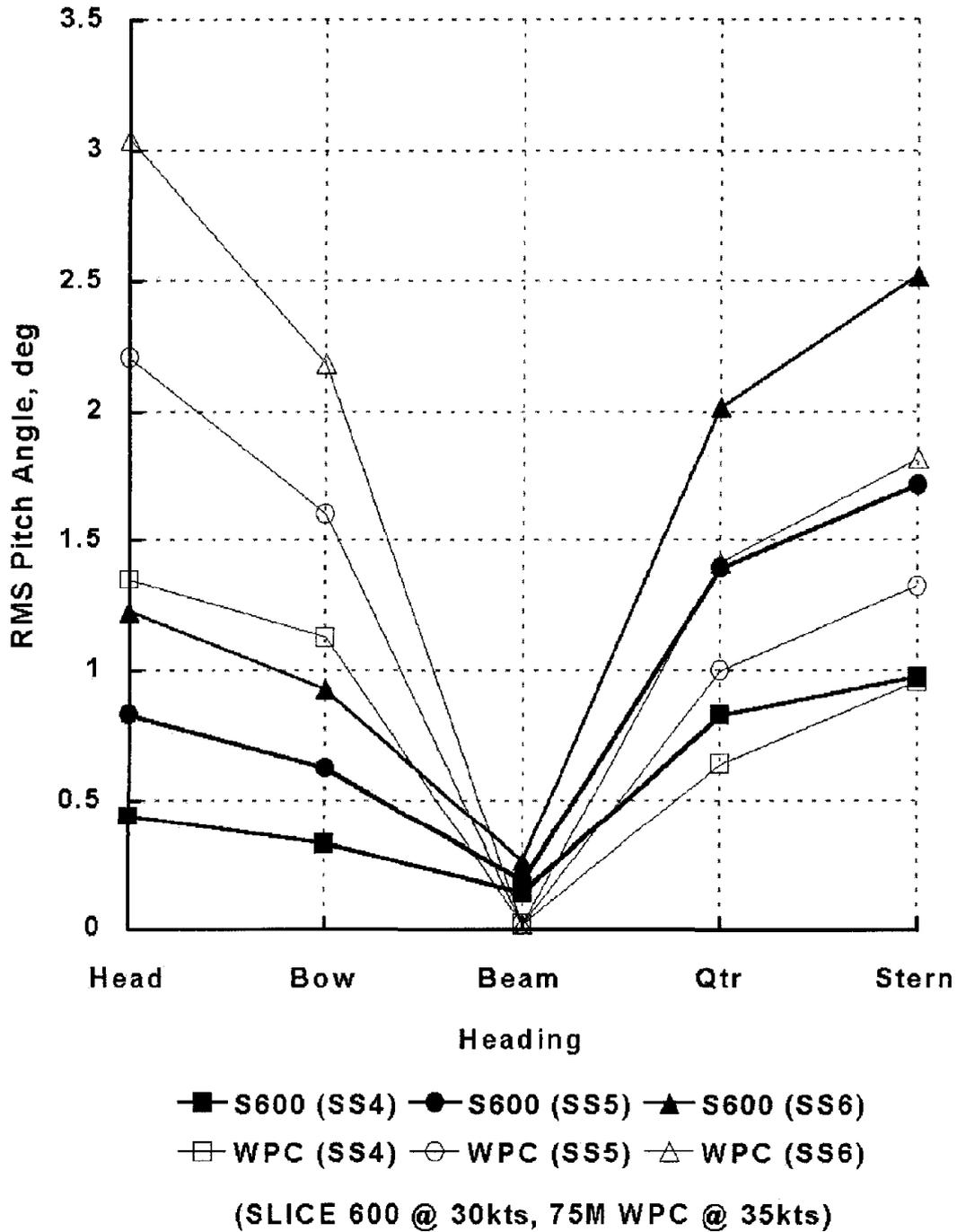
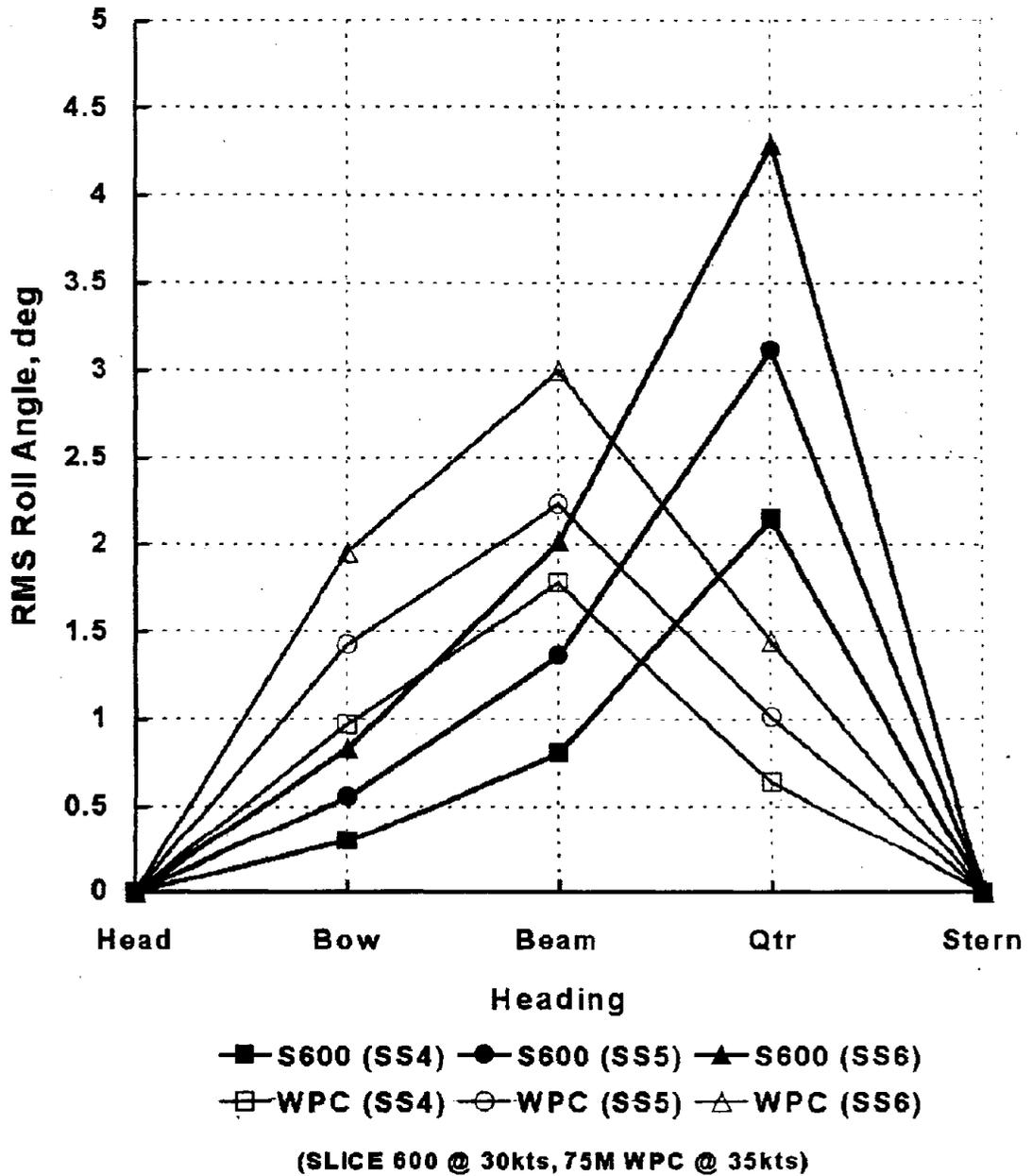


FIGURE 5-8: SLICE 600 AND 75 M WPC - ROLL ANGLE VERSUS HEADING AND SEA STATE



Limiting Operational Criteria

An approximate assessment of craft performance can be derived from the seakeeping data, by comparison to accepted limits of limiting safe operational criteria. Table 5-9 is a summary of such criteria.¹⁷ The comparison of seakeeping results with long crested waves as their basis to criteria derived from practical experience largely from short crested waves has limitations, but is useful as a relative measure. The results of Figure 5-6 should be borne in mind, as the underlying data show increased vertical accelerations with shorter wave periods. The comparative findings below may, therefore, understate matters because of the sea conditions assumed for this seakeeping analysis.

TABLE 5-9: LIMITING OPERATIONAL CRITERIA

Criterion	Range of Values
Maximum rms pitch motion	Approximately 1.5 to 2.5 degrees
Maximum rms roll motion	Approximately 2.5 to 4.0 degrees
Vertical acceleration rms (cargo)	1.5 to 2.5 m/s ² anywhere on the vessel
Slamming probability	Approximately 0.01 to 0.05
Propulsor emergence probability	Approximately 0.01 to 0.2

Source: *High Speed Craft Sea Performance Comparative Study for the Volpe National Transportation Systems Center*. Seaspeed Technology Limited. Report STL/225/01. September 16, 1999. Page 20.

The substantive results of the comparison of seakeeping results to the limiting criteria of Table 5-9 follow:

- Pitch - none of the vessels studied would be limited within the sea states considered.
- Roll - the 40 meter SWATH would be limited, only in sea state 6.
- Vertical acceleration - of the two larger cargo (vehicles) carrying craft, the 75 meter wavepiercer would be limited in sea states 5 and 6, in head and bow quartering seas.
- Slamming - limitations would occur in the following situations: the 45 meter catamaran in head seas, sea state 4; 40 meter SWATH and 50 meter wavepiercer in head seas, sea state 5; 75 meter wavepiercer in head seas, sea states 5 and 6.
- Propeller emergence - the 45 meter catamaran, 40 meter SWATH, and SLICE 400 are limited in head seas, sea state 5; the 40 meter SWATH, and SLICE 400 also exceed the criterion in beam seas at low speeds (this may not be a limiting condition because of low engine speed).

It is noteworthy that SLICE meets all the criteria with the exception of propeller emergence, although there are unique features in that case. SLICE's minimal relative motions in large waves are the probable cause of propeller emergence due to its approximate amidships location. Craft with propellers aft are more likely to undergo emergence in the presence of ship motion. All the other criteria tested are influenced by ship motion, and SLICE is notably absent among those craft exceeding the criteria.

¹⁷ Karppinen, Tuomo, and Timo Aitta. Technical Research Centre of Finland. *Seakeeping Performance Assessment of Ships*. NSTM. Stockholm. 1986.

Kinetosis, ISO 2631

ISO 2631, "Evaluation of Human Exposure to Whole-body Vibration", requires comparison of the results of a third octave analysis of the motion response of the vessel to threshold curves of vertical acceleration, the latter established by experimentation and experience. The ISO 2631 threshold lines for 30 minutes and 2 hours represent a limiting level of tolerance where it is likely that approximately 10% of passengers will experience motion sickness. Inspection of the relevant figures reveals that the 2 hour threshold is lower than that for 30 minutes; this agrees with intuition since less motion over a longer period of time would result in a similar incidence of kinetosis.

This analysis was undertaken for each subject craft, in the head sea condition, at both service and low (5 knots) speeds. The results follow, with SLICE 400 and 600 taken separately.

SLICE 400 and passenger only class

At service speed, the SLICE 400 is the only craft that does not exceed the ISO 2631 limit in all sea states and speeds tested. At operational speed, the 40 meter SWATH performs nearly as well but exceeds the 2 hour limit in sea state 5. The 45 meter catamaran and 50 meter wavepiercer exceed both the 2 hour and 30 minute standard in sea states 3 and 4. The model indicates that all four craft in this class would perform within the ISO 2631 2 hour specification at 5 knots with heads into sea state 3, 4, and 5 waves; again, SLICE is the best performer, but the advantage is quite narrow. Figure 5-9 and Figure 5-10 show the results for the two speeds in sea state 5.

SLICE 600 and passenger/RoRo class

The SLICE 600 as well was superior to its competition, in this case the 75 meter wavepiercer. At operational speed, SLICE 600 performed within specification for 2 hours exposure in all seas up to and including sea state 6, while the wavepiercer exceeded the ISO acceleration limits in sea states 4, 5, and 6 (see Figure 5-11). At 5 knots into head seas, both craft met the specification; the SLICE 600 was again the better performer, but its advantage was much smaller (see Figure 5-12).

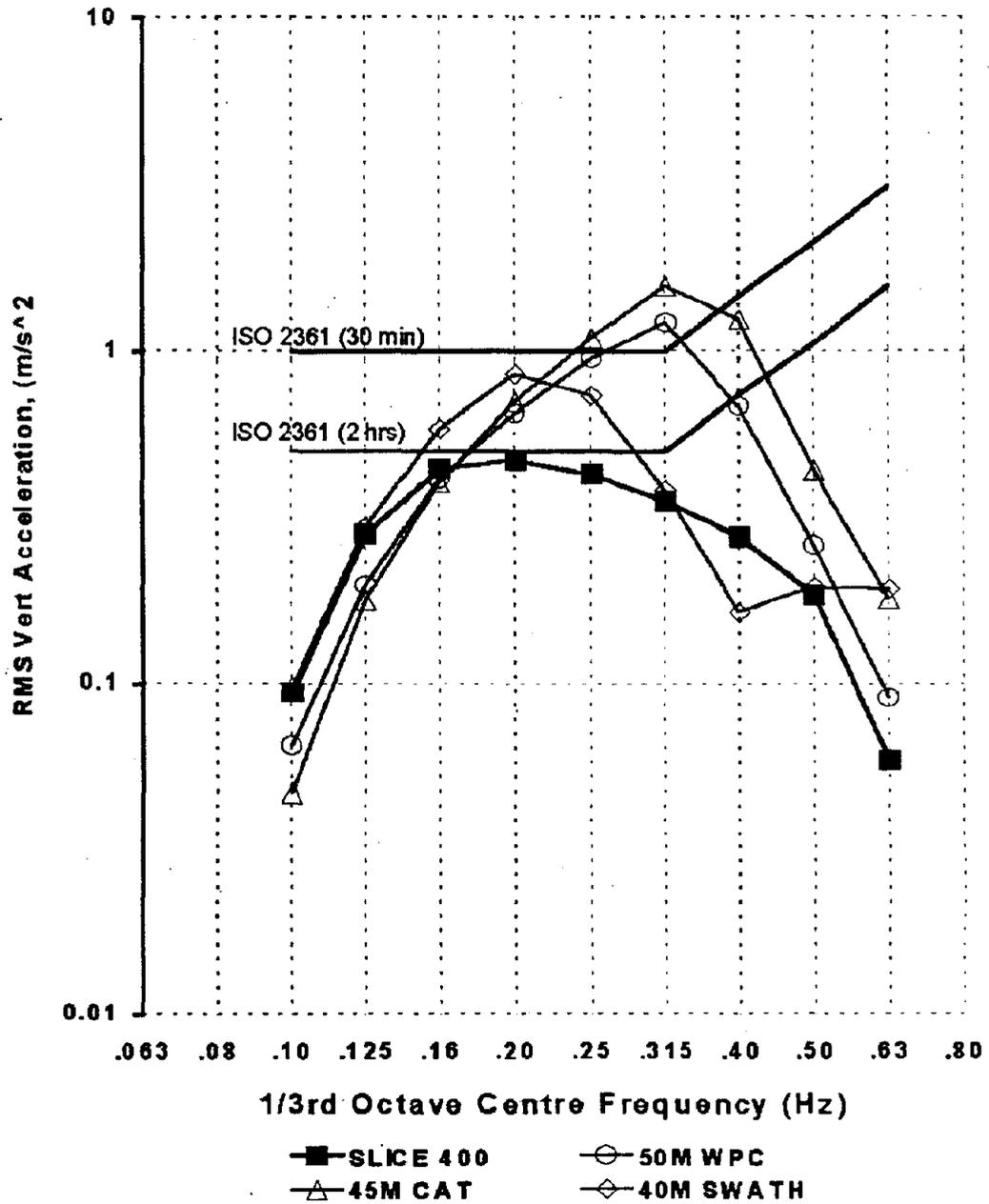
5.3.3 Conclusions

The ship motions analysis shows clearly that SLICE would fulfill its promise of superior seakeeping at high operating sea states. Weather reliability and ride quality would be marked advantages to an operator for whom the service area conditions are rough enough to cause recurrent problems for other craft types. The case studies to follow include characterizations of operating conditions which, along with these results, will indicate whether SLICE performance yields a sufficient economic advantage to induce operators to buy it.

Ride quality for passengers is the focus for the case studies appearing in subsequent chapters. Excepting vehicles for the larger class of craft, safety of cargo carriage is not important (see results of Chapter 6). SLICE's seakeeping performance margin relative to other craft is greatest at service speeds, implying that the operational advantage would be greatest for scheduled ferry service or for excursions requiring long exposed runs. The margin narrows appreciably at low "hoteling" speed with less fortunate implications for SLICE in many types of excursion service. Finally, all these considerations must be predicated on the presence of sea conditions severe enough to bring consideration of SLICE into the operator's picture.

It should be noted that these seakeeping data are based on craft without active ride control systems in operation. It may be assumed that performance for all would improve, at least in the lower sea states, to some extent, but the SLICE advantage would remain. Experience has shown that the SLICE demonstrator performs well with a less than optimal ride control system and that other high speed types, catamarans in particular, have had trouble with motion sickness in rough weather. It is also probable that effective ride control would assist the small waterplane craft to a greater extent than the others.

FIGURE 5-9: ISO 2361 CHART COMPARISON (OPERATIONAL SPEEDS IN HEAD SEA, SS 5) VERTICAL ACCELERATIONS AT THE LCG



**FIGURE 5-10: ISO 2361 CHART COMPARISON (5 KNOTS IN HEAD SEA, SS 5)
VERTICAL ACCELERATIONS AT THE LCG**

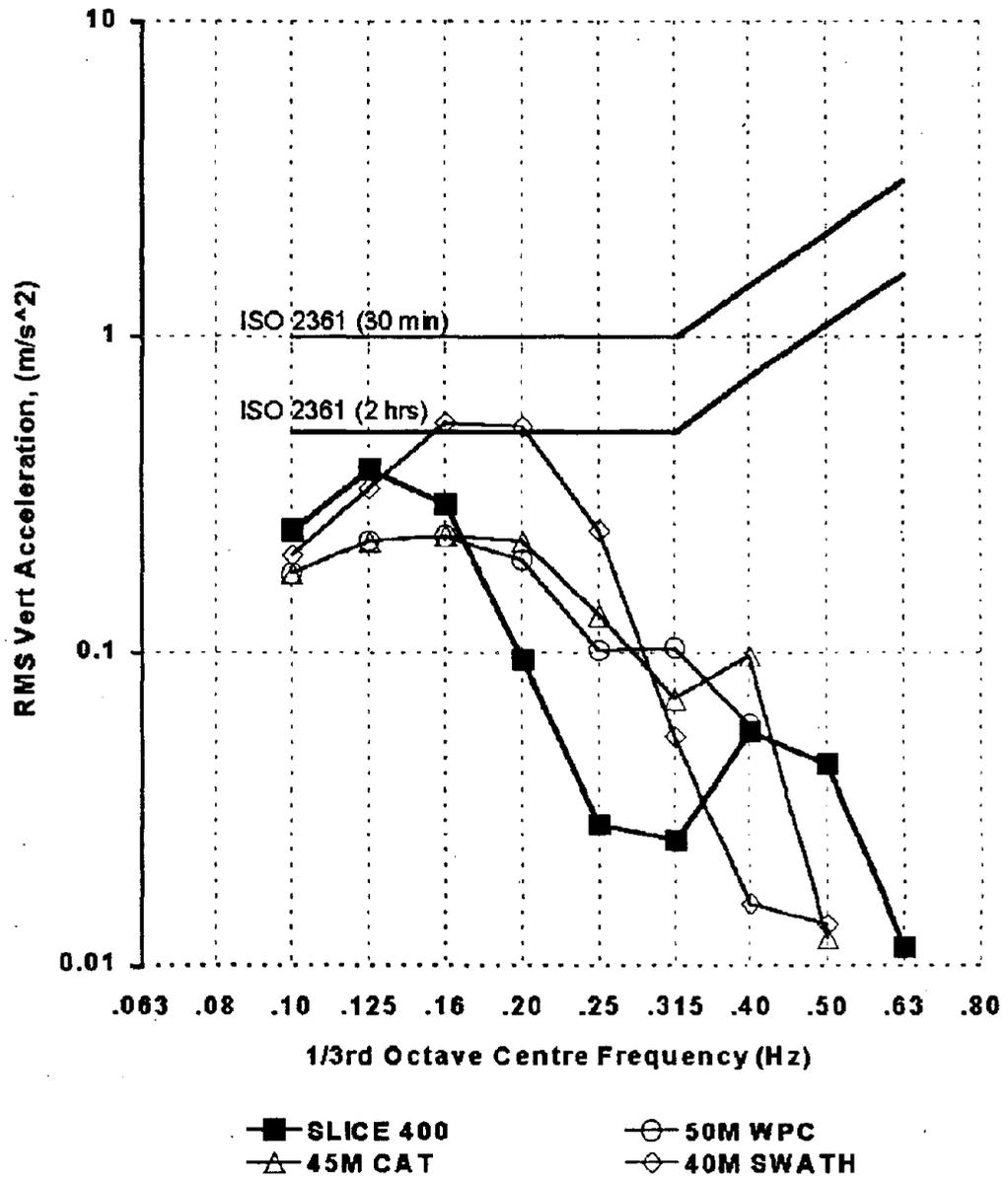


FIGURE 5-11: ISO 2631 CHART COMPARISON - SLICE 600 VERSUS 75 M WPC AT OPERATIONAL SPEED IN HEAD SEAS - VERTICAL ACCELERATIONS AT THE LCG

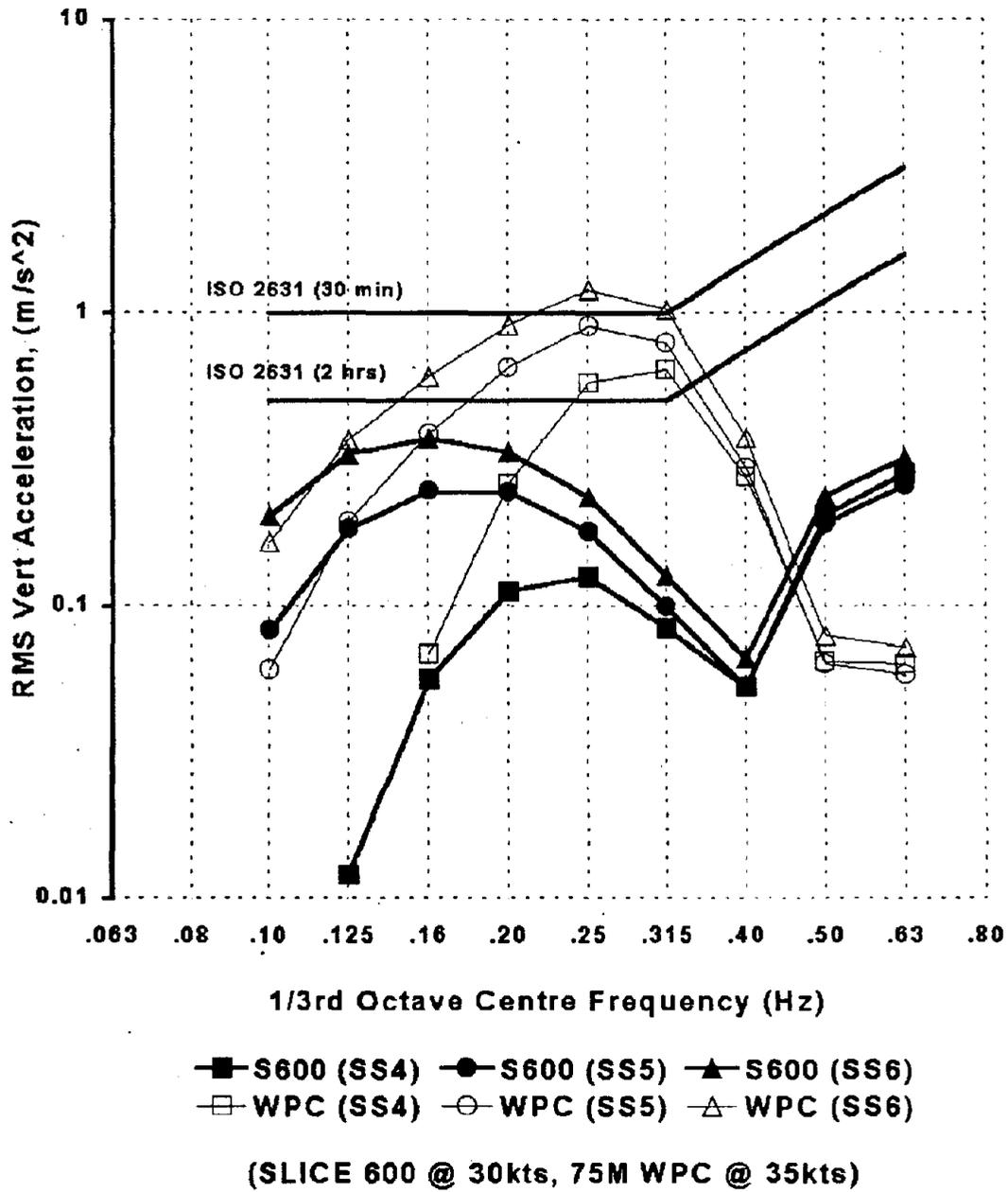
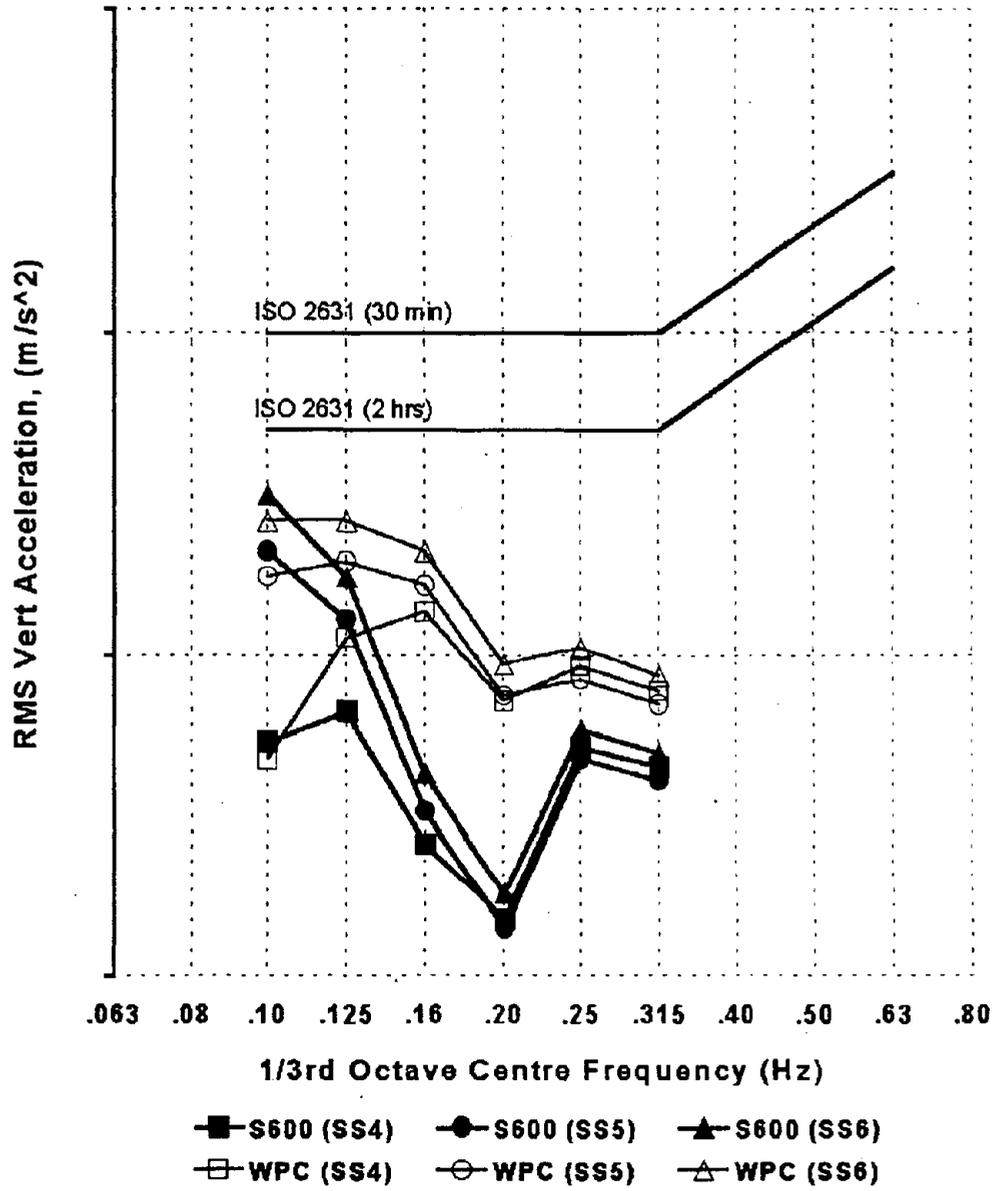


FIGURE 5-12: ISO 2631 CHART COMPARISON - SLICE 600 VERSUS 75 M WPC AT 5 KNOTS IN HEAD SEAS - VERTICAL ACCELERATIONS AT THE LCG



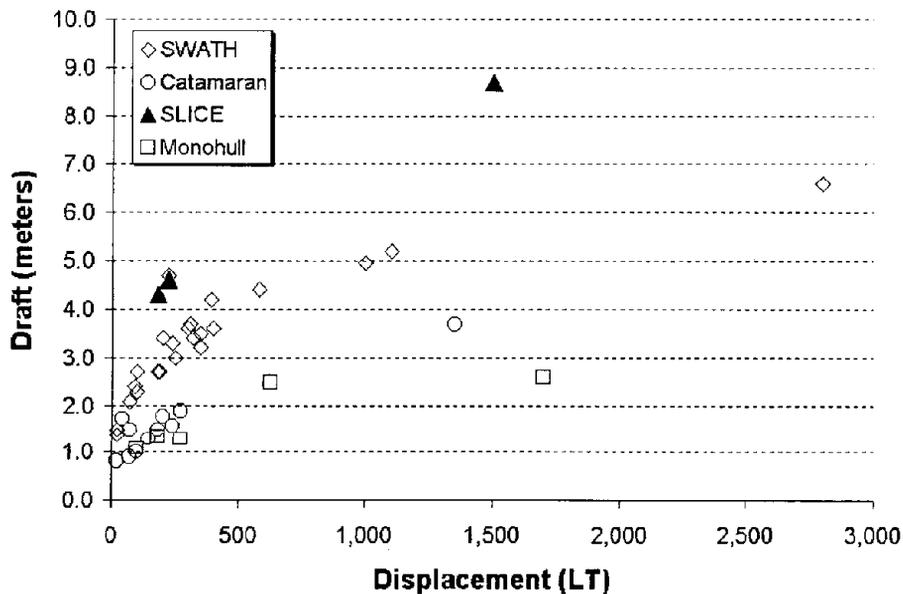
5.4 Other Features

5.4.1 Draft

Deep displacement pods enable SLICE's most beneficial performance features, its superior seakeeping and wavemaking characteristics. This hull form has its associated costs, as might be expected. As noted previously, the relatively large wetted surface brings a penalty in resistance and powering. The large draft also carries a significant operational restriction relative to shallow waterways and terminal areas.

It has been noted above that SWATH vessels are deep drafted by comparison to other high speed craft. The caution of an operator in this regard would be greater in the case of SLICE, all of whose variants are deeper drafted than comparable SWATHs. Figure 5-13 indicates drafts for four high speed craft types and shows clearly that SWATH vessel types, SLICE in particular, draw up to four times the water as do comparable catamarans and monohulls.

FIGURE 5-13: DRAFT VERSUS DISPLACEMENT FOR HIGH SPEED CRAFT



Source: SWATH International Ltd. for SWATH vessel data; Lockheed Martin for SLICE data; Fast Ferry International for other vessel data.

5.5 Summary

SLICE is an excellent seakeeping vessel, better than all other high speed types it was compared to. A comparative analysis of kinetosis effects at sea states 4 and 5 shows both SLICE 400 and 600 superior at service speed, where the competition fail to meet the ISO 2631 standard, and at slow speed, although the others tested performed much better here than at service speed.

SLICE at 30 knots is slow relative to most of the high speed craft coming into the market today, and requires more power than most, because of the large wetted area associated with its deep draft displacement. The "transportation efficiency" number, measuring payload and speed against required power, shows that three SLICE craft (250, 400, and 600) have the lowest range of numbers relative to groups of catamarans, wave piercers, SWATH, and high speed monohulls.

SLICE has two seriously conflicting design requirements: the limited space within the displacement pods for machinery arrangements and the need for higher powered engines relative to other high speed craft. The resulting design concepts have included pod mounted gas turbines, because of their more compact geometry, and deck mounted marine diesels geared to the propeller by Z drives. Capital, fuel, and maintenance costs are in both cases higher than the conventional marine diesel configurations found on most high speed craft. There is also a question as to the ease of routine maintenance for pod mounted engines.

SWATH is in fact SLICE's closest competitor; it is another stable and seakindly craft in high sea states, whose speeds in some cases now exceed 30 knots (SLICE design service speed). Lastly, and perhaps most significantly, SLICE draws more water than SWATH, and a lot more than its other competitors in the high speed market. Draft is a severe limitation for SLICE (whose variants draw from 14.0' to 28.5'), most certainly eliminating it from many waterways whose channel depths will not suffice. In addition, these deep drafts are unsuitable for most Coast Guard missions (except the deep water cutter service now provided by the 378' Hamilton class) where maximum access to coastal waters is necessary.

There are two notable anomalies in the powering and resistance data available for the SLICE. Firstly, Lockheed's technical data packages state that both the SLICE 250 and 400 variants will make a service speed of 30 knots with twin TF40 gas turbine engines, rated at 6,850 total horsepower, while Pacific Marine reports that the SLICE demonstrator, a slightly smaller craft, can make 23-25 knots at 85% mcr with its twin marine diesels rated at 6800 horsepower. Secondly, the speed vs. power curve predicted by Lockheed shows a power hump at about 12 knots followed by a minimum at about 16-18 knots and then an exponential rise with increasing speed above 18 knots. Fox Associates noted, however, that SLICE's wavemaking energy was at its maximum at 18 knots, precisely at the point of the predicted minimum.

In sum, the craft's delivered speed does not match the prediction and the nature of its observed wavemaking resistance does not bear out the modeled power curve. The Volpe Center has accepted the performance modeling results provided by Lockheed for the purpose of our economic performance models but do so with reservations about the in-service performance of SLICE.

Chapter 6: Service Needs Assessment

The case study approach for the SLICE commercial viability assessment required a process for the identification and screening of possible service applications as an initial step. To briefly recapitulate the methodology, the main thrust of this study is to examine the common carrier, scheduled service ferry market, and then to examine the possibilities in other services and markets. The premise that people are the most valuable commodity for carriage by SLICE or other high speed craft remains central, as may be seen by inspection of the roster of “other services” presented below.

This chapter addresses services other than common carrier ferries. The approach taken is not a quantitative analysis, but a qualitative judgment by a group of marine transportation and transportation systems professionals based on a thoughtful compilation of SLICE’s advantages and disadvantages relative to each service. The results of the performance comparison in Chapter 5 were foremost in the minds of the group. It should, however, be pointed out that the seakeeping results do not play directly into the service needs assessment because almost all commercial and government operators fail to specify seakeeping performance. The advantage of SLICE seakeeping performance could only, therefore, be qualitatively characterized at this stage.

6.1 Identification and Screening of Candidate Services

The aim of the work described in this section is the reduction of the universe of possible non-military, non-ferry SLICE applications to a small number of high potential candidate services for the quantitative comparison of case studies. Table 6-1 presents the results of the group’s¹⁸ thinking and includes all identified candidate services, with SLICE’s strengths and drawbacks cataloged for each. The candidates are not listed in any particular order. More detailed discussion on the outlook for each service follows the table, where those selected for further study are identified.

The team identified sixteen possible non-ferry commercial applications for SLICE, including inland, coastal, and deep water operations for a variety of passenger, industry, response, and research services. The matrix was developed to identify strengths and weaknesses of the SLICE with regard to each possible application; to identify competing forms of transport in that service; and to note where competitive advantage may exist. The matrix includes qualitative assessments only, as a starting point for further analysis.

6.1.1 SLICE Service Briefs

The following are individual briefs for each of the services identified in Table 6-1. Selection for a quantitative case study is indicated in the two pertinent instances. Additional services showing some promise are also identified.

Crew/supply boats, offshore oil industry: SLICE strengths of high speed, ability to maintain speed in waves, reduced motions for crew comfort and safety, and high proportion of usable deck space appeared to outweigh possible drawbacks of deeper draft and higher cost. Speed is an important factor for reducing time spent aboard by rig crews in transit, providing an economic advantage to the operator. Fast SWATH vessels are now gaining acceptance in this trade, indicating that there may be customer demand for improved ride quality over conventional monohulls. *This service was selected for further quantitative analysis.*

¹⁸ The group consisted of project team members Michael Dyer and Robert Armstrong (Volpe Center), and Krishna Jain and Ted Dickenson (EG&G Dynatrend).

TABLE 6-1: CANDIDATE SERVICES FOR SLICE VESSELS

Service	SLICE Strengths	SLICE Drawbacks	Competition	Remarks / Motivation
Crew/supply boat, offshore oil industry	Speed; Reduced motions; Maintained speed in waves; Usable deck space	Deep draft	Conventional monohull; SWATH	Get to the rig and back quickly even in heavy seas; reduced motions for crew comfort and safety and working effectiveness. However deep draft may present problems in some areas
Pilot boat	Reduced motions in stationary and transit modes	Higher cost for speed may not be justified	Conventional monohull	Reduced motions transiting to rendezvous point and in standby mode waiting for ship, leading to more restful environment for pilots on board, improved effectiveness on duty
Spill response	Speed; seakeeping in rough weather; reduced motions in low-speed operations	Weight sensitivity (for stowage of recovered pollutants); endurance; cost	Monohull	Get to the spill fast even in heavy seas; reduced motion may improve spill cleanup effectiveness
Firefighting vessels	Speed; stability; maintained speed in waves; reduced motions in low-speed or stationary mode	Deep Draft	Conventional monohull, surface effect ship	Get to the fire quickly even in rough seas; reduced motions may improve effectiveness of firefighting efforts
HAZMAT transport	Stability and seakeeping for safety	Weight sensitivity	Barge, freighter	Unclear at present if speed is important
Gambling/casino excursion vessels	Speed; reduced motions in open water; passenger capacity	Deep draft (inland use)	Monohull; SWATH	Reach jurisdiction limits quickly. Reduced motions improve passenger comfort. Inland use has no need for speed or rough sea capability
High-value container feeder service to hubs	Speed; maintained speed in high seas; seakeeping	Weight sensitivity, limited payload	Trucking, railroads, small conventional containerhips, tug-barges	Seakeeping for physical protection of cargo—avoid green water over decks. May not tolerate variation in cargo weight
Salvage vessels	Stability, speed and loss of speed, reduced motions in stationary mode	Weight sensitivity	Conventional monohull	Get there first, heavy seas operating capability
Whale watch vessels	Speed; reduced motions in moderate to heavy seas in both high and low speed operation		Conventional monohull; catamaran	Get out and back from offshore viewing grounds quickly; improved passenger comfort in both transit and viewing modes

CANDIDATE SERVICES FOR SLICE VESSELS (continued)				
Service	SLICE Strengths	SLICE Drawbacks	Competition	Remarks / Motivation
Diving excursion vessels	Speed; reduced motions during transit and on station; usable deck space	High freeboard	Conventional monohull; SWATH; catamaran	Get to and from dive site quickly even in moderate seas; reduced vessel motions on station may facilitate divers' climb aboard
Ecotourism / glacier / iceberg tourist excursion vessels	Speed; seakeeping in moderate seas; maintained speed in waves	Deep draft	Conventional monohull; SWATH; catamaran	Transit open water quickly for access to more remote areas; passenger comfort
Charter offshore fishing vessels	Speed; seakeeping in transit and on station	Deep draft	Conventional monohull	Transit to fishing grounds quickly without discomfort to passengers; reduced motions on station
Cruise ship mini excursion vessels (concept)	Speed, reduced motions in transit and on station	Deep draft	Monohull	Transit from "mother ship" to places of interest. Unaware of any cruise ships in service where this concept is used
Oceanographic research vessels	Stability; reduced motions on station; speed; maintained speed in waves		Conventional monohull; SWATH	Fast transit to and from station; reduced motions improve conditions for research work on board
Commercial fishing vessels	Speed; maintained speed in waves; stability; seakeeping in high and low speed modes	Weight sensitivity, deep draft, cost	Conventional monohull	Transit to and from fishing grounds quickly; reduced motions may improve safety conditions for crew; but weight sensitivity may be difficult to overcome
Oceangoing Tugs	Seakeeping; stability	Deep draft	Conventional monohull	Speed not of interest; low towing efficiency if designed for high speed
Coast Guard Patrol Boat	Speed; seakeeping	Deep draft	Monohull; catamaran	Draft limited to 6 feet
Buoy tender	Seakeeping	Weight sensitivity, deep draft	Monohull	Weight sensitivity makes heavy lift capability infeasible.

Pilot boats: SLICE's reduced motions offer significant value to the pilot boat operator who may need to heave-to in rough seas for many hours waiting for a ship or while otherwise prevented from returning to shore; however, there is no differentiation between the SLICE and the SWATH in this regard. Indeed, SWATH pilot boats are now in service in at least one major U.S. port. The marginal increased speed offered by SLICE does not appear to present an advantage to pilots, who travel relatively short distances, often through speed restricted zones. Therefore no clear competitive advantage for SLICE was evident and the pilot boat application was dropped from further consideration.

Spill response vessels: There are a variety of types and sizes of spill response vessels but generally their mission requires transit to a spill site, deployment and recovery of spill cleanup equipment, separation of seawater from oil, and storage of recovered pollutants. Additionally some spill response vessels are equipped for helicopter operations for scouting, monitoring, or transfer of personnel and equipment.

SLICE presents possible advantages in the spill response market by providing speed to reach the scene of the accident faster, and in providing a very suitable, steady helicopter platform for spill reconnaissance missions. Reduced vessel motions, in addition to providing a helicopter capability in higher sea states, would also improve the restfulness and effectiveness of the on-board crew when operating in exposed areas. The weight sensitivity of the SLICE would prevent the on-board stowage of large volumes of recovered polluted seawater; however, it is current practice to utilize accompanying barges or other vessels for this purpose when the tanks of the lead spill response vessel are full. It is feasible for SLICE to tow objects such as bladders; however it would be inefficient at doing so since the design point for the propulsion system of SLICE is at high speed.

Another drawback of the SLICE for this service is its reduced endurance in comparison with a standard mono-hull, which may force either a premature return to port or refueling at sea, which complicate logistics and add cost. Despite an abundance of open deck space, SLICE's high freeboard means that it is not well suited to deployment and retrieval of oil spill containment and cleanup apparatus such as booms and skimmers¹⁹. It is not feasible to alter the design of SLICE to significantly reduce its freeboard height because its seakeeping performance relies in part on the air gap between the waterline and the underside of the wet deck. Finally, many oil spills occur in coastal areas where depths may be shallow. SLICE's draft would limit its use in this regard as well.

The outlook in the response and salvage business is for operators to use multi-mission vessels. A recent Coast Guard report indicates that oil spill response organizations (OSRO) have adequate equipment now on hand to meet currently regulated response capabilities plus the 25% increase planned for the near future.²⁰ The salvage business has been shrinking for twenty years as accident rates have decreased. Operators in the business cannot afford single mission dedicated vessels, particularly costly high speed multi-hulls. Newbuildings are likely to be high payload workhorses capable of multiple missions. This service was not selected as a SLICE opportunity.

Firefighting: SLICE's high speed and excellent seakeeping characteristics would allow it to transit to the site of the fire or oil spill quickly, even in a heavy seaway. Its reduced motions in low-speed or stationary mode may enhance the effectiveness of the firefighting effort by providing a steadier platform, facilitating the ability to keep water and foam streams on target. The most critical limitation of SLICE for this service is endurance. Again, the need for multi-mission vessels is a serious obstacle, particularly when salvage operations requiring heavy lift capability are considered. This service was not selected as a SLICE opportunity.

HAZMAT transport: Transport of hazardous materials in any mode presents health and safety issues, both for the public at large and for the occupational population, as well as environmental risks. A recent study

¹⁹ Design requirements for Marine Spill Response Corporations' Responder Class of oil spill response vessels (OSRVs) are discussed in the SNAME paper entitled "MSRC Responders: Construction and Operation of Sixteen Oil Spill Response Vessels" (Marine Technology, July 1995). Although freeboard height is not mentioned as a specific design requirement, note is made of the suitability of a converted offshore supply vessel (OSV) "with its open deck and low freeboard makes the ideal platform for oil recovery work."

²⁰ U.S. Department of Transportation, U.S. Coast Guard Headquarters G-MOR, Office of Response. *Response Plan Equipment Caps Review*. May 1999.

by the Volpe Center for the Research and Special Programs Administration of the U.S. Department of Transportation concluded that although voyage distance, and the associated human and environmental exposure, constitute an important risk factor, trip duration does not.²¹ Speed is therefore not a beneficial feature relative to HAZMAT transport; high speed at sea or in a waterway may indeed worsen risk relative to conventional vessels or other modes. SLICE is a weight sensitive craft, restricted in its cargo-carrying capacity. Cargoes would be relatively small (particularly since HAZMAT tends to have a large liquid constituent) and expensive. With these factors in mind, HAZMAT transport service was dropped from further consideration.

Excursion vessels: Passenger excursion vessels generally are an opportunity service SLICE because of its reduced motion in waves, seakindly ride characteristics, and weather reliability. Passenger comfort benefits the operator through both repeat and word-of-mouth business and the customers' inclination to spend money while on board. Furthermore, the speed of SLICE offers the operator lower transit times to event destinations (e.g., whale watching sites or jurisdiction limits for gaming boats). The potential for high revenue business and the added premium on passenger comfort make excursion service a very attractive opportunity. Six excursion services were identified in Table 6-1. The added capital cost of SLICE relative to other high speed craft is an indicator that a higher revenue service should be explored. The SLICE 400 configuration is most suitable for excursion service since it may efficiently carry a large number of passengers and no vehicle capacity is required. *The gaming boat is selected for a case study.*

High-value container feeder service to shipping hubs: SLICE's high speed, the ability to maintain speed in waves, and weather reliability are potentially desirable characteristics for this market, where transport time is the apparent driver. However, SLICE's weight sensitivity would limit cargo capacity significantly. Conversations with container ship operators indicate that the economics for such service are not presently favorable. Spoilage of perishable cargoes has been greatly reduced by improved intermodal scheduling, faster port handling methods, and modern refrigerated container technology. An economic study of short to medium haul container service by high speed vessels on European routes had quite conclusive negative results in markets where road congestion is at least as bad as found in U.S. metropolitan areas. Competition in the U.S. from overland trucking, rail, conventional containerships, and tug-barges is keen and the economic outlook for high speed service is therefore unfavorable. This service was not considered for further analysis.

Salvage vessels: SLICE's speed and seakeeping would allow it to quickly reach the site of the incident even in rough weather. Its reduced motions in station keeping mode may enhance salvage operations. However its endurance is limited, and its weight sensitivity may make it unsuitable. Therefore this service was not selected for further analysis.

Whale watch, diving, ecotourism, charter offshore fishing excursion vessels: Excursion vessels in general are treated above and will not be separately considered for further analysis.

Cruise ship mini excursion vessels : This case merits some further discussion apart from other excursion types because of its unique mode of operation. Shuttle services to shoreside destinations and cruising excursions from large cruise ships are common. In addition to the positive attributes already discussed, SLICE offers superior motion characteristics for the transfer of passengers at sea, eliminating the trauma and risk to those unaccustomed to shipboard environment. Embarkation would not be draft limited as at port facilities, except for the case (only conceptual at this point) where the excursion vessel gains access to the "mother" cruise ship by a stern gate to a well deck. Although potentially promising, this service was not considered for further analysis.

Oceanographic research vessels: SLICE would provide excellent motions characteristics on station for handling of underwater vehicles and for crew and scientific staff comfort during the transit period. In fact SWATH vessels have become accepted for oceanographic research purposes because of these same characteris-

²¹ R.A.M. *Transport Risk Study*.

tics. However, the limited endurance of the SLICE may curtail its effectiveness for lengthy missions. Additionally, there seems to be little added value to the research community for the increased speed offered by SLICE. Therefore this vessel type is not considered for further analysis.

Commercial fishing vessels: SLICE's speed and maintained speed in high seas would decrease transit time to and from the fishing grounds. Its stability and motions characteristics may improve safety conditions for the crews. But the weight sensitivity and endurance limitations of the SLICE would reduce its effectiveness to bring in large catches and go on long trips. Cost is also a major drawback for an industry in serious economic decline. Fishing service is therefore not considered for further analysis.

Oceangoing tugs: SLICE does not appear to be a good match for this vessel type because speed is not an issue in this trade, and vessels designed for high speed generally are ineffective at pushing or towing loads. Additionally, SLICE's endurance limits would affect the ability of the tug to make long ocean tows. The maneuverability characteristics of SLICE are not well known. Effects of impact loads against the lower hulls are unknown. This service is not promising and therefore was not selected for further analysis.

6.2 Coast Guard Missions

While Coast Guard floating platforms must generally have multi-mission capabilities, the existing US Coast Guard fleet could be described under the following four categories: patrol boats, aid-to-navigation servicing vessels, icebreakers, and open ocean cutters. Each will be considered in turn, starting with the most promising: patrol boats.

The patrol boat's performance of its mission would benefit from SLICE's speed and reduced motions. However, SLICE's draft is not feasible for the patrol boat given the coastal areas in which it must operate. The U.S. Coast Guard's Circular of Requirements (COR) for the new coastal patrol boat sets a required maximum draft of six feet (1.83 meters), while the SLICE demonstrator has a draft of approximately 14 feet and other variants are even deeper. Therefore the SLICE was not given further consideration in this study for the patrol boat application.

The minimization of vessel motion for personnel working on deck is an attractive feature of SLICE for aid-to-navigation servicing. These vessels must be capable of carrying heavy aid-to-navigation equipment as deck and hold cargo, however, a requirement for which SLICE is not well suited. In addition, the aids-to-navigation vessels are draft limited because they must be able to work aids in shallow water which mark shoals or other obstructions to navigation.

Icebreakers must have extremely robust hulls for breaking ice and are required to travel great distances without replenishing consumables. SLICE is poorly suited for this service.

For open ocean law enforcement and search and rescue work, the SLICE strengths of high speed and reduced motion are attractive. The SLICE hull form appears to offer an excellent platform for helicopter operations as well. SLICE is currently a candidate for this service in the US Coast Guard's Deep Water Capability acquisition program, for which the acquisition managers will conduct a very thorough analysis of its capabilities. As a result, this study will not attempt further analysis of SLICE for this application.

Chapter 7: North American Common Carrier Ferry Market Analysis

In order to adequately characterize both the existing and potential future markets for common carrier ferry service in North America, the Volpe Center developed a comprehensive and detailed inventory of both existing and proposed common carrier ferry route segments throughout North America, including the United States, Canada, Mexico and the Caribbean.²² A population of 759 existing and 69 proposed ferry route segments was identified, with these totals based on information current as of the spring of 1999. The database described in this chapter provided the initial basis for the ultimate selection of the final case study candidates reviewed in subsequent chapters.

7.1 Data Acquisition

To perform the higher level overview of North American ferry service markets called for in this chapter, other existing sources of related data were first identified and thoroughly reviewed. It was determined that these existing data sources were in many ways inadequate in either their scope, content, timeliness, accuracy or reliability, thus necessitating the development by the Volpe Center of the inventory described here. Examples of some of the shortcomings exhibited by these existing data sources include sources that contained data for ferry routes located in the U.S. only, with no data for routes in other areas of interest to this study, sources that lacked certain data fields of interest, sources that contained data that were not up-to-date, and sources that contained factual errors regarding the existence of particular ferry routes or their attributes. Although not suitable in their original form, these initial data sources did provide a starting point from which substantial additional development and refinement yielded the ferry route inventory produced by the Volpe Center.

The major categories of data sources utilized to perform this additional development included information from federal, state and provincial, and local government agencies, from the World Wide Web (WWW) sites of ferry operators or their oversight agencies, from ferry industry periodicals and related literature, and to a limited extent from various commercially available sources of information, for example digital street atlases, many of which identify both passenger-only and RoPax ferry route locations. Also, to identify proposed routes, local planning studies were utilized as an additional source of information. Specifically, some of the data sources utilized included:

- Federal Transit Administration (FTA), National Transit Database (formerly Section 15 data)
- Federal Transit Administration (FTA), Transit GIS
- Federal Transit Administration (FTA), Urban Harbors Institute (UHI) National Waterborne Passenger Transportation Database
- American Public Transit Association (APTA)
- Federal Highway Administration (FHWA), National Highway System GIS data
- US Department of Commerce, Bureau of the Census, TIGER/Line GIS data, census feature class code (CFCC) A65 (Feature Class A, Road; "Road with Special Characteristics" subcategory, A65 "Ferry crossing, the representation of a route over water that connects roads on opposite shores; used by ships carrying automobiles or people)

²² A "ferry route segment" is defined here as direct nonstop ferry service between two locations, and may or may not comprise part of a greater overall multi-stop route or route system. Thus, for example, the multi-stop route Seattle, WA - Friday Harbor, WA - Victoria, BC consists of two nonstop route segments (Seattle - Friday Harbor, and Friday Harbor - Victoria) that comprise the overall Seattle, WA to Victoria, BC route. Many services are simply point-to-point serving only two locations, in which case the route consists of only a single nonstop route segment.

- U.S. Geological Survey topographic maps
- U.S. Army Corps of Engineers, Waterborne Transportation Lines of the United States (WTLUS)
- U.S. Coast Guard, MSIS (Marine Safety Information System) data
- Miscellaneous federal, state/provincial and local documents (e.g., reports from Transport Canada, etc.)
- Jane's Information Group, *High Speed Marine Transportation*
- Jane's Information Group, *Urban Transport Systems*
- American Automobile Association (AAA) *Bridge and Ferry Directory*
- General Literature (e.g., Sarah Bird Wright, *Ferries of America*, 1987)
- Industry Literature (*Marine Log*, *Fast Ferry International*, etc.)
- World Wide Web sites of ferry operators, oversight agencies, and other ferry industry stakeholders

Although some of the sources used here could be considered somewhat unorthodox, to rely solely upon pre-existing ferry route databases, with their various shortcomings as noted earlier, would have simply resulted in an inventory which replicated many of these same weaknesses. Therefore, a multitude of data sources were combined and reconciled in order to maximize both the breadth and accuracy of the inventory.

The specific types of ferry services included within the scope of the inventory were those providing itinerant²³, fixed route, common carrier²⁴ passenger and/or vehicle (RoPax) ferry service. Ferry operations that were exclusively non-itinerant (e.g., "cruise-to-nowhere" services), excursion services (e.g., whale watches, casino boats, day cruises, dinner cruises, etc.), passenger-only water taxi services not operating on a fixed route, LoLo (Lift-on/Lift-off) freight/auto carrier services, or long distance passenger-only cruise ship services were excluded.

The inventory of existing ferry route segments was developed separately from that of proposed ferry route segments, although they share many features in common. Because the existing ferry route inventory represents the bulk of the services that were identified (769 existing route segments, as opposed to 69 proposed route segments identified), and was the most well developed in terms of its presentation and distribution to the public, it is the primary focus of this chapter, and is subsequently referred to as the *North American Ferry Route Inventory*, or the inventory.

The *North American Ferry Route Inventory* was distributed both on diskette at the February, 1999 *Fast Ferry International* conference in Boston, MA, and thereafter on diskette and via Volpe Center anonymous FTP. Thus far, the inventory has been well received by a broad spectrum of ferry industry stakeholders, and their use and evaluation of the ferry route inventory has also provided an important element of peer review.

7.2 Database Structure

As noted earlier, the *North American Ferry Route Inventory* contains information on 759 nonstop ferry route segments, which comprise 555 routes and serve a total of 923 ferry terminal locations. Many ferry routes consist of multi-stop service between multiple ports of call (e.g., the Alaska Marine Highway System); therefore routes are sometimes comprised of more than one nonstop route segment, resulting in fewer overall routes than there are individual route segments.

²³ Service between two different ferry terminal locations or ports of call. Such service need not necessarily operate on a regular schedule, but instead might be characterized as "demand-responsive." Examples of such demand-responsive service include various inland river RoRo ferry crossings in United States and Canada that operate "on-demand" during a defined period of service each day.

²⁴ "Common carrier" can be generally defined as a for-hire carrier that holds itself out to serve the general public at reasonable rates and without discrimination.

The fundamental data record structure of the *North American Ferry Route Inventory* is such that an individual record represents a distinct combination of:

- Route
- Nonstop route segment
- Operating entity
- Distinct service types (passenger only, RoPax, conventional, or high speed²⁵)

The database structure allows both for detailed review of individual route segments and services and the ability to also review information at higher levels (e.g., at the route level instead of the route segment level) if so desired. An illustrative example of this record structure can be seen in looking at the ferry services between Bremerton, WA and Seattle, WA (see Figure 7-1). Service between these two locations is reflected in the route inventory by three separate records, one representing the RoPax service operated by Washington State Ferries with a trip time of one hour, the second representing the passenger-only service operated by Washington State Ferries with a trip time of 45 minutes (using the vessel *MV Tyee*), and the third representing the passenger-only service operated by Washington State Ferries with a trip time of 30 minutes (using the vessel *MV Chinook*).

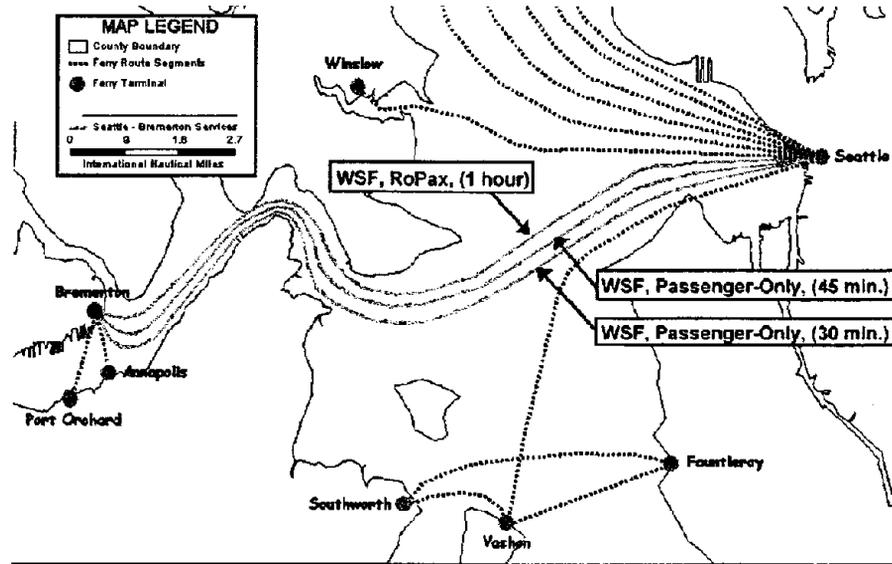
For each data record, the primary data fields or attributes include:

- Route name
- Route segment
- Geographic coordinates of route and route segment ferry terminal locations
- Operator and/or sponsoring agency
- Type of service (RoPax or Passenger-Only)
- Type of service (High Speed or Conventional)
- Route segment length (nautical miles)
- Existing scheduled route segment travel time
- Name of the body of water crossed
- Vessel names
- Telephone contact information
- Hyperlinks to World Wide Web homepages

Given seasonal and year-to-year changes that can occur in schedules, fares and other attributes of a given ferry service, and the overall pace of change affecting many routes (new vessels being introduced, etc.), the WWW hyperlinks provide a convenient method of updating the information in the inventory without manual updating of the data fields.

²⁵ The determination as to whether or not service is "high speed" is based on the general rule-of-thumb of 25 knots operating speed and greater, although some suggest that 25 knots is too modest a threshold for characterizing a service as being truly high speed.

FIGURE 7-1: GRAPHICAL EXAMPLE OF FERRY ROUTE INVENTORY FUNDAMENTAL RECORD STRUCTURE



The route segment inventory was developed in Microsoft Access, a widely used commercial database software application. A form-based interface was developed (see Figure 7-2), providing a clean and well organized interface for users to interact with the data. This interface enables the use of form-based queries with drop down pick-lists, enabling straightforward extraction of customized data sets based on any number of user-defined criteria (e.g., operator, location, service type, route length, scheduled travel time, etc.).

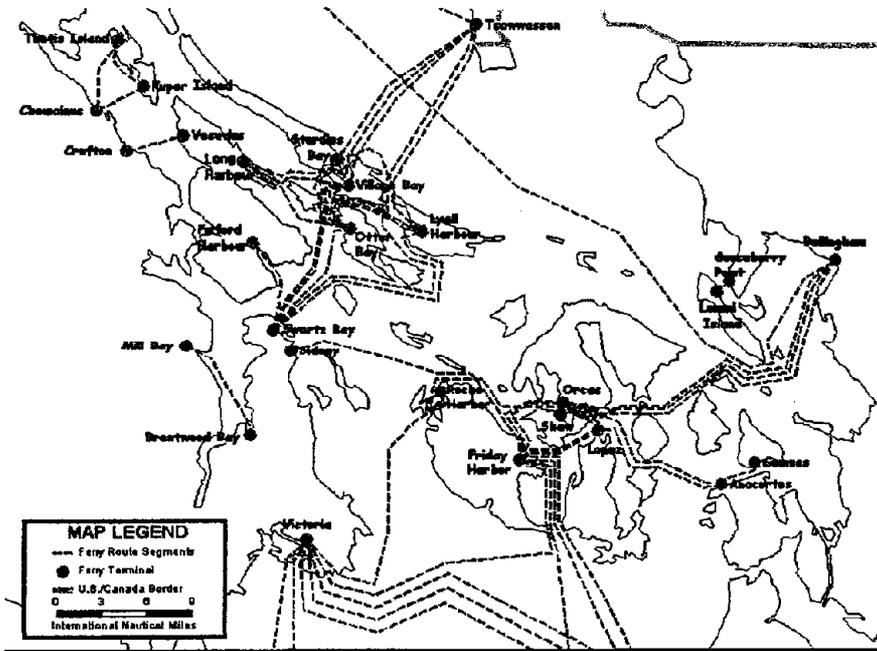
FIGURE 7-2: FORM-BASED INTERFACE OF NORTH AMERICAN FERRY ROUTE INVENTORY

ROUTE NAME Seattle - Bremerton					
INDEX ID# 718	REGION United States	TYPE OF SERVICE Passenger only	HIGH SPEED SERVICE? Yes	TRAVEL TIME 00:30	LENGTH (NMI) 15.1
OPERATOR Washington State Department of Transportation, Washington State Ferries					
SPONSOR					
ROUTE SEGMENT DETAIL					
TERMINAL #1 - COUNTRY United States	TERMINAL #1 - STATE/PROVINCE Washington	TERMINAL #2 - COUNTRY United States	TERMINAL #2 - STATE/PROVINCE Washington		
ROUTE SEGMENT - TERMINAL #1 - PLACE NAME Seattle		ROUTE SEGMENT - TERMINAL #2 - PLACE NAME Bremerton			
BODY OF WATER CROSSED Puget Sound			PRIMARY WWW URL http://www.wsdot.wa.gov/ferries/default.cfm		
TELEPHONE CONTACT INFORMATION (206) 464-8400			SECONDARY WWW URL		
NOTES Passenger only service. Passenger only high speed service travel time is 30 minutes on the Chinook, and 45 minutes on the Tye. Sails from Pier 50, Seattle.					
VESSEL #1 NAME Chinook	VESSEL #2 NAME	VESSEL #3 NAME	VESSEL #4 NAME	VESSEL #5 NAME	VESSEL #6 NAME

7.3 Database Geographic Information Systems (GIS) Capabilities

Geographic representations of the ferry route segments and ferry terminal locations identified in the route segment inventory were developed to facilitate further analysis. Individual GIS route segment records, such as those shown in Figure 7-3 for the San Juan Islands and Southern Gulf Islands in Washington State and British Columbia, were coded so as to maintain their distinct identity, with each GIS route segment linked to the data field attributes describing that route segment. In addition to the role it can play in data analysis, GIS also provides an effective means of representing, communicating and conveying the information contained in the route inventory in a more compelling visually-oriented manner. The route segment and ferry terminal GIS locations developed for the route inventory are generally meant to be abstract, approximate representations to be used for analytical purposes. They are generally not exact, realistic representations of the precise routes traveled, and thus would not be suitable for navigation purposes, for example. When combined with other GIS data files, such as census bureau demographic data or representations of the other transportation facilities such as highways, the ferry route segment and ferry terminal GIS data files created here can provide the spatial data building blocks with which to conduct additional analyses (for example, helping to determine the location of possible new services, etc.).

FIGURE 7-3: GIS FERRY ROUTE DATA - EXISTING FERRY ROUTE SEGMENTS IN THE SAN JUAN ISLANDS / SOUTHERN GULF ISLANDS



7.4 Summary Findings

The *North American Ferry Route Inventory* proved to be a useful tool for accurately characterizing the extent and nature of the common carrier ferry market in North America. A selection of some of the many possible applications of the inventory and cross tabulations that can be derived from the inventory are presented here. Based on the data contained within the *North American Ferry Route Inventory*, Figure 7-4 presents the geographic distribution of existing ferry services in North America.

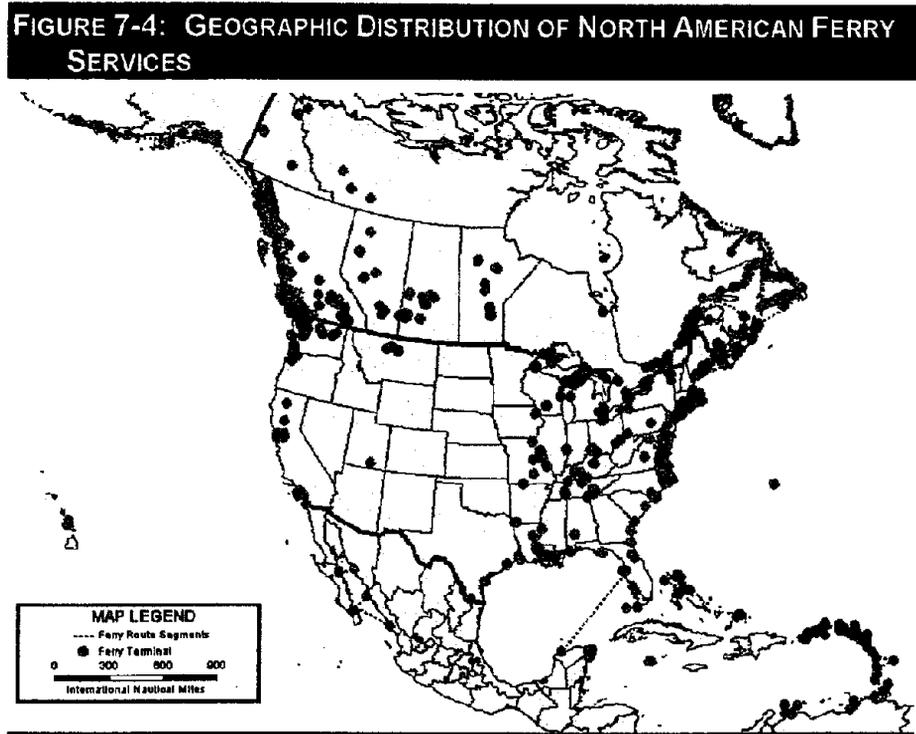
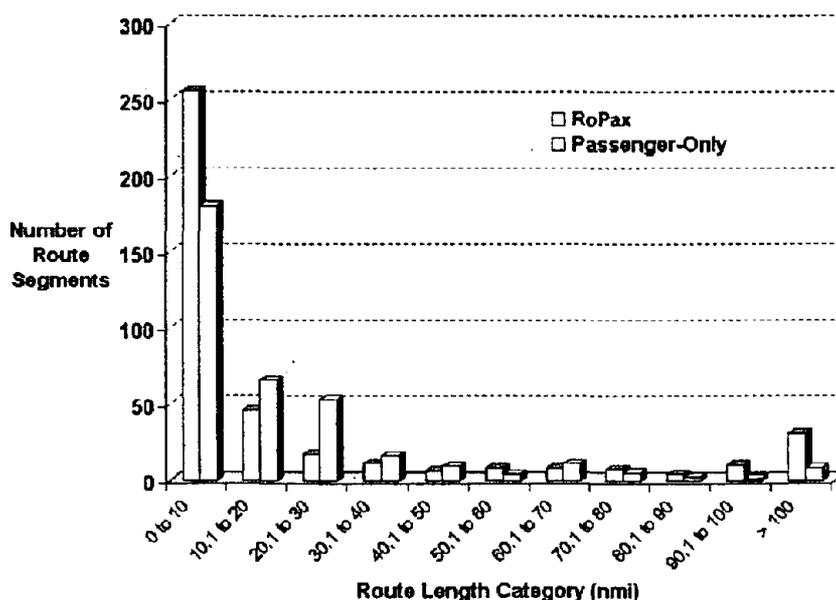


Figure 7-5 presents the distribution of the number of existing ferry route segments by service type (RoPax or Passenger-Only) by route length in nautical miles. This figure reveals that for both RoPax and passenger-only service types, the majority of ferry route segments (51% of passenger-only route segments and 63% of RoPax route segments) are of less than 10 nautical miles in length. Only 8.7% of passenger-only route segments and 16.8% of RoPax route segments are of greater than 50 nautical miles in length.

Although passenger and vehicle ridership data were not collected for most ferry route segments, it is estimated that for U.S. ferry routes, total annual passenger ridership for 1998 was between 80 million to 113 million annually. The figure of 134 million for total annual U.S. ferry passenger ridership is found in the September 1999 Marine Transportation System (MTS) Report to Congress,²⁶ based on the National Waterborne Passenger Transportation Database, developed by the University of Massachusetts at Boston, Urban Harbors Institute (UHI) for the Federal Transit Administration in the early 1990's. This figure is flawed in two major respects, however.

²⁶ *An Assessment of the U.S. Marine Transportation System. A Report to Congress.* September 1999. Pages 11, 19, 30, 34, and 46.

FIGURE 7-5: DISTRIBUTION OF EXISTING NORTH AMERICAN FERRY ROUTE SEGMENTS BY ROUTE LENGTH AND SERVICE TYPE



First, it is based on the reported ridership of 50% of 168 ferry operators surveyed between 1990 and 1994, totaling 67.9 million annual passenger boardings. The Urban Harbors Institute then simply doubles this value to estimate total national ferry ridership at 134 million. However, of this reported value of 67.9 million passenger boardings, two of the approximately 84 ferry operators who responded (Washington State Ferries and the New York City DOT Staten Island Ferry) alone account for almost half (46.6%) of the total. In effect, all of the largest and most highly patronized ferry systems responded to the ridership portion of the survey, whereas many smaller and less well patronized ferry systems did not. By doubling the original estimate of 67.9 million, UHI introduces a sample selection bias, since it assumes that the 50% of operators who did not report ridership data are similar in terms of their aggregate ridership levels as the 50% who did report. Therefore, the adjustment applied by UHI substantially overestimates total annual U.S. ferry ridership for the early 1990's. Based on the 67,900,000 reported ferry passengers, and considering the issue of sample selection bias discussed above, a more accurate estimate of U.S. national ferry ridership for the early 1990's probably lies somewhere between 80 to 100 million annually. As an accurate and contemporaneous point of reference, the fourteen ferry boat operators reporting information via Section 15 of the Federal Transit Act (currently known as the National Transit Database), reported a combined total of 42,656,400 annual unlinked passenger trips (i.e., passenger boardings) for the 1992 report year.²⁷ The magnitude of this figure is generally consistent with the 80 million to 100 million total national ferry ridership estimate for the early 1990's, which represents a larger and more comprehensive population of ferry operators than the relative few reporting on Section 15.

In addition to the problem described above, the ridership data reported via the UHI survey is currently between seven and ten years old. With no comprehensive, accurate and current total ferry ridership data available, it is difficult to estimate what growth in national ferry ridership might have occurred between the early 1990's and

²⁷ Section 15, 1992 Report Year, Table 21.

1998. Using annual ferry ridership reported by the Federal Transit Administration (based on a small representative portion of U.S. ferry operators) in the National Transit Database for the 1992 and 1997 report years as a rough indicator of nationwide trends, ferry ridership has probably remained relatively stable. The data reveal virtually no change in total ridership during the period in question, with a total of 42,656,400 unlinked passenger trips reported for 1992 and a total of 42,047,680 unlinked passenger trips reported for 1997.²⁸ Therefore, a more current and accurate estimate of U.S. national ferry ridership for 1998 probably lies somewhere between 80 to 113 million annually, which on the low end assumes no growth over the period from the early 1990's, and on the high end assumes a compound annual growth rate in national ferry ridership of 2.5%. The number of vehicles carried by ferries annually is more difficult to estimate, and the MTS Report to Congress estimates is in the "tens of millions." As a point of reference, annual vehicle boardings for Washington State Ferries, the largest ferry system in the U.S. ranked in terms of passenger and vehicle boardings, exceed ten million.

For Canadian ferry routes, it is estimated that companies that are members of the Canadian Ferry Operators' Association (CFOA) represent the major providers of passenger and vehicle ferry service, and account for more than 95% of total ferry traffic in Canada.²⁹ In 1997, these operators had total patronage of 38.2 million passenger boardings and 14.4 million vehicle boardings, with British Columbia Ferries alone having 22.2 million passenger boardings and 8.1 million vehicle boardings. Reliable statistics on all ferry operators in the Caribbean and Mexico are not available.

Table 7-1 presents a detailed cross tabulation by region (Canada, U.S., Mexico, Caribbean, or multi-region cross-border), service type (passenger-only or RoPax), operating speed (conventional or high speed), and for the proposed route segments, the likelihood of implementation (high, moderate/high, moderate, low)³⁰, of the ferry route inventory data for both the 759 existing ferry route segments identified and the 69 proposed route segments identified. Overall, the U.S. has the greatest number of all ferry route segments, with 393, followed by Canada with 220 and the Caribbean with 107. In Canada, 74.5% of ferry route segments are RoPax, whereas in the U.S. 50% are RoPax, and in the Caribbean, only 16% are RoPax. For the proposed route segments, 81% are proposed for service within, to or from the United States. Of all 69 proposed ferry route segments, only about 4.5% are proposals for conventional ferry service, and the majority (56.5%) are proposals for high speed, passenger-only ferry services, mostly in the United States.

²⁸ National Transit Database, 1997, Table 26.

²⁹ Canadian Coast Guard. *Ferry Services. Service Profile 96*. WWW at URL <http://www.ccg-gcc.gc.ca/archives/profile/ferries.htm>

³⁰ This was a largely subjective determination of the likelihood that the proposed ferry service will actually be implemented within a reasonable time frame (i.e., 5 to 10 years). This determination is based upon various factors including, but not limited to, the experience and current extent of operations (if any) by the intended operating and/or sponsoring entity, and the level of detail in which feasibility studies and business plans appear to have been developed.

TABLE 7-1: CROSS TABULATIONS OF FERRY ROUTE SEGMENT DATA

		Region							Marginal Totals		
		Canada	Canada / U.S.	U.S.	U.S. / Mexico	Mexico	Caribbean	Caribbean / U.S. ⁽¹⁾			
Existing Route Segments⁽²⁾											
RoPax	Conventional	162	20	198	2	4	15	--	401		
	High Speed	2	1	--	--	--	2	--	5		
Passenger-Only	Conventional	52	3	143	--	1	63	--	262		
	High Speed	4	5	52	--	3	27	--	91		
Existing Route Segment Totals		220	29	393	2	8	107	0	759		
Proposed Route Segments⁽²⁾											
Likelihood of Implementation	High	RoPax	Conventional	--	--	--	--	--	--	0	
			High Speed	--	--	--	--	--	1	1	
			unknown	--	--	--	--	--	--	--	0
	Pass.-Only	Conventional	1	--	--	--	--	--	--	1	
		High Speed	1	--	2	--	--	3	--	6	
		unknown	--	--	--	--	--	--	--	0	
	unknown	Conventional	--	--	--	--	--	--	--	0	
		High Speed	--	--	--	--	--	--	--	0	
		unknown	--	--	--	--	--	--	--	0	
	Moderate / High	RoPax	Conventional	--	--	--	--	--	--	0	
			High Speed	--	1	2	--	--	--	--	3
			unknown	--	--	--	--	--	--	--	0
		Pass.-Only	Conventional	--	--	--	--	--	--	--	0
			High Speed	--	1	15	--	--	--	--	16
			unknown	--	--	--	--	--	--	--	0
	unknown	Conventional	--	--	--	--	--	--	--	0	
		High Speed	--	--	--	--	--	1	--	1	
		unknown	--	--	--	--	--	1	--	1	
	Moderate	RoPax	Conventional	--	--	--	--	--	--	0	
			High Speed	--	--	--	--	--	--	--	0
			unknown	1	--	--	--	--	--	--	1
		Pass.-Only	Conventional	--	--	--	--	--	--	--	0
			High Speed	2	--	8	--	--	--	--	10
			unknown	--	--	--	--	--	--	--	0
unknown	Conventional	--	--	--	--	--	--	--	0		
	High Speed	--	--	--	--	--	--	--	0		
	unknown	2	--	--	--	--	1	--	3		
Low	RoPax	Conventional	--	--	--	--	--	--	0		
		High Speed	--	--	1	--	--	--	--	1	
		unknown	--	--	--	--	--	--	--	0	
	Pass.-Only	Conventional	--	1	1	--	--	--	--	2	
		High Speed	--	--	14	--	--	--	--	14	
		unknown	--	--	1	--	--	--	--	1	
unknown	Conventional	--	--	--	--	--	--	--	0		
	High Speed	--	--	7	--	--	--	--	7		
	unknown	--	--	1	--	--	--	--	1		
Proposed Route Segment Totals		7	3	52	0	0	6	1	69		

Notes:

(1) Caribbean / U.S. routes include Miami-Freeport (Bay Ferries), Miami-Nassau (Bay Ferries), and Palm Beach-Freeport (SeaJets) as of late summer 1999.

(2) Data as of March, 1999.

Chapter 8: Ferry Case Studies

The case study approach adopted herein incorporates technical and economic characteristics of various vessels and their operation in specific geographic markets, providing the detail needed for conclusions to be drawn with good confidence. When an existing public or private ferry service provider considers the implementation of new or improved ferry service, many difficult questions regarding technical and economic attributes of the vessels and service must first be addressed satisfactorily in order for the service to have a reasonable chance of success. The case studies are in many ways comparable to this "real world" approach, while improving upon it in many respects, and thus provides a reasonable assessment of the commercial feasibility of SLICE relative to other high speed craft.

Previous analytical studies regarding the commercial feasibility of SLICE have utilized both generalized and more detailed case study approaches. In both the June 1995 marketing study conducted by Nigel Gee and Associates for Pacific Marine³¹, and the June 1995 SLICE marketing study conducted by Art Anderson Associates³², a high-level generalized approach was taken, considering a large number of potential routes with limited technical and economic detail attributes. In contrast, the July 1995 Pacific Marine Hawaii Inter-Island Ferry Business Plan utilized a far more detailed case study approach, analyzing just two routes in great detail.

The present study combines elements of both of approaches, and adds other quantitative analyses. The general approach adopted by Gee has been taken in developing the inventory of existing and proposed North American ferry routes, and in selecting the case study markets. The selected market case studies go beyond the Pacific Marine approach in some ways, including the rigorous quantitative analysis of wave climate in the selected case study markets and the seakeeping analyses to determine the suitability of SLICE and other high speed vessel types in given markets and operating environments.

This chapter reviews the approach taken in selecting the common carrier ferry case studies from the North American ferry services inventories and follows with detailed discussion of the elements considered in evaluating each case study market.

8.1 Selection of Case Study Markets

This section addresses the process by which ferry routes or ferry route systems were selected for detailed case study analysis from among the universe of 759 existing North American ferry route segments and 69 proposed North American ferry route segments identified in Chapter 7. These comprehensive ferry route inventories, with data on route length, service types, scheduled travel times, and other basic data elements, served as the initial basis for the selection of the final case study candidates. A series of selection criteria were developed, and a systematic process of elimination was then applied in order to screen out routes deemed unsuitable for further consideration. The primary criteria utilized were:

- Route length
- Wave climate
- Draft restrictions and controlling depth
- Existing or forecast ridership
- Service profile
- Seasonality

³¹ Nigel Gee and Associates, Ltd. *Sea SLICE Marketing Study for Pacific Marine. Volume 3 - Route Studies.* June 1995.

³² Art Anderson Associates. *Study of Marketing Possibilities for Two Variants of the SLICE Design.* June 1995.

- Likelihood of implementation
- Sponsor and other industry stakeholder input

As indicated, the first criterion utilized was that of **route length** in nautical miles. Either the actual reported route length, or the route length estimated using geographic information systems (GIS) software in combination with the geo-referenced ferry route inventory, was utilized. For passenger-only ferry services, route segments of less than 32 nmi in length (approximately the 85th percentile for passenger-only route segments) were eliminated from further consideration. Similarly, for RoPax ferry routes, route segments of less than 60 nmi in length (approximately the 85th percentile for RoPax route segments) were eliminated. These route length criteria were developed with the following in mind.

First, ride quality and passenger comfort issues increase in importance as route length and total travel time increase, thus providing SLICE an advantage on longer routes. This can be seen in the ISO standards for vertical accelerations and passenger motion sickness, with lower acceleration limits for longer trip times and longer exposure to vessel motions. Route length also serves as a partial proxy for operation in “exposed waters,” with longer routes more likely to experience operations in difficult sea states for a given meteorological region. Furthermore, in previous SLICE case studies, the great majority of routes analyzed were in excess of the threshold distances used here. Finally, if SLICE provides a travel time advantage over alternative vessel types, routes must be long enough to provide a significant time savings. Terminal operations for RoPax vessel loading/unloading add to total trip time and increase the requirement for significant travel time savings.

The second criterion used was that of wave climate or **sea state**. Annual and seasonal wave height frequencies, extracted from the NOAA Coast Pilot meteorological tables, were utilized to identify regions of relatively difficult sea states. More detailed and refined quantitative wave climate analyses were conducted for the final case study markets that were ultimately selected; however, this higher level approach provided an initial indication of regions that would be generally suitable for further study. As shown in the Seaspeed vessel seakeeping analyses, SLICE does indeed provide an advantage of other vessel types under many conditions, thus providing SLICE an advantage in operational reliability, operating speed and ride quality in difficult sea states. Figures 8-1 through 8-5 provide a graphical representation of this macro-level sea state analysis, presenting both annual and seasonal characterizations.

The third criterion was **draft restrictions and controlling depth**. As shown earlier in Chapter 5, the draft of all SLICE variants is significantly greater than that of other vessel types of similar displacement and capacity, including even SWATH vessels, which themselves have comparatively deep draft compared to other vessel types. Assuming that dredging would be prohibitively difficult or costly, use of SLICE would be unlikely where controlling depths in harbors and waterways are currently insufficient.³³

³³ The Technical Data Packages for the SLICE 400 and SLICE 600 were not received from Lockheed Marine Systems prior to the case study market selection process. Therefore, reasonable estimates of the draft for these two SLICE vessel designs were instead made based on the SLICE ATD vessel, the observed draft of SWATH vessels of varying displacements (with data obtained from SWATH International, Ltd.), and the estimated draft of a 1,700 long ton deadweight SWATH design reviewed in a 1992 study of alternative hull types performed by the Alaska Marine Highway System. Despite this, the 28.5 foot draft of the SLICE 600 significantly exceeded the original draft estimate of approximately 22 feet for the SLICE 600, with the result that certain case study route candidates do not necessarily have sufficient controlling depth to accommodate the SLICE 600 vessel.

FIGURE 8-1: WAVE HEIGHT FREQUENCIES - ANNUAL

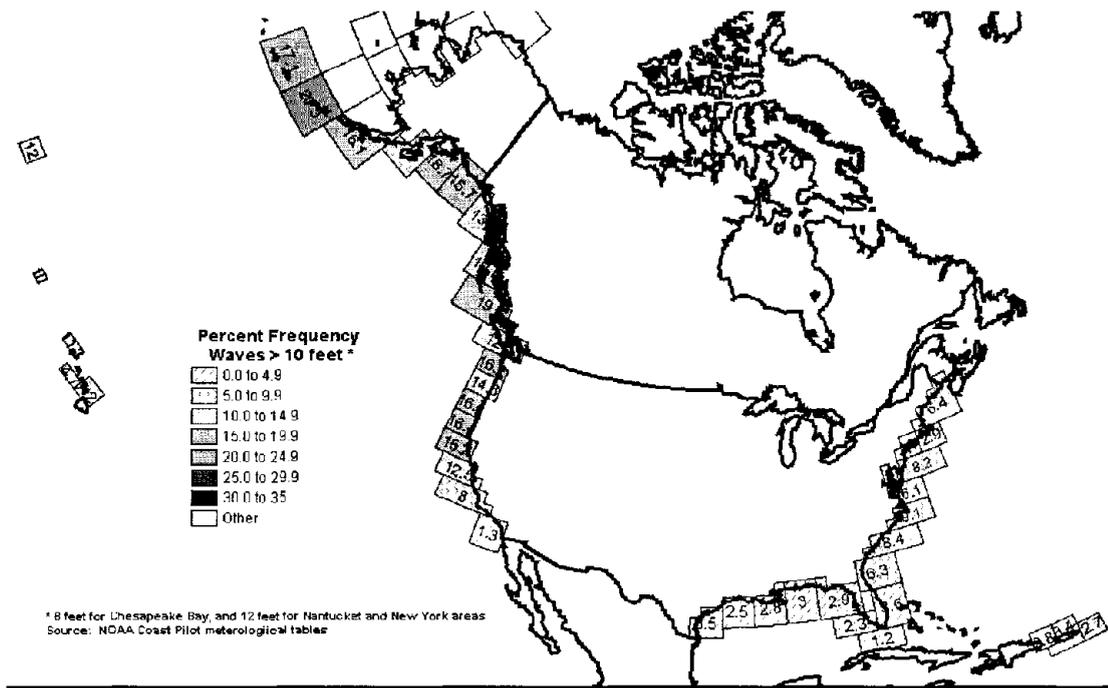


FIGURE 8-2: WAVE HEIGHT FREQUENCIES - WINTER (DECEMBER TO FEBRUARY)

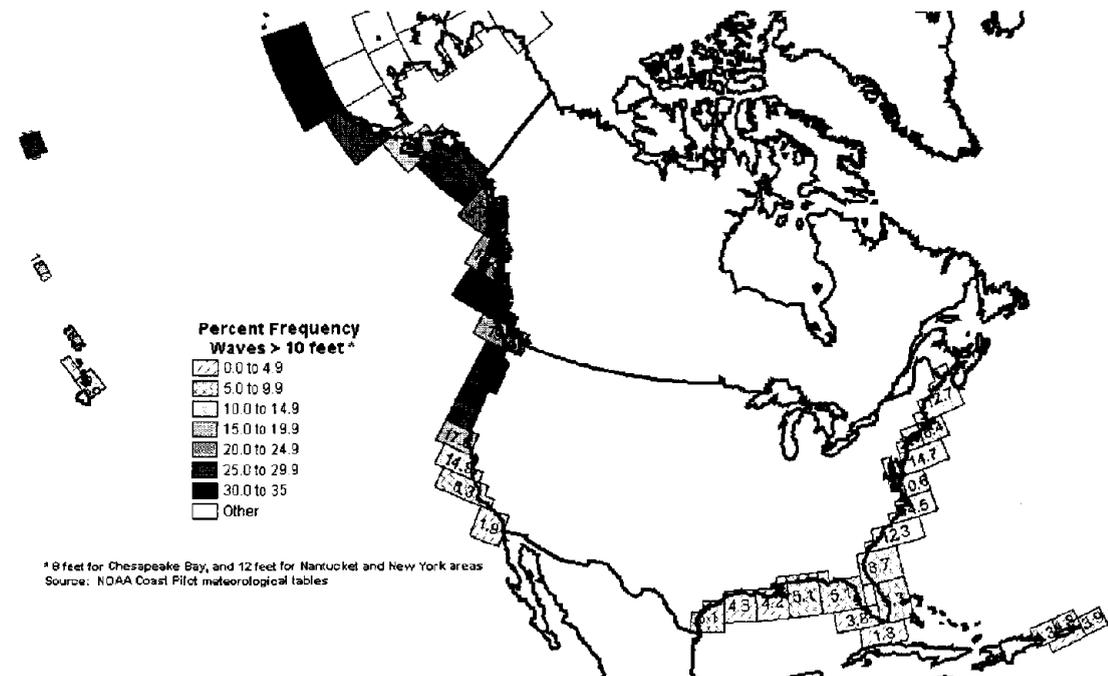


FIGURE 8-3: WAVE HEIGHT FREQUENCIES - SPRING (MARCH TO MAY)

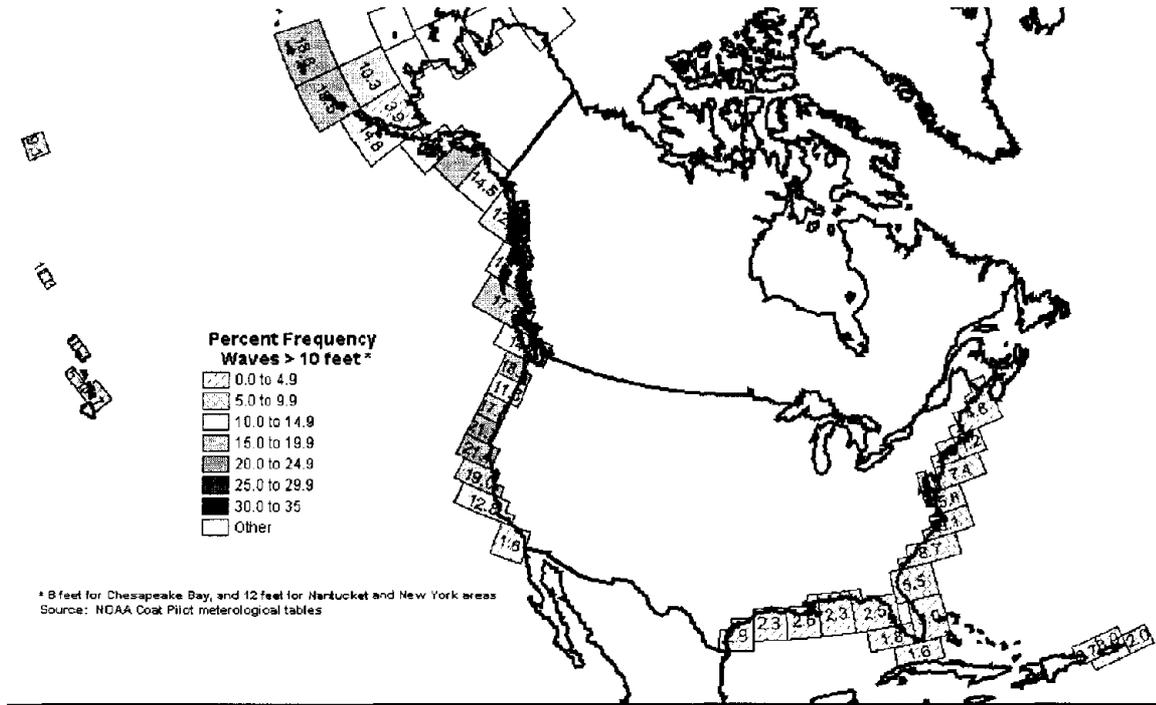


FIGURE 8-4: WAVE HEIGHT FREQUENCIES - SUMMER (JUNE TO AUGUST)

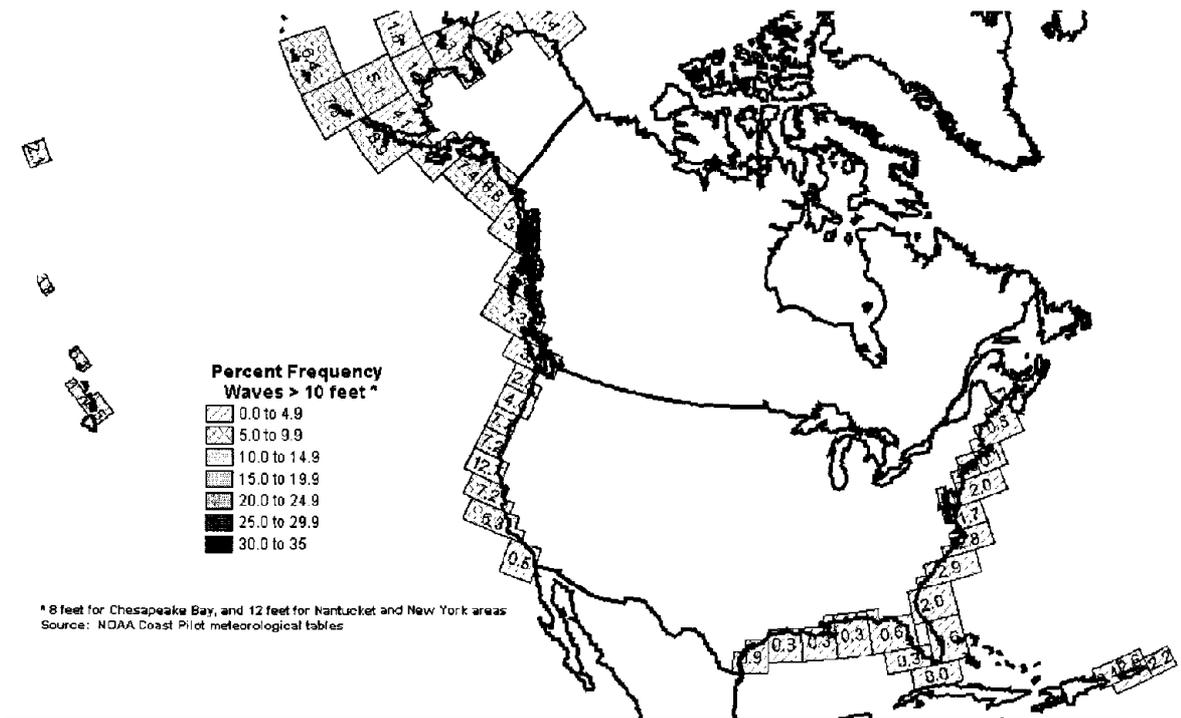
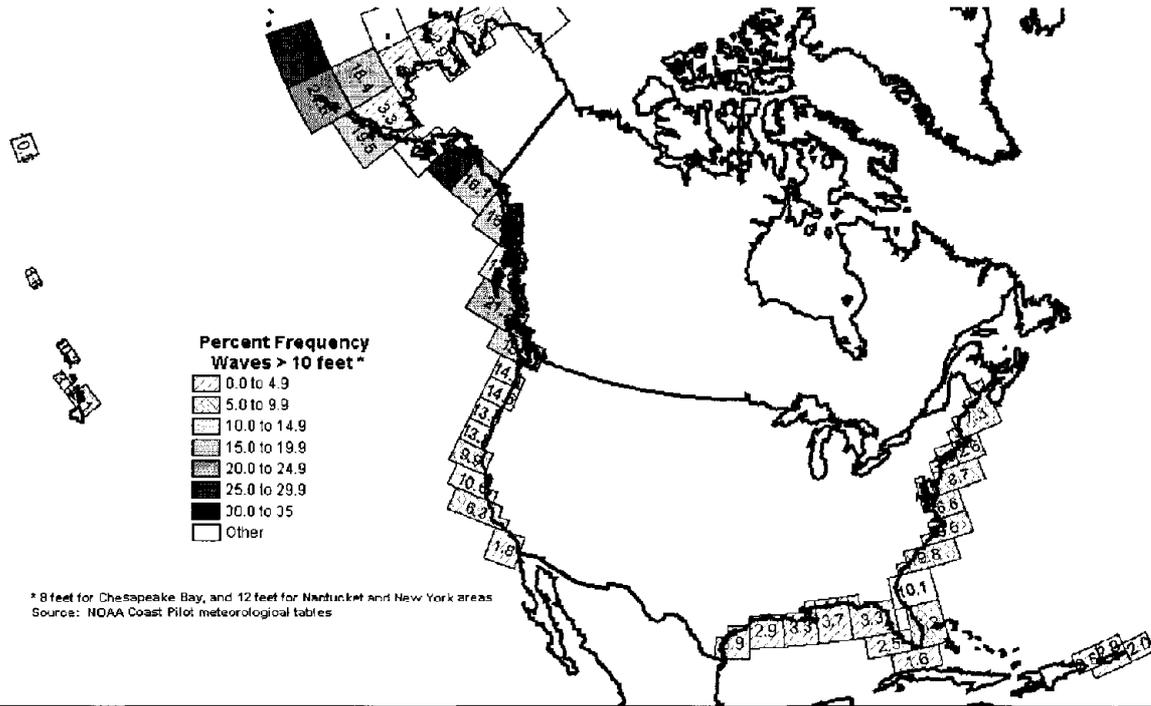


FIGURE 8-5: WAVE HEIGHT FREQUENCIES - FALL (SEPTEMBER TO NOVEMBER)



The fourth criterion was **ridership**. Even though the potential advantages of SLICE such as superior ride quality and (in certain cases) greater speed may increase ridership on a given route, routes where existing or forecast ridership is relatively low, the existing or proposed vessel capacity is relatively small, and service is infrequent are likely to be poor candidates for viable SLICE service, and were eliminated as possible case study candidates.

The fifth criterion was existing or proposed **service profile**. Certain existing routes, although meeting some of the criteria discussed here, exhibit service profiles that would likely be unsuitable for SLICE. For instance, services best characterized as coastal supply boat services, that are infrequent, have relatively low ridership and are in some cases seasonal, are likely to be poor candidates for viable SLICE service and were therefore eliminated as possible case study candidates.

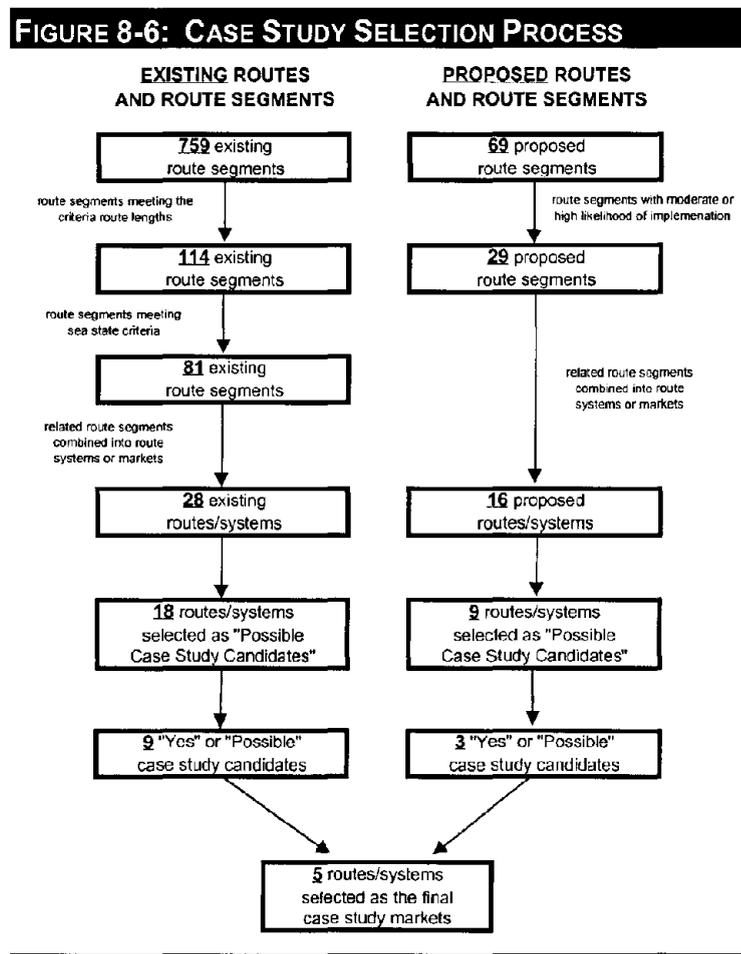
The sixth criterion was **seasonal service** versus year round. The capital cost of SLICE and its performance in rough seas would argue for year round service on a given route. Routes having a limited seasonal service would likely therefore be poor candidates for viable SLICE service, although conceivably the vessels could be repositioned in the off season to other markets.

The seventh criterion was the **likelihood of implementation for proposed new ferry services**. This is a largely subjective determination of the likelihood that the proposed ferry service will actually be implemented within a reasonable time frame (i.e., 5 to 10 years). This determination is based upon various factors including, but not limited to, the experience and current extent of operations (if any) by the intended operating and/or sponsoring

entity, information concerning the financial capacity of the intended operating and/or sponsoring entity, and the level of detail in which feasibility studies and business plans appear to have been developed. Proposed routes that appeared to have a low likelihood of actual implementation were eliminated from further consideration as case study candidates.

Finally, discussion with and input from the Office of Naval Research project sponsor, as well as limited input from other industry groups and individuals, contributed in part to the selection of the final five case study ferry markets.

The following figure shows the overall process, and the number of route segments that remained after screening



step.

The 18 existing route systems and 10 proposed route systems that survived into the final rounds of the selection are presented in the following tables, along with basic information describing these route systems.

Table 8-1: Existing Routes - Potential North American Case Study Ferry Markets

Region	Operator / Sponsor	Names of Route(s)	Services Type	Number of Route Segments	Possible Case Study Candidate?	Route Length (nm)	Percent Time Wave Height > 10 feet (1)
United States	Alaska Marine Highway System	Alaska Marine Highway System - Southeast (Skagway, AK - Beaufort, WA)	Conventional, RoRo	15	Yes	92 to 687	10.7 to 18.0
United States	Alaska Marine Highway System	Alaska Marine Highway System - Southwest (Cordova, AK - Uneraska, AK)	Conventional, RoRo	16	No	90 to 248	9.0 to 18.7
Canada / United States & United States	Clipper Navigation, Inc.	Victoria, BC - Seattle, WA	High Speed, Passenger only	3	No	68 to 77	** no data **
United States	Clipper Navigation, Inc.	Victoria, BC - Seattle, WA	Conventional, RoRo	1	No		
United States	Clipper Navigation, Inc.	Seattle - Friday Harbor	High Speed, Passenger only	1	Possible	32	1.0 to 8.3
United States	Clipper Navigation, Inc.	Dana Point - Avalon	High Speed, Passenger only	1	No	104	1.7 or less
United States	Key West Shuttle, Mass Barge/Light, Inc.	New London - Liberty State Park	High Speed, Passenger only	1	Possible	90 to 133	1.2 to 3.2
United States	Key West Shuttle, Mass Barge/Light, Inc.	Fort Myers - Key West	High Speed, Passenger only	1	Possible		
United States	Key West Shuttle, Mass Barge/Light, Inc.	Fort Myers - Key West	High Speed, Passenger only	1	Possible		
Canada / United States	Bay Ferries	St. John - Digby	Conventional, RoRo	1	Yes (St. John - Digby)	40 to 96	9.4
Canada / United States	Bay Ferries	Yarmouth - Portland	Conventional, RoRo	1	No	180	9.4
Canada / United States	Prince of Fury Cruises, Ltd.	North Sydney - Argyle	Conventional, RoRo	1	Possible	91 to 276	** no data **
Canada	Marine Atlantic, Inc.	North Sydney - Port-aux-Belques	Conventional, RoRo	1	Possible		
Canada	British Columbia Ferry Corporation (BC Ferries)	Prince Rupert - Port Hardy Ferry	Conventional, RoRo	1	No	97 to 281	10.7 to 18.0
Caribbean	Compagnie Charron, L'Express Des Iles	Pointe-à-Pitre - Castries	High Speed, Passenger only	3	Yes	44 to 110	** no data **
Caribbean	Virgin Hydrooil Services, Inc.	Pointe-à-Pitre - Fort-de-France	High Speed, Passenger only	1	Possible	38 to 73	0.08 to 2.7
Caribbean	Virgin Hydrooil Services, Inc.	Charlotte Amalie - Christiansted	High Speed, Passenger only	1	Possible		
Caribbean	Virgin Hydrooil Services, Inc.	Charlotte Amalie - San Juan	High Speed, Passenger only	1	Possible		
Caribbean	Sea Link	Nassau - Abaco	Conventional, RoRo	1	Possible	61 to 119	** no data **
Caribbean	Sea Link	Nassau - Bahaia	Conventional, RoRo	1	No	87	** no data **
Caribbean	Sea Link	Nassau - Freeport	Conventional, RoRo	1	No		
Caribbean	Port Authority of Trinidad and Tobago	Port of Spain - Scarborough	Conventional, Passenger only	1	No	62 to 77	** no data **
Caribbean	Consolidated de Ferry (CONFERRY)	Curaçao - Margarita Island	High Speed & Conv., RoRo	2	No		
Caribbean	Consolidated de Ferry (CONFERRY)	Puerto La Cruz - Margarita Island	Conventional, RoRo	1	Possible	83 to 118	** no data **
Caribbean	Falcon Ferries Corporation	Puerto Fijo - Oranjestad	Conventional, RoRo	1	Possible		
Caribbean	Falcon Ferries Corporation	Puerto Fijo - Willemstad	Conventional, RoRo	1	Possible		
Mexico	Grupo Semar de California S.A. de C.V.	La Paz - Mazatlan	Conventional, RoRo	1	No	81 to 240	** no data **
Mexico	Grupo Semar de California S.A. de C.V.	La Paz - Topolobampo	Conventional, RoRo	1	No		
Mexico	Alzcarra-Hydroil	Santa Rosalita - Guaymas	Conventional, RoRo	1	No	43	** no data **
Mexico	Alzcarra-Hydroil	Cancun - Cozumel	High Speed, Passenger only	1	No		

(1) Except for the Great Lakes, where average annual wave height in feet is presented based on hindcast data from 1956 to 1987.

Asterisk indicates a route or route system that has been selected for further analysis as a case study ferry market.

Routes or route systems considered as possible case study candidates are highlighted in grey.

Table 8-2: Proposed New Routes - Potential North American Case Study Ferry Markets

Region	Operator / Sponsor	Names of Route(s)	Service Type	Number of Route Segments	Possible Case Study Candidate ?	Route Length (nmi)	Percent Time Wave Height > 10 feet (1)
Canada / United States United States	Lake Ontario Fast Ferry Corporation HydroPark / Milwaukee Port Authority	Toronto - Rochester * Milwaukee - Manhattan	High Speed, RoRo High Speed, RoRo	1 1	No Possible	88 78	Avg 1.0 to 2.1 feet Avg 2.8 to 3.1 feet
United States	SeeConn Flying Boats LLC	Black Rock, Bridgeport - E 34th Street Ferry Terminal Stamford - Financial Center Stamford - La Guardia Airport Black Rock, Bridgeport - Manhattan Black Rock, Bridgeport - La Guardia Airport New Haven - Financial Center Midtown Manhattan - La Guardia Airport	High Speed, Passenger only High Speed, Passenger only	1 1 1 1 1 1 1	No	41 to 70	1.7 or less
Canada	Governments of Canada, Nova Scotia and Prince Edward Island New Sea Escape Ltd.	Port Hood - Souris	Conventional, RoRo	1	No	81	** no data **
United States	Bay Ferries	* Miami - Key West * Honolulu, Oahu, HI - Maui, Maui, HI	High Speed, Passenger only High Speed, Passenger only	1 2	Yes Yes	165 49 to 84	1.2 to 3.8 7.2
Caribbean / United States	Bay Ferries	Miami - Nassau	High Speed, RoRo	1	No	178	3.6
Caribbean	Bahamas Fast Ferries Service Ltd.	Nassau - Governors Harbour Nassau - Harbour Island	High Speed, Passenger only High Speed, Passenger only	1 2	Possible	39 to 63	** no data **
Caribbean Caribbean	Autoridad Portuaria de Santo Domingo Cuba Ministry of Transport	Mayaguez - Santo Domingo Mexico - Cuba	Conventional (?), RoRo (?) High Speed, RoRo (?)	1 1	No No	165 255	** no data ** ** no data **

(1) Except for the Great Lakes, where average annual wave height in feet is presented based on hindcast data from 1956 to 1987.

* Asterisk indicates a route or route system that has been selected for further analysis as a case study ferry market.

□ Routes or route systems considered as possible case study candidates are highlighted in grey

As noted in the above tables, after the selection process was complete, a total of five common carrier passenger and/or vehicle ferry routes or route systems were selected for further analysis. Three of the five are existing routes or route systems:

- **Southeast Alaska:** conventional RoPax ferry service, provided by the state-run Alaska Marine Highway System (AMHS), serving multiple points between Bellingham, WA and Skagway, AK
- **Bay of Fundy (Saint John, NB - Digby, NS):** conventional RoPax ferry service, provided with a federal operating subsidy by the private sector operator Bay Ferries, Ltd., serving Saint John, New Brunswick, and Digby, Nova Scotia
- **Caribbean (Leeward and Windward Islands):** high speed passenger-only ferry service and limited high speed RoPax ferry service, provided by the private sector operator *L'Express des Iles*, serving the islands of Guadeloupe, Dominica, Martinique and Saint Lucia

The Caribbean case study could not be completed due to the lack of available economic and environmental data, although inferences concerning the likely outcome of this case study can be drawn from the other cases that were evaluated. In its place, the findings of an earlier 1995 Pacific Marine case study of possible SLICE service in the Hawaiian Islands are presented.

The remaining two case study routes are proposed new routes on which services are planned in the near future, and that have a high likelihood of actual implementation. These two include:

- **Lake Michigan (Milwaukee, WI - Muskegon, MI):** high speed RoPax ferry service, to be provided by the proposed private sector operator *HydroLink*, serving Milwaukee, Wisconsin and Muskegon, Michigan.
- **Florida Keys (Miami, FL - Key West, FL):** high speed RoPax ferry service, to be provided by the proposed private sector operator *Boomerang Fast Ferry*, serving Miami, Florida and Key West, Florida.

8.2 Case Study Approach

The technical and economic characteristics of each of the above five ferry markets are examined in detail in the subsequent five chapters of this report, with the existing or proposed baseline vessel types examined, as well as SLICE variants that may be suitable as an alternative vessel type in these particular markets. For each case study, the "baseline" refers to either the existing vessel or vessels and their current actual operating profile, or the vessels and operating profile proposed in present plans to institute new service.

Each case study represents a comparative analysis of alternative vessel types and specific operating scenarios, in common carrier ferry markets meant to be illustrative of those most likely to be suitable candidates for application of SLICE vessels. The primary elements considered for each case study analysis include the following:

- Introduction and Regional Overview
- Ferry Market Overview and Operational Profiles
- Existing and/or Proposed Vessels
- Related Infrastructure and Facilities
- Weather and Wave Climate

- Navigational Considerations
- Environmental Considerations
- Market Forecasts and Financial Analysis

In the remainder of this chapter, these elements are briefly reviewed in the order that they are addressed within each case study.

8.2.1 Introduction and Regional Overview

This brief introductory section is meant to acquaint the reader with the general character of the region, and to provide an overall context within which the subsequent technical and economic case study elements are considered. This is accomplished by describing the physical and political geography of the region, and providing general background information related to its economy and demographic characteristics.

8.2.2 Ferry Market Overview and Operational Profiles

This section reviews any currently existing ferry routes in the region, any ferry routes operated historically but no longer in service, and any proposed new ferry routes. For each service profiled, the location of the ports of call and the specific route segments served are described, as are the attributes of the operating schedule, including the seasons, days of the week, and times of day that service is or will be provided. The scheduled travel time, passenger and vehicle fares, and passenger and vehicle patronage levels are also noted for each route. For proposed services, reasonably conservative assumptions and inputs were utilized in evaluating vessel operating speeds and travel times, in the hopes of avoiding an overly optimistic assessment of possible operating conditions and financial performance. The existing or proposed baseline vessel types, as well as the most suitable SLICE variant, are briefly described, with detailed vessel particulars presented in a subsequent section of the case study outline.

8.2.3 Existing and Proposed Vessels

Detailed vessel particulars, some of which were presented earlier in Chapters 4 and 5, are briefly reviewed in this section. Existing vessels operating on the case study routes, proposed baseline vessel types and SLICE variants that may be suitable as an alternative vessel type in these particular markets are examined. For the proposed new ferry services reviewed for the Lake Michigan case study and the Miami - Key West case study, specific baseline vessel types were identified on the basis of information obtained from the proposed ferry operators.

8.2.4 Related Infrastructure and Facilities

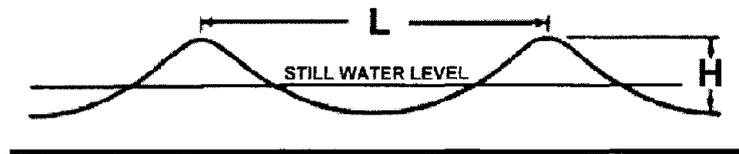
The specific location of ferry terminal facilities is identified here, and details regarding various physical characteristics are presented. Vessel berths are described (length, controlling depth alongside, freeboard height), and any applicable harbor regulations such as speed restrictions are noted. Controlling depths of channels are discussed in a subsequent section under navigational considerations. Sources of data here included contact with local port authorities, digital nautical charts, and information drawn from the U.S. Coast Pilot. Landside ferry terminal facilities are also described (parking, structures and buildings, facilities for the handling of passengers and/or vehicles, customs facilities, and landside ground access). Using this information, conclusions are made regarding the interface of SLICE or other high speed vessel types with existing terminal facilities, and whether infrastructure improvements may be required to suitably accommodate SLICE or other high speed vessel types and their passenger and vehicle payloads.

8.2.5 Weather and Wave Climate

In this section, meteorological conditions that could affect vessel operations are reviewed, and the nature and extent of possible weather hazards such as fog and ice are identified. In addition to weather, wave climate is also reviewed in detail. The vessel seakeeping analyses conducted by Seaspeed for the Volpe Center, discussed earlier in Chapters 4 and 5, indicate that SLICE vessels have superior ride quality when compared to the best existing vessels in sea states 3 and above. Given this important finding, in this section of each case study a rigorous quantitative analysis of wave climate was performed in order to address the question of whether historical wave climate conditions in each region afford SLICE adequate opportunity to provide superior ride quality.

Waves observed on the surface of a large body of water are caused principally by wind, although tide and currents can contribute somewhat to waves as well. The principal physical characteristics of waves include the *wave height* (the vertical distance between the trough and crest of a wave), the *wavelength* (the horizontal distance between successive crests) and the *wave period* (the time interval between the passing of successive crests at a stationary point). Note that the wave height is the vertical distance between the trough and crest, and not the

FIGURE 8-7: A TYPICAL SEA WAVE



vertical distance between the still water level and the crest (see Figure 8-7).

In reporting the visually observed "average" wave height, mariners generally tend to disregard many of the lower height waves and overestimate the height of larger waves when making their observations. Therefore, it has been found that the reported wave height value tends to be approximately equal to the average for the highest 1/3 of the waves observed. This value, the average of the highest 1/3 of waves, is referred to as the *significant wave height* (typically referred to with the notation H_{m0} or H_s) and is the wave characteristics of primary interest to the review of wave climate in this report. The approximate relationship between the significant wave

TABLE 8-3: RELATIONSHIP BETWEEN SIGNIFICANT WAVE HEIGHT AND OTHER WAVE HEIGHT MEASURES

Wave Height Measure	Relative Height
Average	0.64
Significant	1.00
Highest 10%	1.29
Highest	1.87

Source: National Imagery and Mapping Agency (NIMA). *The American Practical Navigator*. Pg. 446.

height and other wave height measures that are sometimes reported are presented in Table 8-3.

TABLE 8-4: SIGNIFICANT WAVE HEIGHTS AND CORRESPONDING SEA STATE CONDITION

Sea State	Significant Wave Height						Typical Mean Wind Speed (knots)
	meters			feet			
	Lower Bound	Average	Upper Bound	Lower Bound	Average	Upper Bound	
0-1	0.00	0.05	0.10	0.00	0.05	0.33	0 to 6
2	0.10	0.30	0.50	0.33	0.98	1.64	8.5
3	0.50	0.88	1.25	1.64	2.87	4.10	13.5
4	1.25	1.88	2.50	4.10	6.15	8.20	19.0
5	2.50	3.25	4.00	8.20	10.66	13.12	24.5
6	4.00	5.00	6.00	13.12	16.40	19.68	37.5
7	6.00	7.50	9.00	19.68	24.60	29.52	51.5
8	9.00	11.50	14.00	29.52	37.72	45.92	59.5
>8	>14	---	---	>45.92	---	---	>59.5

In Table 8-4, the various significant wave heights classifications and their corresponding sea state conditions are presented.

The primary sources of available wave height data suitable for research and operation applications include (1) observations made by ships in passage, (2) global satellite altimeter missions, (3) measured data obtained from buoys operated by various governments and marine research organizations, (4) and computer modeled hindcast data.

As noted earlier, ship-based observations can be of questionable accuracy, both because of the subjective nature of mariner observations, and because such ships tend to avoid bad weather when possible, thus biasing the wave height data toward more benign sea states. The wave height data utilized earlier for the case study route selection process was obtained from U.S. Coast Pilot meteorological tables, and are themselves based upon observations by ships in passage. For this reason, and because this data has a spatial resolution too low to be suitable for the more precise locations reviewed in the case studies, ship-based observations were not used for the case study wave climate analyses.

During the past decade, global satellite altimeter missions have included Geosat, ERS-1, ERS-2, and TOPEX / Poseidon. At present, the Topex/Poseidon, ERS-1 and ERS-2 satellites are still in operation (see Table 8-5). Some issues related to satellite altimeter wave height data include the available spatial resolution, which varies by mission, and can sometimes pose a problem if wave climate data is required at a local regional level of detail. Also, there are data quality problems in coastal areas. First, when making measurement in coastal areas, readings are distorted out to approximately 7 km from shore. Also, when the satellite is tracking from land to sea, often no data or erroneous data on wave heights is obtained for about 30 km from land.³⁴ For these reasons, and because of limited the limited availability and high cost of data that has undergone a suitable level of quality control, satellite altimeter wave height data were not used for the case study wave climate analyses.

With the above data sources eliminated from consideration, a combination of measured wave height data obtained from buoys and hindcast data obtained from computerized wave models were utilized for the case study

³⁴ Carter, D.J.T. "WAVSAT: Background. Marine Climate Information for Design and Operational Planning." Satellite Observing Systems (SOS), Surcy, United Kingdom. February 1997.

TABLE 8-5: OVERVIEW OF GLOBAL SATELLITE ALTIMETER MISSIONS

Satellite	Agency	Launched	Operating	Exact Repeat Period	Latitude Coverage / Direction of Travel	Altitude (km)	Separation (km) of Track Cross-Over Points at Equator
Geosat	U.S. Navy	March 1985	Nov. 1986 to Dec. 1989	17 days	72 deg. (westward)	800	163
GFO (Geosat Follow On)	U.S. Navy	Feb. 1998	1998 to present	17 days	72 deg. (westward)	800	163
Topex/Poseidon	U.S. NASA / French CNES	August 1992	Sept. 1992 to present	10 days	68 deg. (eastward)	1,336	315
ERS-1	European Space Agency	July 1991	April 1992 to Dec. 1993	35 days	81.5 deg. (westward)	785	78
ERS-2	European Space Agency	April 1995	April 1995 to present	35 days	81.5 deg. (westward)	785	78

Sources:

(1) Barstow, Steve, and Ola Haug. *World Wave Atlas: A PC MS-Windows Product for Wave Climate Assessment Globally*. OCEANOR. Norway.
 (2) U.S. Navy, Geosat Follow On Mission homepage, WWW URL at <http://gfo.bmpcoe.org/gfo/>.

wave climate analyses. The sources of measured buoy data that were utilized for the case study wave climate analyses include (1) National Oceanic and Atmospheric Administration (NOAA) buoy data, (2) Florida Coastal Data Network (FCDN) buoy data, (3) Scripps Institution of Oceanography (SIO) buoy data, and (4) Network for Engineering Monitoring of the Ocean (NEMO) buoy data.

The NOAA data sets contain data from a series of moored buoys operated by the NOAA National Buoy Data Center. Date, time, wind speed, significant wave height, wave period and wave direction data are contained in these data sets. Although additional NOAA data from Coastal Marine Automated Network (C-MAN) stations were also available, these stations did not contain wave height data measurements, and only the buoy data containing wave height information was utilized. The FCDN data is derived from a series of eight station locations along the coast of Florida that collected significant wave height and peak wave period data during the 1978 to 1994 time period. The SIO data is obtained from the Coastal Data Information Program (CDIP) at the Scripps Institution of Oceanography. The NEMO data are derived from a series of several stations that record date, time, significant wave height, wave period and wave direction.

The modeled hindcast wave height data sets that were utilized for the case study wave climate analyses included data from the U.S. Army Corps of Engineers, Wave Information Study (WIS). The original purpose of the WIS effort, begun about 20 years ago, was to develop hindcast wave climate data for U.S. coastlines to serve as input for the design of coastal structures, though most of the data cover both coastal and open water areas. WIS data are computer modeled wave height estimates developed using the WISWAVE model. The WISWAVE model is a second generation, directional spectral, time dependent model which can be used in both deep and shallow water. It is a peer reviewed, state-of-the-art model that is considered accurate to within +/- 0.3 meters in wave height when compared to measured data.

The WIS hindcast data have much better spatial resolution than any of the other data sources reviewed here including the measured data, and they represent a longer time series than the measured data sources. In general, the trade-off is that the measured data has poor spatial resolution and a limited time series, but high accuracy because of the use of actual measured wave height values. In contrast, modeled hindcast data has much improved spatial resolution and a more extensive time series, but are of somewhat lesser accuracy because they are estimated rather than actual wave height values.

All measured and hindcast data files were obtained from the Coastal Engineering Data Retrieval System (CEDRS) at the U.S. Army Corps of Engineers, Coastal Engineering Research Center. Because most of the measured and hindcast data sets contain frequently recorded data (in many cases hourly observations), and several stations were usually located in the vicinity of a given case study ferry route, each case study wave climate analysis was based on many thousands of observations, in some cases spanning a period of up to 20 years.

For each case study, both the measured and hindcast wave height data records were merged into a combined dataset. For each day of the year over the multi-year period being analyzed, the average, standard deviation, variance, minimum and maximum significant wave heights were calculated. Next, different sea states were defined according to their corresponding significant wave heights as presented earlier in Table 8-4. The probability of the occurrence of each state on any given day of a typical year, based on the observed historical time series, was then calculated. For each day of the year, it was assumed that observed wave heights were normally distributed, with a mean and standard deviation as observed in the dataset. In reality, the observed historical wave height distribution for each day conforms with a distribution that is truncated at zero (i.e., there are no negative wave heights, and the observed probability of a zero wave height or calm seas is not zero). The important issue here is that the use of a probabilistic analysis such as this, assuming any reasonable probability distribution, at least reflects the fact that, based on the observed data, higher wave height events do occur, albeit with a very low probability in most cases. Therefore, these high wave height observations are not inadvertently "averaged out" of the analysis as they might otherwise be if, for instance, one erroneously assigned entire days to a given sea state based on that day's average wave height observed over the past 20 years.

The final step was to develop a distribution of annual vessel operating hours by sea state category, based on actual or proposed ferry operating profiles in each case study market. An important distinction exists between (1) the distribution of hours during the year during which a particular sea state prevails, and (2) the distribution of annual *vessel operating hours* during which a particular sea state prevails. This distinction is an important one, since in the northern hemisphere, routes often operate more frequently during the summer, even in the Caribbean, due largely to seasonal variation in non-business ferry travel demand. Therefore, more benign summer sea states tend to be operated in more often, to the disadvantage of SLICE and its superior seakeeping ability.

Details regarding the specific data sources used, buoy and station locations, the specific time series availability for each location, and the characterization of the wave climate derived from the available data are reviewed separately in each case study analysis.

8.2.6 Navigational Considerations

Issues or potential problems related to the navigation of the different vessel types considered for each case study are reviewed in this section. One important item considered here, particularly with respect to SLICE, is the controlling depths of channels and berths, and the presence of any reefs, sandbars, shipwrecks and other submerged obstacles. These depths are generally noted in either feet, meters or fathoms, and at a given low water datum, typically "mean low water," although other low water datums are sometimes used.

The existence of any operating restrictions, such as vessel speed restrictions, or restricted operating areas that may be related to safety, environmental, or other reasons is also reviewed. Also considered are overhead clearances under bridges and cables, typically measured in feet or meters and at mean high water, and for a given vessel type under lightship conditions. Floating debris, other potential obstacles (e.g., lobster pots), ice conditions and the amount of other commercial vessel or recreational boating traffic are also reviewed.

Sources of information utilized here included an extensive set of up-to-date digital nautical charts and electronic charting software provided by Jeppesen Marine. Other sources include various volumes of the U.S. Coast Pilot, and various Sailing Directions publications for non-U.S. areas such as Canada and the Caribbean. Discussions with local U.S. Coast Guard district staff and port authority staff were also utilized.

8.2.7 Environmental Considerations

The potential for environmental impact resulting from ferry service provided by the different vessel types under consideration in each case study are reviewed in this section. Specific environmental impacts sometimes associated with ferry service include wake wash, impacts upon marine mammals and other marine life, noise and air quality issues. The primary environmental impacts focused on in the case studies are wake wash, as well as possible impacts upon marine mammals. Possible mitigating actions and their potential impact upon the vessel performance (e.g., speed restrictions) are noted where applicable.

Arguments are sometimes made that vessel generated wake wash can be a nuisance or risk to people on beaches, a source of coastal erosion, and pose a threat to small boats. The earlier review of vessel wake wash characteristics in Chapters 4 and 5 indicate that SLICE has superior performance relative to other vessel types. With regard to the possible impact of SLICE vessels upon marine mammals, various whale species are present in certain of the case study regions reviewed here. SLICE vessels, with their deep draft, could conceivably have a somewhat higher probability of striking a large marine mammal while underway, and with their use of propellers rather than water jets for propulsion, SLICE vessels could also inflict somewhat greater physical harm if such an impact were to occur. The particular whale species present in each case study region, and the times of year when they are most likely to be encountered, are reviewed in each case study.

8.2.8 Market Forecasts and Financial Analysis

This section, drawing in part upon the findings of the elements reviewed in previous portions of each case study, is the final and perhaps most important element of each case study analysis. For each vessel type under consideration, the existing or forecast passenger and vehicle travel demand on the case study ferry route is examined, with consideration given to changes in level of service parameters (e.g., travel time, frequency of service, ride quality, etc.) associated with the use each vessel type under each operating scenario. Then, for each vessel type, operating scenario, and passenger and vehicle demand level, a detailed review of the operating costs and revenues resulting from providing the corresponding level of service is performed. The commercial feasibility or ultimate success or failure of a particular ferry service is thus judged here on the basis of the economic performance of the ferry operator in providing the necessary level of service, while operating under the various technical and other constraints dictated by a particular vessel design, area of operation, or other exogenous environmental, legal or political constraints.

Travel Market Forecasts

Limited resources precluded the use of more advanced state-of-the-art travel forecasting methods for each case study analysis. Such methods include conducting consumer research studies to elicit information regarding traveler preferences for alternative modes of transportation (i.e., the development of “stated preference” data), and the use of disaggregate travel demand models based on discrete choice modeling techniques. These more advanced techniques for estimating patronage are often utilized in developing an “investment-grade” ridership forecast of the type typically required to secure private sector financing and/or government loan guarantees for a transportation project requiring significant investment. Where recent travel demand studies have been performed by public sector or private sector organizations in the case study regions and made available to the Volpe Center, these existing studies have, however, been utilized to the greatest extent possible in providing guidance for the development of patronage estimates for each case study analysis.

Ferry Travel Level of Service Measures and Travel Demand Elasticity

High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

For the three case studies where existing ferry routes are analyzed, observed historical ferry passenger and vehicle ridership data were used as the basis for estimating ferry ridership under different service conditions expected with an alternative vessel type such as SLICE or other high speed vessel. The primary level of service parameters considered in arriving at these scenario ridership estimates include (1) travel time, (2) fare levels, (3) frequency of service, (4) passenger ride quality resulting from vessel seakeeping performance, and (5) operational reliability resulting from vessel seakeeping performance. Travel time, fare levels, and frequency of service are significant because historically they have consistently proven to be those variables that most affect the demand for common carrier modes of travel, including ferry travel.³⁵ Passenger ride quality and operational reliability are also considered because of the superior seakeeping ability of SLICE vessels, and an interest in determining what if any impact this might have upon the demand for ferry travel in the case study markets.

Increases or decreases from the historically observed baseline ferry passenger and vehicle ridership resulting from a change in the travel time, fare and frequency of service parameters are quantitatively estimated utilizing the concept of *elasticity*. The *elasticity of demand*, in this case the demand for ferry travel, is an economic concept for measuring how much the quantity demanded (i.e., patronage) changes in response to changes in a given variable that affects demand (e.g., price, service quality, etc.).

Quantitatively, the elasticity of ferry travel demand with respect to a given level of service parameter, such as travel time or fare, represents *the percentage change in quantity demanded resulting from a 1% change in the level of service parameter under consideration*. For example, if the elasticity of ferry travel demand with respect to travel time is estimated to be -0.6, this value of -0.6 means that if travel time increased by 20%, then ferry ridership would decrease by 12%. If the absolute value of the elasticity measure is less than 1.0, then the demand for ferry travel is referred to as being "inelastic" with respect to the level of service parameter under consideration. Similarly, if the absolute value of the elasticity measure is greater than 1.0, then the demand for ferry travel is referred to as being "elastic" with respect to the level of service parameter under consideration. Finally, if the elasticity measure is equal to 1.0, then travel demand is said to be of "unitary elasticity."

To apply this approach in practice for the case study analyses, reasonable numerical estimates of the elasticity of ferry travel with respect to travel time, fare, and frequency of service were required. The elasticity measures that were used for the case studies in this report are based on estimates derived from actual ferry travel behavior observed in various markets that was either analyzed in previous demand studies of ferry travel, or calculated directly from observed changes in ferry travel demand in certain ferry route markets. For example, Table 8-6 presents elasticity estimates derived from a 1998 study of ferry travel on the Alaska Marine Highway System.

³⁵ A comprehensive compilation of approximately 150 documents and other information related to both urban and intercity travel demand forecasting methods can be found in the U.S. Department of Transportation, Bureau of Transportation Statistics CD-ROM product entitled "Travel Demand Forecasting: A Compilation of Transportation Plans, Reports and Data." BTS-CD-11. 1997.

On the ferry route between Bar Harbor, Maine and Yarmouth, Nova Scotia, fares for the 1998 season when the high speed RoPax vessel *The Cat* was introduced were kept at the same levels as the previous season when the conventional RoPax vessel *MV Bluenose* serviced this route. With fare levels remaining the same, and a total travel time reduced from 6 hours to 2 hours and 45 minutes, Bay Ferries reports that ridership during the 1998 season on *The Cat* approximately doubled over the previous year. It is estimated based on the number of vessel trips performed by *The Cat*, its capacity and an assumed average capacity utilization rate of 50% that as result of this decrease in travel time, patronage increased from approximately 95,500 annually to 191,000 annually. This suggests a demand elasticity with respect to travel time of about -0.89. Finally, a 1990 study of the Staten Island Ferry service estimated a ferry travel demand elasticity with respect to travel time of between -0.70 and -0.80.³⁶

Although derived from different sources, the elasticity estimates are generally consistent, and reveal that ferry patronage demand is inelastic with respect to these three level of service parameters, and that ferry passengers are most sensitive to changes in travel time, followed by fare and then frequency of service. On the basis of the above data, the ferry travel demand elasticities used for the case study analyses are as follows:

ferry travel demand elasticity with respect to travel time: -0.75
ferry travel demand elasticity with respect to fare: -0.61
ferry travel demand elasticity with respect to frequency of service: -0.26

In practice, when applying these elasticity estimates to the baseline observed ferry patronage levels, they are assumed to affect travel demand independent of each other. For example, if the baseline ferry ridership in a market is 100,000, and for a certain operating scenario travel time is assumed to be reduced by 20% and fares increased by 10%, then the resulting estimated of ferry ridership would be equal to:

Baseline ridership:	100,000
Change in baseline ridership resulting from reduced travel time:	+15,000
Change in baseline ridership resulting from increased fare:	- 6,100
Resulting scenario ridership:	108,900

Also, the level of service parameters for other modes of travel that may be possible substitutes for ferry travel on the route being analyzed (such other nearby ferry routes, auto, air, rail or bus travel modes) are assumed not to vary, that is, all else is assumed to be equal when the elasticity estimates noted above are applied to the baseline

TABLE 8-6: FERRY TRAVEL DEMAND ELASTICITIES

Level of Service Parameter	Trip Purpose						Average for all Trip Purposes
	Work	Shop	Medical	School	Rec/VRF	Personal Business / Other	
Travel Time	-0.80	-0.85	-0.95	-0.50	-0.40	-0.80	-0.72
Fare	-0.60	-0.95	-0.60	-0.50	-0.40	-0.60	-0.61
Frequency of Service ⁽¹⁾	-0.30	-0.30	-0.50	-0.08	-0.10	-0.30	-0.26

Source: State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 10: Existing and Future Demand for Inter-Community Travel in Southeast Alaska*. May 14, 1998. Appendix B.

(1) Frequency of service is expressed as the amount of time between vessel departures, not the number of vessel departures performed during a given period of time, thus the negative sign on the elasticity measure.

³⁶ Berkowitz, Carl. "Modeling Waterborne Transportation User Characteristics." *Transportation Research Record 1263*. 1990. Page 75.

ferry ridership to estimate the scenario ferry ridership.

As for possible changes in ferry ridership with respect to passenger ride quality and operational reliability, these two level of service parameters are also considered quantitatively, although using a different method because elasticity estimates for these service parameters were not available in the literature or from observed ferry operations. The weather and wave climate analyses conducted for each case study, in combination with the vessel seakeeping analyses in Chapter 5, provide the basis for determining whether there may be any change in these level of service parameters as a result of the introduction of SLICE vessels on a particular route. First, the seakeeping analysis from Chapter 5 is referred to for the relevant vessels types, or similar vessel types, being compared in the case study. The sea states in which each vessel type exceeds either the ISO 2631 2 hour criterion for motion sickness are determined from the vessel seakeeping analysis. Next, the percent of annual vessel operating hours during which these sea states are experienced is determined from the wave climate analysis presented in each case study. An estimate was made of the percentage of time in each sea state condition that the third octave center frequencies for which the vessel exceeds the ISO 2631 criteria are experienced. This results in an estimate of the percent of annual vessel operating hours during which the ISO 2631 criteria are exceeded for each vessel. As a simplifying assumption, this percentage is assumed to apply also to the number of one-way vessel departures performed annually in the baseline scenario, and baseline annual ridership, resulting in an estimate of the number of annual passenger trips during which ISO 2631 is exceeded in the baseline scenario.

The ISO 2631 limit represents the point at which it is likely that approximately 10% of passengers will experience motion sickness. This 10% figure is then applied to the earlier estimate of the number of annual passenger trips during which ISO 2631 is exceeded. The resulting amount of passenger boardings is added to the baseline ridership for the scenarios in which the SLICE 600 or SLICE 400 is utilized. As an example, assume that the baseline vessel is a 74 meter WPC, which exceeds the ISO 2631 limit in sea states 4 and above, and that the SLICE 600 does not exceed this limit up to sea state 6. Next, it was assumed a regional wave climate in which sea state 4 and above is experienced for 20% of annual vessel operating hours, and that the percentage of time in each sea state condition that the third octave center frequencies for which the vessel exceeds the ISO 2631 criteria are experienced is 50%. Therefore, based on this information, it can be estimated that the ISO 2631 criteria are exceeded during 10% of annual vessel operating hours, and since the ISO 2631 limit represents the point at which it is likely that approximately 10% of passengers will experience motion sickness, than approximately 1% of total baseline passengers will experience motion sickness. If estimated baseline patronage for the baseline vessel is 200,000 annually, then an additional 2,000 passengers annually is forecast for the SLICE 600.

Regarding possible impacts upon ridership from changes in operational reliability, if existing operations experience any missed trips or cancellations due to weather, it is assumed that with SLICE these trips would be able to operate. To reflect this, an amount of annual ridership equivalent to the number of missed trips experienced with the baseline vessel, at the average capacity utilization rate of the baseline vessel observed historically, is added to the SLICE scenarios.

A final note here is that despite the superior seakeeping ability of SLICE, passenger perceptions and preconceived notions regarding the usual relationship between poor weather conditions and the tendency for motion sickness may work against the ability of SLICE's superior performance to result in gains in ridership. For example, passengers may simply observe poor weather on a given day and decide not to travel for fear of poor ride quality on the ferry route. The superior ride quality of SLICE would need to be highlighted in advertising and marketing materials in order to minimize this from this occurrence.

For the two case studies where entirely new ferry services have been proposed, an approach similar to the one described above is utilized, where the only significant difference is the way of estimating the baseline ferry ridership is estimated. Because these are proposed rather than existing routes, there are no observed historical ferry ridership data to rely on. Instead, information regarding the proposed operating profile for the new route was obtained from the actual groups currently planning to implement service on these routes. Although these groups

did not agree to release detailed information concerning their marketing plans and patronage estimates, their proposed operating profile, including information such as the capacity of the baseline vessel types proposed, and the proposed operating schedule and frequency of service, was available in both cases. These operating profiles reveal in part a range of possible credible patronage estimates, assuming that they reflect what the proposed operators have determined to be a reasonable estimate of patronage. Therefore, at a minimum, possible patronage estimates can be bounded on the low end at zero, and at the high end at 100% of the capacity (seats, vehicle deck spaces) being supplied under the proposed operating schedule with the baseline vessel. Beyond this broad range, a reasonable baseline patronage level is assumed to be at a level that returns a reasonable profit to the operator, specifically at the point where a 15% return on required equity investment is earned on a discounted cash flow basis, with the baseline vessel under the baseline operating profile. The specifics of the financial analysis methods utilized for the case studies are discussed in the following section.

In addition to reviewing the currently proposed operating plans, ridership and levels of service on other travel modes serving the same market were also reviewed where data were available, in an attempt to independently verify the capacity and demand levels currently forecast by the proposed ferry operator. Where data were available, the review included travel in the same geographic market by auto, air, rail, bus, and in certain cases other ferry services serving nearby markets.

Previous experience with both newly implemented ferry services, as well as with the adoption of new travel modes in particular travel markets, suggests that a full "equilibrium" or "steady state" level of ridership is rarely ever achieved during the first full year of operation. On the basis of this information, it is expected that equilibrium levels of ridership would not occur until year 3 of any new ferry service in the Milwaukee - Muskegon and Miami - Key West markets. Specifically, the anticipated ridership "growth path" for these new services is assumed to have year 1 ridership equal to approximately 40% of the year 3 equilibrium ridership, and year 2 ridership equal to 87% of year 3 equilibrium ridership.

Financial Performance

The financial performance of the different vessel types and operating scenarios evaluated in the case study analyses is measured by calculating the rate of return on required equity investment over the project life cycle on a discounted cash flow (DCF) basis. The project life cycle refers here to the time period over which a new vessel is introduced and operated, which is based here largely upon a reasonable estimate of vessel service life of 25 years, the length of which is discussed in more detail in a subsequent section of this chapter. Even for government subsidized ferry services, minimizing the subsidy amount required to generate a positive return on equity investment is an appropriate measure of the economic performance of the ferry operator, even though the operation might not be considered a strictly commercial enterprise.

The income statement known as a *statement of cash flows* is used here as the basis for determining the return on equity investment on a discounted cash flow basis. A series of annual cash flow statements are estimated for every year of the project life cycle, under the various operating scenarios, using different vessel types and with the resulting different levels of ridership. The net cash flows before taxes (sometime referred to as the residual) for each year of the project are then compared to the required equity investment over the project life, all on a discounted basis. Required equity investment typically includes a portion of the vessel purchase price (i.e., the down payment), start-up expenses and provision of working capital for new routes, and any cash deficits experienced during the project life cycle. Start-up expenses and provision of working capital represent one-time costs associated with the start-up of a completely new service (e.g., marketing and advertising, accounting, legal, permitting, licensing, etc.). In this report, this cost category is applicable only to the Lake Michigan case study and the Miami - Key West case study. Based on the 1995 Pacific Marine *Hawaii Inter-Island Ferry Business Plan*, this cost is assumed to equal 11% of total year 3 (equilibrium patronage) passenger and vehicle revenues, including ancillary revenues, and is assumed to be provided from owner equity in year zero (before project start-up).

The stream of annual cash flows is then compared to the required equity investment on a discounted basis, resulting in the calculation of the project's internal rate of return (IRR). The internal rate of return is the discount rate or interest rate that equalizes the expected positive cash flows with the negative cash flows (equity investment) of the project. That scenario which yields the greatest internal rate of return provides the greatest return on required equity investment over the project life cycle, and is therefore considered superior in its economic performance to other scenarios with lesser internal rates of return.

In keeping with generally accepted principals and methods for the financial analysis of transportation business entities, total expenses (cash outflows) are classified into three mutually exclusive categories of *vessel debt repayment*, *direct operating costs* and *indirect operating costs*. Vessel debt repayment includes principal and interest payments on the portion of the vessel purchase price not funded by the equity investment of the owners. Direct operating costs are defined here as vessel direct operating costs, which are generally considered to include crew costs (in this case deck and engine crew only, excluding passenger service crew), fuel and lubricant costs, hull insurance, and vessel maintenance. Indirect operating costs are defined here as including items that are not included under the direct operating costs category, for example, passenger service crew costs, terminal related costs such as passenger facility charges and docking fees, marketing and advertising, and general administration.

In evaluating vessel attributes affecting operator financial performance (e.g., fuel consumption, vessel maintenance, vessel purchase price, etc.), data were obtained from the Technical Data Packages provided by Lockheed Marine Systems for the SLICE variants. For the other existing or proposed baseline vessels and comparative high speed vessel types, data were obtained from sources such as the current baseline vessel operators, other operators of similar vessels, vessel designers and shipyards, and Seaspeed, among others.

In evaluating the economic performance of a particular vessel type and operating scenario, operating and financial data obtained from various ferry operators, as well as from other ferry service feasibility studies, were used to develop plausible estimates of unit costs that were subsequently utilized in arriving at the estimated annual income statements for each case study. Wherever possible, estimates based on actual operating experience were utilized. Just a few of the many sources referred to for actual operating and financial data include the British Columbia Ferry Corporation (BC Ferries), the twenty-six ferry operator members of the American Public Transit Association (APTA) for report year 1997, and the thirteen ferry operators reporting data to the U.S. Federal Transit Administration National Transit Database (formerly known as Section 15 data) for report year 1997. Just a few of the many previously performed ferry service feasibility studies that were referred to include a 1992 study of potential ferry services in the New York City metropolitan area, a 1998 study of ferry service in San Juan, Puerto Rico, and the SLICE marketing studies performed by Nigel Gee and Associates, and Art Anderson Associates.

Certain cost elements, such as labor expense, and to a lesser extent vessel debt repayment, usually represent a disproportionately large share of total expenses, whereas certain indirect costs elements are quite modest and in some cases relatively insignificant relative to overall expenses. Therefore, when necessary priority was placed upon obtaining reasonable and accurate estimates for those cost elements that represent the largest share of overall operating costs, since it is here where any variation would result in the greatest relative changes in financial performance. Also, for many of the indirect cost categories, it is not clear that there is any basis for assuming that costs incurred for utilizing SLICE vessels would be substantially different from those of a ferry operation utilizing other either conventional or high speed vessel types.

The economic performance of a given vessel type and operating scenario is estimated both for the projected levels of passenger and vehicle patronage, as well as for a "break-even" level of patronage for the proposed operating schedule. The break-even level is defined here as the level of passenger and vehicle patronage required to achieve an internal rate of return of 15% at a particular fare level.

TABLE 8-7: DISCOUNTED CASH FLOW ANALYSIS EXPENSE AND REVENUE CATEGORIES

EXPENSES
Annual Vessel Debt Repayment
Annual Vessel Debt Repayment (combined principal and interest)
Direct Operating Costs
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)
Vessel Fuel and Lubricants
Vessel Maintenance Costs
Marine Hull Insurance
Indirect Operating Costs
Salaries, Wages and Benefits (Onboard Passenger Service Crew)
Marketing and Advertising
Reservations & Sales
Dockage Fees / Passenger Facility Charges / Shore Operations
Protection and Indemnity (P&I) Insurance
General Administration
Outside Professional Services
Onboard Food & Beverage Sales - Cost of Sales
Gift Shop - Cost of Sales
Onboard Gaming - Cost of Sales
REVENUES
Passenger Fares
Vehicle Fares
Ancillary Sales - Onboard Food & Beverage Sales
Ancillary Sales - Gift Shop Sales
Ancillary Sales - Onboard Gaming
Federal, State or Local Operating or Non-Operating Subsidy
NET CASH FLOW BEFORE TAXES
Net Cash Flow Before Taxes

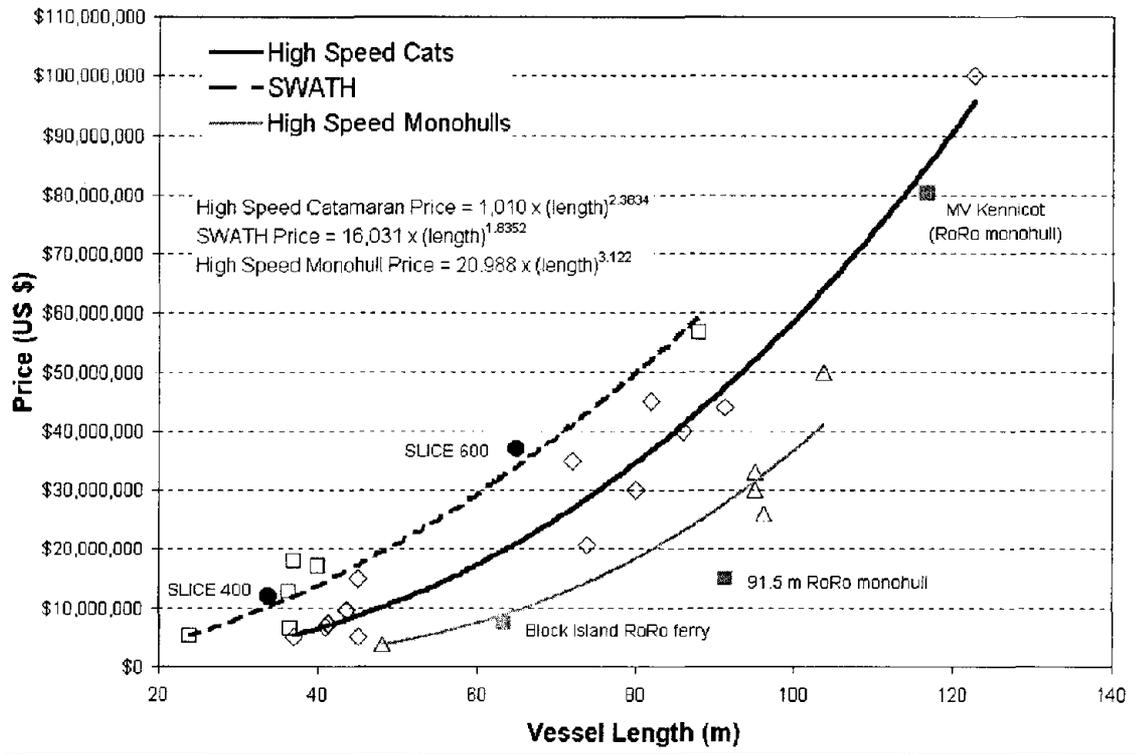
Table 8-7 presents the discounted cash flow analysis expense and revenue categories examined for each case study. The definition of each individual element of expense and revenue reviewed, and how each varies as a function of items such as vessel hours, number of passengers, or other factors, is presented in the remainder of this chapter.

Vessel Debt Repayment

Vessel debt repayment represents principal and interest payments on the portion of the vessel purchase price not funded by the equity investment of the owners. Leasing expense, for example under a bareboat charter arrangement, would be an alternative method of accounting for ownership expenses, and in some cases, leasing allows for the indirect realization of certain tax advantages. On some of the existing routes analyzed in the case studies, the current baseline vessels are 25 to 35 year old, and thus fully depreciated, such that ownership cost per se is virtually zero. However, in such cases maintenance and overhaul expenses are often higher than if a newer vessel were to be utilized.

Official purchase price estimates for the SLICE 400 and SLICE 600 variants have yet to be developed by Lockheed Marine Systems or any U.S. shipyards that may be licensed to produce these designs. In an attempt to arrive at reasonable purchase price estimates for the SLICE 400 and SLICE 600, the purchase prices for recently acquired vessels of varying types and capacities were analyzed. For three different high speed vessel types (catamaran, SWATH, and high speed monohull), separate relationships were estimated based on the observed data in which purchase price is a function of vessel length. The data and resulting purchase price model func-

FIGURE 8-8: VESSEL PURCHASE PRICE BY VESSEL TYPE AND LENGTH



tions are presented in Figure 8-8. Given that SLICE vessels are of a related design family to that of SWATH vessels, it is a reasonable hypothesis that the construction cost of SLICE vessels will be of a similar magnitude as SWATH vessels of similar size and capacity, with a slight upward adjustment to account for certain design differences, i.e., complexity and number of pods. Based on these findings, the purchase prices for the SLICE 400 and SLICE 600 have been estimated at \$12 million and \$37 million, respectively.

In industry practice, various vessel financing terms are possible, including various amortization schedules, loan terms, and interest rate amounts and types (fixed, variable, etc.). For vessels receiving a loan guarantee under the Title XI program of the U.S. Maritime Administration, a minimum ownership equity contribution (down payment) of 12.5% is required, and a level principal, rather than equal payment, amortization schedule is used in almost all cases. This results in larger payment amounts earlier in the loan term, when the interest component is the largest. A reasonable service life assumption for a large aluminum hulled RoPax catamaran is about 25 years. The first 74m Incat was delivered in June 1990, so longer term experience with large RoPax aluminum catamarans is relatively limited. A similar service life is assumed for the SLICE variants, which for the steel hulled SLICE 600 may be somewhat conservative.

To calculate the debt repayment expense in each of the case studies, an equal payment amortization schedule is assumed, with a required owner equity (down payment) of 20% of the purchase price, a loan term of 15 years, and a fixed interest rate of 10%.

Direct Operating Costs - Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)

The total crew complement required for the operation of each vessel is classified into the three functional categories of *deck crew*, *engine crew*, and *passenger service crew*, with the passenger service crew category reviewed later under indirect cost elements. For the purpose of assigning appropriate rates of compensation, both the deck crew and engine crew functional categories are assigned the further job classifications of either *officer* or *general crew*. Depending upon the vessel type and size, the deck crew labor category typically may include positions such as the captain, deck officers, navigator and other bridge crew, and deckhands. Similarly, the engine crew labor category typically may include a chief engineer, other engineering officers and engineering crew.

Hourly compensation rates by labor function and job classification represent the cost of salaries, wages and benefits (i.e., fully burdened rates). Total expense for this income statement category is therefore a function of the hourly compensation rate by job function and job classification, vessel operating hours or block hours, plus an additional amount of time equal to 25% of vessel operating hours, added to account for labor time required for vessel preparation and vessel turnaround activities.

The operation of ferry routes as "day boats" can contribute significantly to a reduced crew size, largely as a result of the lack of overnight accommodation services. For example, studies by the Alaska Marine Highway System have suggested that reductions of between one-half to two-thirds over existing crew sizes could be achieved with the use of high speed vessels and day boat operations in southeast Alaska.³⁷

The total crew complement for each vessel type analyzed was determined on the basis of the observed manning requirements of existing vessel types, the manning requirements reported by the proposed operators of new routes or services, and regulatory considerations under the U.S. Code of Federal Regulations and the Canada Shipping Act. Other sources of information included other ferry service feasibility studies, previous SLICE feasibility studies performed by Nigel Gee and Associates, Art Anderson Associates, and Pacific Marine, the SLICE Technical Data Packages obtained from Lockheed Marine Systems, and information obtained from vessel designers and shipyards. In Figure 8-9, observed crew complements for approximately forty vessels are presented, by vessel type and vessel passenger capacity. As mentioned earlier, note the relatively large crew complements for the Alaska Marine Highway System vessels, which often operate over long distances on overnight voyages, thus requiring additional crew.

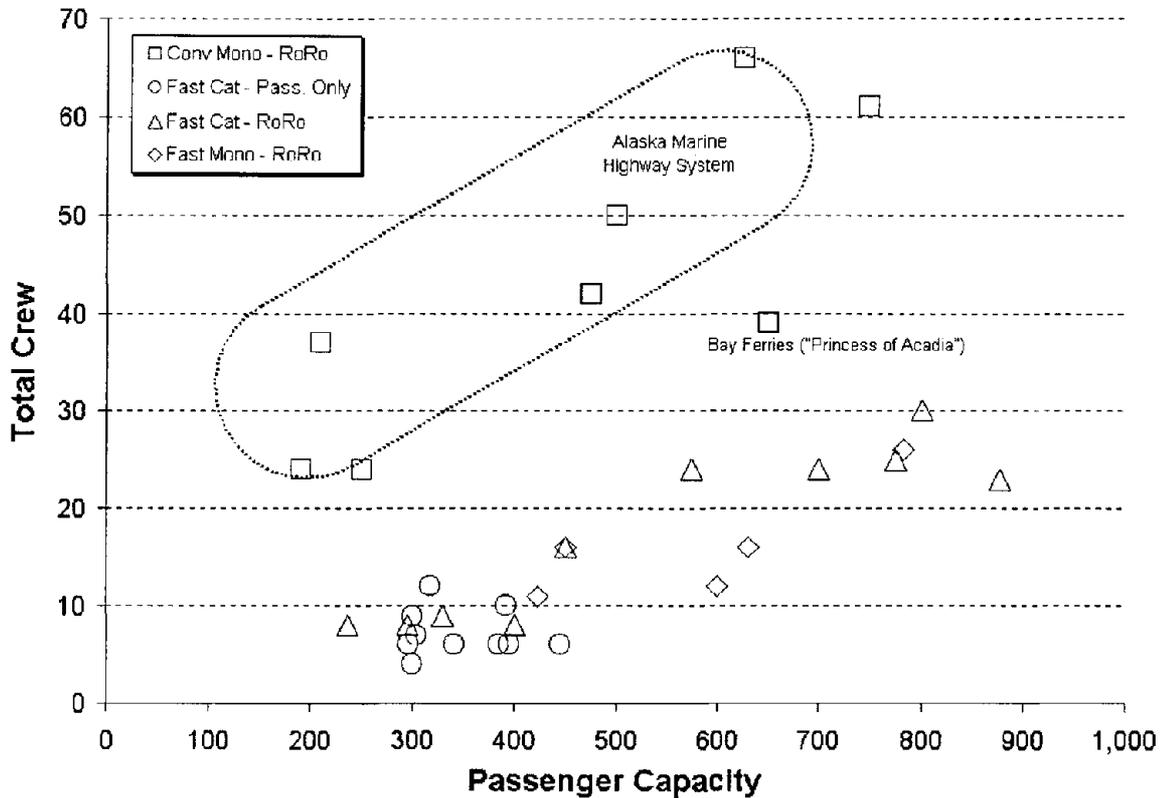
Direct Operating Costs - Vessel Fuel and Lubricants

Vessel fuel and lubricant expenses represent the capital, maintenance, and administrative costs associated with the provision of fuel and refueling services. For a specific vessel type, total annual fuel and lubricant expense is a function of total vessel hours by operating mode, fuel consumption rate by operating mode, and the unit fuel and lubricant cost. Fuel consumption at idle is accounted for by assuming that vessel hours at idle are equal to 15% of vessel operating hours or block hours.

Route profiles detailing the distance traveled and operating speed over each segment of a route for each vessel type were developed using the electronic charting software and digital nautical charts. Fuel consumption rates by vessel and by operating mode (e.g., service speed, intermediate speed, slow speed, idle, etc.) are based on detailed data obtained for both the existing and proposed baseline vessels, SLICE variants, and comparative high speed vessels. For example, for the Alaska Marine Highway System vessels, fuel consumption rates at service speed were obtained from Alaska Marine Highway System planning documents, with rates at other speeds estimated based on powering data and the specific fuel consumption of the various engine types. For the SLICE 400 and SLICE 600, fuel consumption rates and powering requirements at all vessel speeds were obtained from the Lockheed Technical Data Packages for each respective vessel design. For the proposed baseline high speed vessels proposed for the Lake Michigan and Florida Keys case studies, data from vessel designers, shipyards,

³⁷ State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 3: Potential Implications of Technological Improvements*. September 29, 1997. Page 12.

FIGURE 8-9: VESSEL CREW COMPLEMENT BY VESSEL TYPE AND CAPACITY



and current operators of similar vessels were obtained where possible, with other values estimated based on powering data and the specific fuel consumption of the various engine types.

There is a wide variety of commercially available diesel fuel oils. It is assumed that a suitable grade or type of diesel fuel as defined in ASTM Specification D 975 is used to power both diesel engine and gas turbine engine propulsion systems. During 1998, real dollar fuel costs in the U.S. were some of the lowest in recent history, however fuel prices have been on the increase throughout 1999. A unit price per gallon of \$1.00, including taxes, is assumed for the case studies, with local adjustments made to this overall price to account for significant regional variation in diesel fuel costs, with prices generally being higher in Canada, the Caribbean, and the West Coast of the U.S..

Based on discussion with shipyards and vessel operators, the quantity of lubricant consumed is assumed to be 0.4% of the quantity of fuel consumption, with the unit cost of lubricant assumed to be \$6.50 per gallon.

Direct Operating Costs - Vessel Maintenance Costs

Vessel maintenance expenses represent the cost of vessel hull and engine repairs and preventative maintenance, including periodic replacement of engines and related systems. Maintenance is assumed to be contracted to an outside service provider, with the maintenance expense representing all components of total maintenance cost, including labor, materials and parts, and burden (overhead).

In general, it is thought that maintenance for high speed vessels such as catamarans and SLICE is more preventative, more proactive, and done more frequently than for conventional vessels. Despite this, maintenance expense for the older conventional monohull vessels currently used by the Alaska Marine Highway System and by Bay Ferries on their St. John to Digby route may not necessarily be less than for a high speed vessel, due in large part to the age of these older vessels and the requirement for more frequent upgrades and overhauls.

Where possible, for baseline vessels on existing routes, observed values for vessel maintenance expense were used. For the high speed vessels proposed as the baseline vessels for the Lake Michigan and Florida Keys case studies, data were obtained on observed maintenance expenditures for similar vessels operating elsewhere, and maintenance cost estimates were in some cases provided by shipyards. For SLICE, maintenance cost values used in previous SLICE feasibility studies were reviewed, as were maintenance cost methodologies used in other ferry service feasibility studies. In order to refine these maintenance costs estimates, and provide estimates for vessels for which limited data was available, the existing data were reconciled and combined into the following maintenance cost estimation methodology.

In general, vessel operating hours on existing proposed routes were observed to range between 2,500 and 4,500 hours per year per vessel. Total annual maintenance expense per vessel is hypothesized to be partially dependent upon total vessel hours per year, especially for engine maintenance. Based on the observed data, total annual vessel maintenance expense is estimated to be equal to 3.5% of the purchase price of the vessel, for a vessel operating 3,000 hours annually. To account for variation in total annual maintenance expense resulting from different levels of annual vessel operating hours, the following formula is used to estimate total annual maintenance expenses for a vessel:

$$(0.021 * \text{vessel purchase price}) + [(0.014 * \text{vessel purchase price}) * (\text{annual vessel hours} / 3,000)]$$

In this formula, 60% of total maintenance expenses is essentially fixed, with the remainder varying as a function of total vessel hours, with nominal annual vessel hours assumed to be 3,000. For a vessel operated less than 3,000 hours annually, total maintenance expense is reduced somewhat, and above 3,000 hours, it is increased. Note that the resulting value for vessel maintenance, expressed as a per hour rate, may actually be *less* for higher operating hours, since although total maintenance expense increases, it increases at a slower rate than do total annual operating hours, resulting in somewhat lower hourly figures for maintenance.

Direct Operating Costs - Marine Hull Insurance

Hull insurance primarily represents property insurance coverage for the vessel and equipment, although it often includes collision liability coverage for damage to other vessels and their cargo as well. In determining insurance premiums, a variety of factors are usually taken into consideration. These include: (1) size of vessel, (2) age of vessel, (3) hull value, (4) area of navigation, (5) years of operating experience, (6) completion of USCG safety courses, and (7) extent of fire protection equipment on the vessel. Although high speed craft do not currently seem to have a substantially greater insurance risk than conventional vessels, some industry observers agree that the risk issues with high speed craft are different than with conventional vessels, and that the insurance underwriting market has yet to fully assess high speed craft for the potential risks that may be associated with them.³⁸

The hull insurance expense element is calculated here as a function of the new vessel purchase price. Estimates obtained from shipyards, existing ferry operators, and other ferry service feasibility studies suggest that annual marine hull insurance expense typically equals between 2% to 3% of the purchase price of the vessel being insured. A value of 2.5% of the vessel purchase price is used here as a reasonable estimate of annual hull insurance expense.

³⁸ *Fast Ferry International*. July-August 1997. Page 21.

Indirect Operating Costs - Salaries, Wages and Benefits (Onboard Passenger Service Crew)

As noted earlier, the total crew complement required for the operation of each vessel is classified into the three functional categories of *deck crew*, *engine crew*, and *passenger service crew*, with the deck crew and engine crew categories reviewed earlier under direct cost elements. Depending upon the vessel type, size, and typical voyage length, the passenger service crew category typically may include positions such as cabin attendants, pursers, and stewards. The operation of ferry routes as "day boats" can contribute significantly to a reduced crew size, largely as a result of the lack of overnight accommodation services. For example, studies by the Alaska Marine Highway System have suggested that reductions of between one-half to two-thirds over existing crew sizes could be achieved with the use of high speed vessels and day boat operations in southeast Alaska.³⁹

As with deck and engine crew, hourly compensation rates for passenger service crew represent the cost of salaries, wages and benefits (i.e., fully burdened rates). Total expense for this income statement category is therefore a function of the hourly compensation rate, vessel operating hours or block hours, plus an additional amount of time equal to 25% of vessel operating hours, added to account for labor time required for vessel preparation and vessel turnaround activities.

Indirect Operating Costs - Marketing and Advertising

This indirect cost category represents the production and distribution of marketing materials and costs associated with the purchase of print, radio, television or other media advertising. This category is of particular importance to new startup services (e.g., Florida and Michigan) in creating awareness and building ridership.

Based on previous SLICE feasibility studies, other ferry feasibility studies, and data from ferry operators, this expense category is assumed to vary as a function of total passenger and vehicle revenues, including ancillary revenues (and thus indirectly as a function of total ridership), and to be equal to 4% of these revenues.^{40,41}

Indirect Operating Costs - Reservations & Sales

This cost category includes labor costs of reservations and sales personal, and commissions costs, or direct charges arising from sales of passenger tickets.

Based on previous SLICE feasibility studies, other ferry feasibility studies, and data from ferry operators, this expense category is assumed to vary as a function of passenger and fare revenues (and thus indirectly as a function of total ridership), and to be equal to 3.5% of passenger and vehicle fare revenues.⁴²

Indirect Operating Costs - Dockage Fees / Passenger Facility Charges / Shore Operations

For ferry terminal facilities owned by the ferry operator (as is generally the case with the Alaska Marine Highway System), shore operations costs represent the direct and indirect costs to the ferry operator (terminal opera-

³⁹ State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 3: Potential Implications of Technological Improvements*. September 29, 1997. Page 12.

⁴⁰ The 1995 Pacific Marine Hawaii Inter-Island Ferry Business Plan assumes that this expense is equal to 6% of total revenues, or about \$2.73 per passenger under the operating scenario analyzed.

⁴¹ The 1995 Nigel Gee route studies use a fixed amount of \$250,000 annually for "Marketing" for SLICE 600 routes, and \$75,000 annually for SLICE 400 routes, both of which do not vary with the total number of passengers carried or total revenue earned. On a per passenger basis for the nine SLICE 600 routes studied by Gee, the equivalent per passenger expenditure ranged from between \$0.12 to just over \$5.00 per passenger, and averaged about \$1.00 per passenger. For the SLICE 400 routes, the equivalent per passenger expenditure ranged from between \$0.64 to \$1.62, and averaged \$1.13 per passenger. In terms of a percentage of revenues, these levels were about 1% to 1.5% on average.

⁴² As an example, for the fiscal year ended June 30, 1998, the Alaska Marine Highway System had a total "Reservations & Marketing" expense of \$2,142,000 on total ticket sales of \$29,659,000. Therefore, reservations & marketing expenses represents about 7.2% of total passenger and vehicle fare revenues. Because "Marketing & Advertising" is assumed to equal 4% of revenues, reservations expense alone is estimated to be 3.5% of passenger and vehicle fare revenues.

tor) of operating, manning (e.g., ticket sales, etc.), maintaining, insuring, and providing security for the terminal facilities. For example, for the Alaska Marine Highway System, Southeast operations, total expenses under the category of "Shore Operations" were \$2,916,000 for the fiscal year ended June 30, 1998. Alaska Southeast ridership during this period was approximately 300,000 passengers, yielding an average per passenger cost of approximately \$9.72 for ferry terminal operations. For the Bay Ferries St. John to Digby route, total per passenger expenses under the categories of "Terminal Operations" and "Terminal Maintenance" are of the same magnitude, having ranged between US\$9.50 and US\$13.80 per passenger boarding for the period 1989 to 1996.

For ferry terminal facilities owned by another party (a port authority, municipality, private entity, etc.), shore operations costs are typically reflected as a terminal usage fee, often assessed as a per passenger charge, and a vessel docking fee, often assessed per foot of vessel length. For example, although there is currently no fee structure for the use of municipally owned facilities in Key West Harbor by ferries, the fee structure for cruise ships includes a disembarkation fee of \$6.50 per passenger, plus an additional vessel docking fee of \$0.50 per foot of vessel length. On the Bay Ferries route from Miami to Nassau, in addition to the round trip adult fare of \$119, there is an additional \$20 charge resulting from U.S. and Bahamian departure taxes and passenger facility charges. Similarly, on the Bay Ferries route from Miami to Freeport, in addition to the \$99 round trip fare, there is an additional \$20 charge for similar reasons. Therefore, these passenger facility charges and related fees can range from between 14% to 17% of the total amount paid by a passenger on these two routes.

For each case study, the specific method of calculating total expenses for this cost category varies based on whether the shore facilities are owned by the ferry operator or not. In either case, these costs are assumed to vary as a function of total passenger boardings, with the specific per passenger charge used in each case study based on either actual observed data, or the existing or proposed fee structure for the use of terminal facilities on each route and for each port of call.

Indirect Operating Costs - Protection and Indemnity (P&I) Insurance

This expense category includes insurance against passenger liability, crew liability, and other liabilities (which often include liquor liability, pollution liability, premises liability and medical payments). P&I covers a wide range of liability exposures and miscellaneous expenses that a vessel owner might incur. Injuries to crew members and other persons on board the insured vessel are generally the most common claims. Coverage is typically provided for injury to persons aboard other vessels struck by the insured vessel, and for damage to property (other than vessels) struck by the insured vessel. Accidental pollution from the discharge of fuel oil or other similar substances is also often covered, unless due to negligence by the operator.

Based on previous SLICE feasibility studies, other ferry feasibility studies, and data obtained from ferry operators, this expense category is assumed to vary as a function of the number of passengers carried, and to be equal to \$0.30 per passenger boarding.⁴³

Indirect Operating Costs - General Administration

This expense category represents costs of a general corporate nature that are incurred in performing activities which contribute to more than a single operating function. Specific examples include leasing of office space, telephone & communications costs, office supplies, travel, and management and administrative personnel compensation and benefits.

Based on previous SLICE feasibility studies, other ferry feasibility studies, and data obtained from ferry operators, a minimum of \$500,000 annually is assumed for up to 60,000 annual passenger boardings, with an additional \$8.25 per person for every passenger boarding over 60,000 annually.⁴⁴

⁴³ For example, the 1995 Pacific Marine Hawaii case study assumed "non-marine insurance" (presumably P&I insurance) as ranging from between \$0.26 to \$0.39 per passenger, and the 1998 BC Ferries operating data shows that "Insurance, Taxes & Utilities" is equal to US\$0.27 per passenger boarding.

Indirect Operating Costs - Outside Professional Services

This expense category represents costs for outside professional service such as accounting, legal services, financial services and banking, and professional consulting. This cost is assumed to vary as a function of the total number of passengers, with the per passenger amount itself varying as a function of the total number of passengers according to the function:

$$\text{Per Passenger Outside Professional Services Expense} = 1.002098 - (0.01156 * \text{Millions of Annual Passengers})$$

and generally ranges from about \$1.00 per passenger down to about \$0.75 per passenger for very large scale ferry operators carrying in excess of 20 million passenger annually (e.g., BC Ferries or Washington State Ferries). For example, for annual passenger boardings of 4 million, the per passenger expense would be \$0.956, and the total annual expense would be \$3,824,000.⁴⁵

Indirect Operating Costs - Onboard Food & Beverage Sales - Cost of Sales

On most of the vessels and services reviewed in the case studies, it is assumed that ancillary revenues are earned from onboard food and beverage sales. This cost category represents the costs associated with the purchase of supplies and onboard food and beverage sales operations. Based on previous SLICE case studies and standard food service industry practice, it is assumed here that the cost of sales for onboard food and beverage sales is equal to 65% of onboard food and beverage revenues.

Indirect Operating Costs - Gift Shop Sales - Cost of Sales

On most of the vessels and services reviewed in the case studies, it is assumed that ancillary revenues are earned from onboard gift shop sales. This cost category represents the costs associated with the purchase of supplies and gift shop operations.

Generally, souvenir types of items and other "hardgoods" (e.g., key chains, mugs, etc.) typically retail at a markup equivalent to 100% to 150% of their wholesale cost (e.g., an item bought wholesale for \$2.00 retails for between \$4.00 and \$5.00, a markup of between \$2 to \$3). For "softgoods" (e.g., t-shirts, hats, etc.), the markup over wholesale is equivalent to 2.5 to 3 times the wholesale cost (e.g., a t-shirt bought wholesale for \$5 will retail for between \$17.50 and \$20.00, a markup of between \$12.50 and \$15.00). Overall then, the cost of goods ranges from between 25% up to 50% of the retail price, and most shops try to attain an overall average cost of goods of about 40% of retail sales. Based on this standard industry practice, it is assumed here that the cost of sales for gift shop sales is equal to 45% of gift shop sales revenues.

Indirect Operating Costs - Onboard Gaming - Cost of Sales

On some of the vessels and services reviewed in the case studies, it is assumed that ancillary revenues are earned from onboard gaming. This cost category represents the costs associated with the purchase of supplies and gaming operations. It is assumed here that the cost of for gaming operations is equal to 50% of gaming revenues. In practice, this would likely vary depending upon the number of staff required to man gaming tables (if any), or whether gaming was limited to electronic gaming machines only.

Revenues - Passenger Fares & Vehicle Fare

⁴⁴ Though previous SLICE feasibility studies have utilized values of about \$2.00 per passenger, actual experience with the Alaska Marine Highway System and with the Marine Atlantic Saint John - Digby route suggest a value of about \$8.25 per passenger for general administration expenses.

⁴⁵ The 1995 Pacific Marine Hawaii Inter-Island Ferry Business Plan assumes what equates to about \$1.00 per passenger (or \$0.0127 per passenger mile) for this cost category, with a total of 181,422 passengers carried. The 1998 operating data for BC Ferries yield a value of \$0.75 per passenger (or \$0.0384 per passenger mile) for this cost category, with a total of 21,799,000 passengers carried.

As noted earlier, the economic performance of a given vessel type and operating scenario is estimated both for the projected levels of passenger and vehicle patronage, as well as for a "break-even" level of patronage for the proposed operating schedule. Therefore, revenues are estimated for the projected levels of passenger and vehicle patronage, as well as for a "break-even" level of patronage for the proposed operating schedule. Passenger and vehicle fares are the primary source of revenue for all routes. Revenues from the sale of advertising space either onboard the vessel or in the ferry terminals is not considered here, since even in transportation operations where this practice tends to be widespread (e.g., bus and rail public transit), revenues received from advertising are only a small fraction of overall revenues.

For the three case studies where existing ferry routes are analyzed, existing passenger and vehicle fare levels were reviewed. On new ferry routes, the fare levels planned by the proposed operators were utilized as the baseline fare level. When analyzing the use of SLICE or other comparable high speed vessel types on the case study routes, these baseline fare levels were then increased or decreased appropriately to be consistent with the levels of service provided. This may not be the case in all instances, however. For example, when Bay Ferries, Ltd., introduced high speed RoRo catamaran serviced between Bar Harbor, Maine and Yarmouth, Nova Scotia during the summer of 1998, fare levels were kept the same as the previous 1997 season when the conventional RoRo vessel *MV Bluenose* operated on this route. As a result of the greatly improved level of service, patronage during the 1998 seasons approximately doubled over the previous year. Presumably, Bay Ferries considered this approach to be their profit maximizing or pre-tax net income maximizing approach.

Revenues - Ancillary Sales - Onboard Food & Beverage Sales

On most of the vessels and services reviewed in the case studies, it is assumed that ancillary revenues are earned from onboard food and beverage sales. This revenue category represents revenues from food and beverage sales, including bar sales of liquor if applicable, as well as vending machine revenues. This revenue category is assumed to vary as a function of total passenger boardings, with the revenue per passenger assumed at \$5.00.

Revenues - Ancillary Sales - Gift Shop Sales

On most of the vessels and services reviewed in the case studies, it is assumed that ancillary revenues are earned from onboard gift shop sales. This revenue category is assumed to vary as a function of total passenger boardings, with the revenue per passenger assumed at \$3.00.

Revenues - Ancillary Sales - Onboard Gaming

On some of the vessels and services reviewed in the case studies, it is assumed that ancillary revenues are earned from onboard gaming. First, whether or not gaming is legal on the particular ferry service in question must be considered. If legal, it is assumed here that 10% of passengers participate, with an average per person expenditure of \$25.

Revenues - Federal, State or Local Operating or Non-Operating Subsidy

For the Southeast Alaska and the Bay of Fundy case studies only, current federal, state or local operating subsidies provided for the existing baseline service were reviewed. As noted earlier, for government subsidized ferry services such as these, minimizing the total net cost (the difference between total revenues and total expenses), and thus the required subsidy, is an appropriate measure of the economic performance of the ferry operator even though the operation might not be considered a strictly commercial enterprise.

Net Cash Flow Before Taxes

High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

The net cash flow before taxes is the total revenues earned by the ferry operator, net of expenses and before taxes, and represents a summary measure of the financial performance of the operator under a given operating scenario for a particular year of the project period. Negative values for annual net cash flow before taxes are, by implication, considered here to be additional funds provided by the equity investors to cover these cash deficits.

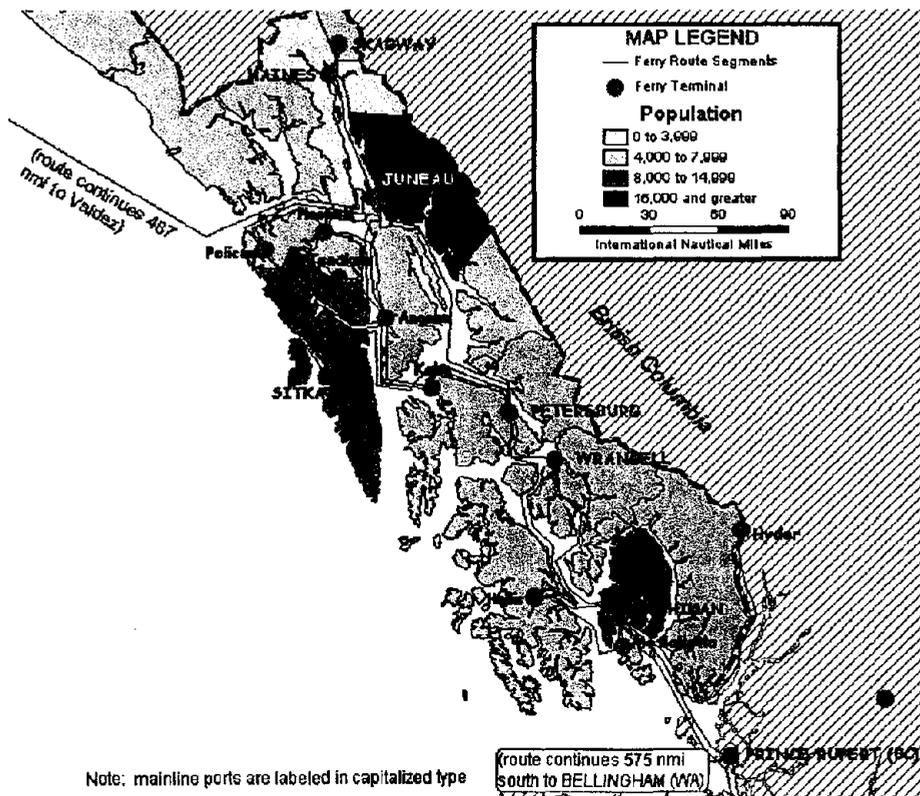
Chapter 9: Case Study #1 - Southeast Alaska

The ferry service reviewed in this case study is a system of existing conventional RoPax routes operated by the Alaska Marine Highway System (AMHS) in southeast Alaska. More than two dozen route segments receive service in southeast Alaska, with route lengths ranging from only 13 nautical miles (Haines - Skagway) up to 595 nautical miles (Bellingham, WA - Ketchikan). With baseline vessel service speeds of around 15 knots, typical travel times for these route segments vary from between 1 hour up to 36 hours. Almost all of the existing vessels in the AMHS fleet are in excess of 20 years old, with the one exception being the *MV Kennicott*, which was first introduced into service during the summer of 1998. The AMHS is also currently evaluating the possible future acquisition of high speed RoPax vessels in order to improve levels of service on its many routes.

9.1 Introduction and Regional Overview

The area reviewed for this case study extends from Prince Rupert, British Columbia north along the Pacific west coast and the panhandle of Alaska to Skagway, referred to here collectively as southeast Alaska (see Figure 9-1). Much of the area of the region is part of the Tongass National Forest. The panhandle of Alaska consists of a 30 mile wide strip of mainland, bordered to the west by an 80 mile wide chain of islands. Most of the islands

FIGURE 9-1: SOUTHEAST ALASKA POPULATION DISTRIBUTION (1997) AND EXISTING FERRY ROUTES



are mountainous, rough, broken, and are covered with dense growths of forest.

The state of Alaska has an estimated 1997 resident population of approximately 609,000 persons, with the southeast Alaska region comprising 74,370 of this total (see Table 9-1).⁴⁶ The southeast Alaska region, like the state as a whole, is sparsely populated overall, with the largest communities of Juneau (with a 1995 population of 28,757), Ketchikan (with a 1995 population of 14,543), and Sitka (with a 1995 population of 8,730) representing 71% of the total population of southeast Alaska. Statewide, average population density is 1.1 persons per square mile, the lowest in the United States.

TABLE 9-1: SOUTHEAST ALASKA POPULATION AND PROJECTIONS

County Name	Year			
	1990	1997	2002	2007
Juneau	26,751	29,934	32,177	34,384
Ketchikan Gateway	13,828	14,611	15,151	15,671
Sitka	8,588	8,564	8,533	8,490
Prince of Wales-Outer Ketchikan	6,278	7,234	7,910	8,577
Wrangell-Petersburg	7,042	7,046	7,031	7,010
Skagway-Yakutat-Angoon	4,385	4,798	5,088	5,372
Haines	2,117	2,183	2,226	2,267
<i>Southeast Alaska Region</i>	<i>68,989</i>	<i>74,370</i>	<i>78,116</i>	<i>81,771</i>
State of Alaska Total	550,043	609,000	653,965	697,797

Sources:

- (1) U.S. Department of Commerce, Bureau of the Census.
- (2) U.S. Census Block Groups with Estimates and Projections. Caliper Corporation, and Applied Geographic Solutions.

The principal natural resources of Alaska are oil, coal, timber, and fish, with timber and fish being those most prevalent in southeast Alaska. In the southeast, major sectors of the economy include forest products, tourism and the commercial fishing industries. Statewide, service related industries comprised more than 34% of total employment, followed by retail trade with 25%.⁴⁷

Although encompassing an area of nearly 37,000 square miles, southeast Alaska is served by only 500 miles of arterial roadways, due primarily to its rugged geography, which includes steep coastlines, various islands, and mountainous terrain. Within the southeast Alaska region, the only communities that are connected to the continental road system are Haines, Skagway, and Klukwan in the northern part of the region, and Hyder at the southeastern part of the region. Of these communities, all but Klukwan are directly served by the Alaska Marine Highway System. The state capital of Alaska, the City and Borough of Juneau, is the only state capital in the United States that is not connected by land transportation to the rest of its state. The general lack of road transportation infrastructure makes the region far more dependent upon air travel and travel by ferry than most other regions in the United States.

⁴⁶ U.S. Department of Commerce, Bureau of the Census.

⁴⁷ U.S. Department of Commerce. *1997 County Business Patterns for Alaska*.

9.2 Ferry Market Overview and Operational Profiles

Ferry service in southeast Alaska dates from 1948, when three residents of Haines purchased and modified a surplus 121 foot Navy landing craft vessel, named the *Chilkoot*, and then began RoPax service up Lynn Canal between Juneau, Haines and Skagway, with a capacity of 14 automobiles and 20 passengers. Coast Guard restrictions limited service to the summer season only. The Territory of Alaska purchased the ferry in 1951, and operated it until 1957, when the *MV Chilkat*, a 99 foot ferry with a capacity of 15 automobiles and 40 passengers, was purchased and put into service. When Alaska achieved statehood in 1959, the federal government transferred the *MV Chilkat* to the state, and one year later voters approved an \$18 million bond issue to finance the construction of three new vessels and several ferry terminals. In 1963, three new 352 foot sisterships, the *MV Malaspina*, *MV Matanuska* and *MV Taku* entered service from Prince Rupert to Skagway. Each vessel had a capacity of 500 passengers and 109 automobile equivalent units (AEU). Service with the new vessels proved successful, and in 1967 service was extended to Seattle, and by 1977, five more vessels joined the AMHS fleet. The *MV Bartlett* was placed into service in 1969 in Prince William Sound in southcentral Alaska. The *MV Columbia* was placed into service in 1974, and the *MV Malaspina* and *MV Matanuska* were lengthened to increase capacity in 1972. The sisterships *MV LeConte* and *MV Aurora* were placed into service in 1974 and 1977, respectively, to serve the smaller communities in southeast Alaska. The *MV Chilkat* was taken out of service and sold in 1990. After more than 20 years without the purchase of a new vessel, the *MV Kennicott* was acquired and placed into service in 1998, primarily serving southeast Alaska and allowing new service joining Juneau and Valdez across the Gulf of Alaska.

In addition to the historical Alaska Marine Highway System services described above, there was a high speed ferry demonstration project conducted in southeast Alaska during the summer of 1992.⁴⁸ Through a contract with the Alaska Department of Transportation and Public Facilities, the Boeing Company conducted a one month demonstration of its Jetfoil hydrofoil vessel from August to September 1982, the purpose of which was to enable the state to determine whether it should add such a vessel to its route system. A second demonstration was conducted during the winter of 1982-1983 to test cold weather operations. The trip from Seattle to Ketchikan in August, and the return trip in September, were made while the vessel was foilborne. Each trip took 17 hours, far less than the existing 36 hour trip time from Bellingham to Ketchikan.⁴⁹ In all, a total of 15,367 passengers were carried during the demonstration period. The vessel returned for another winter demonstration in January and February of 1983.

It was found that throughout the summer demonstration period, weather was not a factor, although fog was present at times and it was necessary to avoid ice from a nearby glacier. Considerable amounts of floating debris were encountered, and several log strikes were made, without any resulting damage to the vessel. An independent opinion research firm, Gilmore Research Group, conducted a detailed analysis of public reaction to the Jetfoil service for the state. The results of this analysis were presented in an October 1982 report, and indicated good public acceptance. The main findings were that 92% of the residents who used the Jetfoil service indicated that they would use the service if implemented, and 80% indicated that Jetfoil service resulting in shorter travel times and more frequent service. The primary disadvantage seen by potential riders was the likelihood of fares being increased over those of the conventional ferry services.

⁴⁸ *Existing and Former High Speed Waterborne Passenger Transportation Operations in the United States*. U.S. Department of Transportation, Urban Mass Transit Administration. August 1984. Report # UMTA-IT-32-001-84-3. Pages II.59 - 62.

⁴⁹ The AMHS ferry terminal location the state of Washington was moved from Seattle to Bellingham in 1989.

Current Southeast Alaska Ferry Services

Although the Alaska Marine Highway System provides almost all of the ferry service in southeast Alaska and is the focus of this case study, there are a limited number of smaller ferry operations that provide local service in some communities. In Ketchikan, the Ketchikan International Airport is located on Gravina Island across Tongass Narrows from the community of Ketchikan. The Transportation Services Department of the Ketchikan Gateway Borough operates a ferry operation for passengers and freight between the airport and Ketchikan, using two vessels, the *MV Ken Eichner*, and the *MV Bob Ellis*, which accommodate passengers and vehicles up to 80 feet in length. Between Haines and Skagway, a privately operated passenger-only water taxi service is provided by the Jacobson family with an aluminum catamaran, the *MV Sea Venture II*, which has a capacity of 80 persons and an operating speed of 18 knots. This service is seasonal only, operating between mid-May to mid-September, with two round trips daily. Another company, Chilkat Transportation, also operates between Haines and Skagway, using the *MV Fairweather*, a 115 foot monohull vessel with an operating speed of 15 knots.

The Alaska Marine Highway System currently serves 17 ports of call in southeast Alaska, as well as Prince Rupert, British Columbia and Bellingham, Washington (see Table 9-2). Seven of the nine vessels in the AMHS fleet service the southeast region. The southeast route system is divided into two subsystems: the mainline routes and the feeder routes. Mainline ports of call are noted in Table 9-2 by an asterisk, and in Figure 9-1 with all capitalized labels, and include Bellingham, Prince Rupert, Ketchikan, Wrangell, Petersburg, Sitka, Juneau, Haines, and Skagway. The mainline routes are primarily served by the *MV Columbia*, *MV Malaspina*, *MV Matanuska*, and the *MV Taku*. The *MV Kennicott* serves both the mainline routes as well as the inter-tie service across the Gulf of Alaska between Juneau and Valdez. The feeder routes connect the other panhandle communities with the mainline ports, which are regional centers in southeast Alaska for commerce, health care, government, or provide access to other transportation modes. The northern panhandle communities of Kake, Angoon,

**TABLE 9-2: AMHS
SOUTHEAST PORTS OF
CALL**

* Bellingham, WA
* Prince Rupert, BC
Hyder, AK / Stewart, BC
Metlakatla, AK
* Ketchikan, AK
Hollis, AK
* Wrangell, AK
* Petersburg, AK
Kake, AK
* Sitka, AK
Angoon, AK
Tenakee Springs, AK
Pelican, AK
Hoonah, AK
* Juneau / Auke Bay, AK
* Haines, AK
* Skagway, AK

* Mainline ports

TABLE 9-3: TYPICAL AMHS SAILING TIMES AND ROUTE DISTANCE BETWEEN SOUTHEAST ALASKA FERRY TERMINALS

Route Segment	Typical Sailing Time	Nautical Miles
Bellingham - Ketchikan	36 hours	595
Prince Rupert - Ketchikan	6 hours	91
Ketchikan - Wrangell	6 hours	89
Ketchikan - Hyder	11 hours, 15 minutes	143
Ketchikan - Metlakatla	1 hour, 15 minutes	16
Ketchikan - Hollis	2 hours, 45 minutes	40
Wrangell - Petersburg	3 hours	41
Wrangell - Hollis	6 hours, 30 minutes	100
Petersburg - Hollis	9 hours, 45 minutes	123
Petersburg - Sitka	10 hours	156
Petersburg - Kake	4 hours	65
Petersburg - Juneau/Auke Bay	7 hours, 45 minutes	123
Sitka - Ketchikan	18 hours	228
Sitka - Kake	8 hours	156
Sitka - Angoon	5 hours	67
Sitka - Juneau/Auke Bay	8 hours, 45 minutes	132
Sitka - Tenakee Springs	8 hours, 15 minutes	89
Sitka - Hoonah	9 hours, 45 minutes	118
Juneau/Auke Bay - Kake	28 hours, 15 minutes	114
Juneau/Auke Bay - Hoonah	3 hours, 15 minutes	48
Juneau/Auke Bay - Pelican	6 hours, 30 minutes	91
Juneau/Auke Bay - Haines	4 hours, 30 minutes	68
Juneau/Auke Bay - Skagway	5 hours	81
Haines - Skagway	1 hour	13
Kake - Angoon	4 hours	60
Angoon - Tenakee Springs	2 hours, 30 minutes	35
Angoon - Hoonah	4 hours	63
Tenakee Springs - Hoonah	3 hours, 15 minutes	49
Hoonah - Pelican	4 hours	64

Source:

State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 2: Existing Transportation Conditions and Travel Characteristics in SE Alaska. Final Memorandum.* Table 2, Page 13. June 3, 1997.

Tenakee Springs, Hoonah, and Pelican are served by the *MV LeConte*. The southern panhandle communities of Metlakatla, Hyder, and Hollis are served by the *MV Aurora*. Hollis and Kake also sometimes receive limited mainline service. Table 9-3 presents typical sailing times and distances on the mainline and feeder route segments served by the AMHS in southeast Alaska. Vessel operating speeds average approximately 15 knots for the existing AMHS fleet, and the resulting travel times on most route segments are very long, with almost all in excess of 2 hours, many between 3 hours and 10 hours, and the longest being 36 hours.

Historical passenger and vehicle boardings data for the southeast Alaska route system, the southwest Alaska route system (extending from Prince William Sound, west along the Aleutian Island chain to Dutch Harbor), and both systems combined are presented in Table 9-4. As can be seen from this table, the southeast system represents the vast majority of total passenger and vehicle ferry ridership in the state of Alaska as a whole, with 86% of total AMHS passenger boardings, and 84% of total AMHS vehicle boardings. This was one factor contributing to the selection of the southeast Alaska route system for this case study, rather than the southwest Alaska route system.

TABLE 9-4: AMHS HISTORICAL RIDERSHIP DATA (SOUTHEAST AND SOUTHWEST)

Year	AMHS Southeast		AMHS Southwest		AMHS Total	
	Passenger Boardings	Vehicle Boardings	Passenger Boardings	Vehicle Boardings	Passenger Boardings	Vehicle Boardings
1978	222,150	53,675	46,622	13,217	268,772	66,892
1979	244,678	58,196	49,375	13,858	294,053	72,054
1980	275,778	63,167	49,463	14,021	325,241	77,188
1981	281,632	65,641	55,779	15,058	337,411	80,699
1982	299,538	73,234	54,507	15,606	354,045	88,840
1983	307,782	75,445	55,520	15,911	363,302	91,356
1984	311,459	79,966	55,791	15,544	367,250	95,510
1985	313,147	79,757	56,282	16,509	369,429	96,266
1986	296,070	75,996	51,799	16,029	347,869	92,025
1987	326,644	83,451	52,047	16,524	378,691	99,975
1988	344,209	90,672	50,432	16,642	394,641	107,314
1989	344,389	89,793	44,202	15,743	388,591	105,536
1990	363,122	94,730	50,271	16,310	413,393	111,040
1991	368,780	95,173	36,248	12,860	405,028	108,033
1992	372,680	97,239	47,756	15,656	420,436	112,895
1993	342,613	92,598	48,678	15,696	391,291	108,294
1994	347,998	90,758	48,545	15,245	396,543	106,003
1995	332,712	88,942	45,373	15,031	378,085	103,973
1996	318,864	87,863	46,053	14,809	364,917	102,672
1997	300,653	82,451	49,450	15,878	350,103	96,329
1998	303,076	84,328	48,337	16,490	351,413	100,818

Source: Alaska Marine Highway System. 1998 Annual Traffic Volume Report. Page 7.

From 1978 through 1992 passenger traffic on the southeast system grew at an average annual rate of about 3.9% (see Figure 9-2). Vehicle traffic during this same period grew at an average annual rate of about 5.1%. From 1992 through 1997, however, passenger traffic has declined at an average annual rate of about 4% and vehicle traffic has declined at a rate of about 3%, with both apparently stabilizing in 1998.⁵⁰ The length of this decline in passenger and vehicle volume was the longest thus far in the history of the Alaska Marine Highway System. One factor that is thought to be contributing to this recent trend is the recent increase in cruise ship travel in the region that is likely taking a larger share of the tourist travel market. Since 1992, the volume of cruise ship passengers visiting Alaska has nearly doubled, increasing from 265,000 to an estimated 516,000 passengers in 1997.⁵¹ Major cruise ship ports of call in southeast Alaska include, in order of annual cruise ship passengers, Juneau, Ketchikan, Skagway, Sitka, Haines, Wrangell and Petersburg, all of which are mainline AMHS ports of call as well.

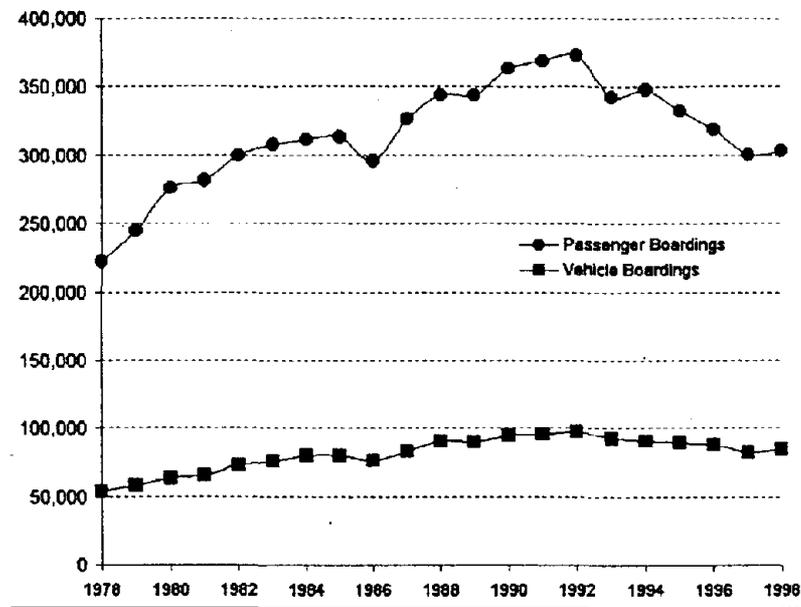
Although AMHS service is year round, there are two major seasons, with the Spring/Summer season extending from May through September, and the Fall/Winter season extending from October through April. Ridership is highly seasonal, due mainly to the large amount of tourists that visit Alaska during the summer months (see Table 9-5).

During the summer, the *MV Malaspina*, *MV Matanuska*, and *MV Taku* operate between Prince Rupert and Skagway, taking 4 days per round trip if a stop is made at Sitka, and 3 days if not. Service provided by the *MV Columbia* changes from year to year. It serves all of the mainline ports except Prince Rupert from the southern

⁵⁰ Care must be taken in comparing traffic data for 1997 and 1998. A fisherman's blockage of the *MV Malaspina* on July 19, 1997, resulted in a 138 day suspension of service to the Canadian port of Prince Rupert. Limited service was restored December 4, 1997, however the disruption had a significant impact on AMHS traffic for 1997.

⁵¹ State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 2: Existing Transportation Conditions and Travel Characteristics in SE Alaska. Final Memorandum.* June 3, 1997. Pg. 19.

FIGURE 9-2: AMHS SOUTHEAST - HISTORICAL RIDERSHIP DATA



terminus of Bellingham, taking one week per round trip. Each vessel stops at Sitka approximately once a week, and these vessels complete 7 round trips through the southeast region in the summer, stopping at each port approximately once each day in each direction. In the peak summer months, a mainline vessel does a double shuffle⁵² on Lynn Canal, and the *MV LeConte* stops at Haines and Skagway once or twice a week to supplement fleet capacity and also provides connections to smaller communities such as Angoon, Hoonah, Tenakee Springs and others.

During the winter months, the much reduced demand for service allows vessels to enter shipyards for scheduled maintenance or refurbishment. Either the *MV Matanuska* or the *MV Malaspina* operates from Bellingham as the *MV Columbia* is laid-up. The *MV LeConte* and *MV Aurora* operate on a reduced schedule, the one not undergoing maintenance operating in a winter panhandle route between Ketchikan, Metlakatla, Hollis, Petersburg, Kake, Sitka, Angoon, Tenakee Springs, Hoonah, and Juneau, requiring 5 days per round trip, and also services Pelican once a month. Due to low traffic volumes, Hyder is not served during the winter season. The *MV Taku* also provides service to Prince Rupert.

For 1997 as a whole, passenger capacity utilization on the AMHS southeast route segments averaged 29.3% of available passenger capacity, and vehicle capacity utilization averaged 47.1% of available vehicle capacity.⁵³ Between October and April, AMHS vessels typically operate well below capacity, however during the peak summer months, many vessels operate fully loaded and are sometimes unable to accommodate all requests for passenger and vehicle reservations and standby traffic.

⁵² During the mainline trip between Skagway and Prince Rupert, a vessel will complete an extra round trip between Skagway, Haines and Juneau as the schedule permits to accommodate travel demand in the Lynn Canal.

⁵³ Alaska Marine Highway System. *1997 Annual Traffic Volume Report*. Pages 61.-62. Total southeast system capacity utilization calculated from individual link volumes and link capacity utilization data. Detailed capacity utilization data and on/off traffic data were not yet available for calendar year 1998 at the time this analysis was conducted, therefore calendar year 1997 data have been utilized.

TABLE 9-5: AMHS SOUTHEAST 1998 RIDERSHIP DATA BY MONTH

Month	AMHS Southeast			
	Passenger Boardings		Vehicle Boardings	
	Number	Percent of Annual Total	Number	Percent of Annual Total
January	10,316	3.4%	3,168	3.8%
February	10,447	3.4%	3,219	3.8%
March	13,407	4.4%	4,110	4.9%
April	13,505	4.5%	4,652	5.5%
May	19,953	6.6%	6,171	7.3%
June	41,899	13.8%	11,118	13.2%
July	56,730	18.7%	14,269	16.9%
August	54,493	18.0%	13,463	16.0%
September	26,647	8.9%	8,143	9.7%
October	19,857	6.6%	6,087	7.2%
November	16,956	5.6%	4,994	5.9%
December	18,666	6.2%	4,934	5.9%
Summer Season ⁽¹⁾	199,922	66.0%	53,164	63.0%
Off-Season	103,154	34.0%	31,164	37.0%
Annual Total	303,076	100.0%	84,328	100.0%

Source: Alaska Marine Highway System. 1998 Annual Traffic Volume Report. Page 21.

Notes:

(1) Summer season is May 1 to September 30.

Detailed passenger ridership data for calendar year 1997 reveal that of the 85 route segments on which passengers were carried, the vast majority of route segments carried very few passengers, with only six heavily patronized route segments carrying more than half (54%) of all passengers in the AMHS southeast system (see Table 9-6). These six route segments include:

- Juneau - Haines
- Haines - Skagway
- Juneau - Skagway
- Juneau - Sitka
- Ketchikan - Hollis
- Metlakatla - Ketchikan

On these particular route segments, average annual passenger capacity utilization ranged from between 9.7% for the route segment between Metlakatla and Ketchikan, up to 41.7% for the route segment between Juneau and Haines.

The vast majority of the 80 route segments receiving vehicle ferry service have low vehicle patronage, with only five heavily patronized route segments carrying more than half (52%) of all vehicles in the AMHS southeast system (see Table 9-6). These five route segments include:

- Juneau - Haines
- Hollis - Ketchikan
- Skagway - Haines
- Juneau - Skagway
- Bellingham - Ketchikan

TABLE 9-7: AMHS SOUTHEAST 1999 ONE-WAY FARES

Adult One-Way Fare (Age 12 or older)

AMHS Ferry Terminal	AMHS Ferry Terminal															
	Bellingham	Prince Rupert	Hyder/Stewart	Ketchikan	Metakatta	Hollis	Wrangell	Petersburg	Kake	Sitka	Angoon	Hoonah	Juneau	Haines	Skagway	Pelican
Ketchikan	\$164	\$38	\$40													
Metakatta	\$168	\$32	\$44	\$14												
Hollis	\$178	\$52	\$54	\$20	\$22											
Wrangell	\$180	\$56	\$58	\$24	\$28	\$24										
Petersburg	\$192	\$68	\$70	\$38	\$42	\$38	\$18									
Kake	\$202	\$80	\$82	\$48	\$52	\$48	\$34	\$22								
Sitka	\$208	\$86	\$88	\$54	\$58	\$54	\$38	\$26	\$24							
Angoon	\$222	\$100	\$102	\$68	\$72	\$68	\$52	\$40	\$28	\$22						
Hoonah	\$226	\$104	\$106	\$74	\$78	\$74	\$56	\$44	\$38	\$24	\$20					
Juneau	\$226	\$104	\$106	\$74	\$78	\$74	\$56	\$44	\$44	\$26	\$24	\$20				
Haines	\$244	\$122	\$124	\$92	\$96	\$92	\$74	\$62	\$62	\$44	\$42	\$38	\$24			
Skagway	\$252	\$130	\$132	\$98	\$102	\$98	\$82	\$70	\$70	\$50	\$48	\$46	\$32	\$17		
Pelican	\$248	\$126	\$128	\$96	\$100	\$96	\$78	\$66	\$52	\$40	\$38	\$22	\$32	\$50	\$60	
Tenakee	\$226	\$104	\$106	\$74	\$78	\$74	\$56	\$44	\$32	\$22	\$16	\$16	\$22	\$38	\$46	\$32

One-Way Fare for Vehicles from 15 feet up to 19 feet in length

AMHS Ferry Terminal	AMHS Ferry Terminal														
	Bellingham	Prince Rupert	Hyder/Stewart	Ketchikan	Metakatta	Hollis	Wrangell	Petersburg	Kake	Sitka	Angoon	Hoonah	Juneau	Haines	Skagway
Ketchikan	\$445	\$90	\$90												
Metakatta	\$443	\$100	\$113	\$25											
Hollis	\$470	\$128	\$141	\$49	\$55										
Wrangell	\$482	\$139	\$153	\$61	\$73	\$61									
Petersburg	\$515	\$172	\$188	\$85	\$107	\$95	\$42								
Kake	\$548	\$207	\$223	\$130	\$141	\$130	\$83	\$52							
Sitka	\$563	\$223	\$238	\$145	\$157	\$145	\$96	\$63	\$58						
Angoon	\$602	\$261	\$277	\$184	\$196	\$184	\$138	\$103	\$71	\$49					
Hoonah	\$636	\$285	\$292	\$200	\$211	\$200	\$150	\$117	\$97	\$58	\$47				
Juneau	\$636	\$285	\$292	\$200	\$211	\$200	\$150	\$117	\$117	\$62	\$56	\$45			
Haines	\$687	\$336	\$342	\$249	\$261	\$249	\$199	\$165	\$165	\$112	\$108	\$95	\$57		
Skagway	\$707	\$356	\$362	\$269	\$282	\$269	\$220	\$168	\$168	\$132	\$127	\$116	\$78	\$31	
Pelican	\$679	\$339	\$354	\$261	\$271	\$261	\$210	\$175	\$136	\$103	\$95	\$56	\$83	\$135	\$156

Source: Alaska Marine Highway System. Alaska Marine Highway Schedule. 1999-2000 Fall/Winter-Spring. Page 26.

vehicle traffic (by vehicle type and dimensions). One-way fares for adults, and one-way fares for standard sized vehicles from 15 feet to 19 feet in length, are shown as a representative sample of these various fare schedules. Statewide, almost 74% of passengers on the AMHS were charged adult fares in 1998, with an additional 9% charged child fares. Standard sized automobiles and recreational vehicles of between 10 feet and 21 feet in length accounted for 77% of total vehicle boardings on AMHS vessels in 1998. Vans, defined by AMHS as vehicles from 12 feet to 13 feet in height, typically commercial, with enclosed cargo space, comprised 5% of total AMHS vehicle boardings in 1998.

In recent years, the cost to maintain and operate the AMHS ferry system has been rising faster than inflation, due largely to new regulatory requirements which require vessel upgrades and different levels of crewing, and labor contracts which dictate wages, benefits and operating conditions.⁵⁴ Capital costs for transportation are covered largely with federal funds (historically about 90% of capital project costs) and do not impact the operating budget of the state of Alaska to the same extent as operating expenses. However, increases in operating and

⁵⁴ Alaska Department of Transportation and Public Facilities. Division of Statewide Planning. Southeast Alaska Transportation Plan. March 1999. Page 8.

maintenance costs are especially important since these costs are financed with state funds. Since the Alaska State Constitution prohibits the dedication of funds for specific purposes, the Alaska Marine Highway System must compete for funds from the state general fund. The AMHS does operate within a "quasi-dedicated" fund in that it is authorized to retain all revenue, however this is subject to annual legislative approval.

AMHS revenues from fares and other sources cover only a portion of the full cost of operation and maintenance of the system, with the remaining costs provided from the state's general fund. For the fiscal year ended June 30, 1998, this shortfall totaled \$30.6 million (45% of total expenditures) for the entire AMHS system (see Table 9-8).⁵⁵ Taken separately, the southeast system performs somewhat better, with approximately 70% of operating costs recovered through fares and other revenues.⁵⁶ Because of declining state revenues, the Alaska State Legislature has called for significant reductions in funding for the AMHS operating budget and the level of state support required for the AMHS. Therefore, the financial performance of any AMHS routes using a different vessel such as SLICE or another comparative high speed vessel would likely be of paramount importance. The Transportation Equity Act for the 21st Century (TEA-21) federal legislation, enacted June 9, 1998, increases the level

TABLE 9-8: AMHS STATEMENT OF REVENUES AND EXPENDITURES (FISCAL YEAR ENDED JUNE 30, 1998)

Revenues	
Ticket Sales	\$29,659,000
Staterooms	\$3,832,000
Dining Room/Cafeteria Sales	\$2,652,000
Bar Sales	\$388,000
Gift Shop Sales	\$260,000
Vending Machine Sales	\$214,000
Video Game Commission	\$40,000
Pillow/Blanket Rental	\$10,000
Concession Fees	\$8,000
Facility Rental	\$15,000
Recovery of Expenses	(\$7,000)
Ketchikan Shipyard	\$300,000
Other	\$3,000
Total Revenues	\$37,374,000
Expenditures - Current Operating	
Support Services	\$1,895,000
Engineering Management	\$508,000
Overhaul	\$1,640,000
Vessel Operations Management	\$850,000
Reservations & Marketing	\$2,142,000
Southeast Shore Operations	\$2,916,000
Southeast Vessel Operations	\$48,066,000
Southwest Shore Operations	\$824,000
Southwest Vessel Operations	\$9,178,000
AMHS Improvement & Overhaul	\$8,000
Total Expenditures	\$68,027,000
Net Revenue (Loss)	
Net Revenue (Loss)	(\$30,653,000)

Source:
Alaska Marine Highway System. *Annual Financial Report*. Fiscal Year Ended
June 30, 1998. Page 2.

⁵⁵ Alaska Marine Highway. *Annual Financial Report*. Fiscal Year Ended June 30, 1998.

⁵⁶ Alaska Department of Transportation and Public Facilities. Division of Statewide Planning. *Southeast Alaska Transportation Plan*. March 1999. Page 64.

of funding for the state of Alaska over previous levels. The state of Alaska feels that this may provide an opportunity to use federal funds for strategic capital investments in transportation facilities in southeast Alaska that will reduce long term operating and maintenance costs for transportation in the region.

Proposed Changes to Southeast Alaska Ferry Services

In 1999, the Alaska Department of Transportation and Public Facilities published a detailed multi-modal transportation plan for the southeast Alaska region. This plan calls for the restructuring of the existing AMHS southeast route system from its current structure of conventional mainline and feeder services, to a two-tiered ferry system which will provide more frequent and higher speed ferry services both within and between four major travel corridors. These four zones include (1) Juneau-Haines-Skagway, (2) Juneau-Sitka-Petersburg, (3) Petersburg-Ketchikan, and (4) Ketchikan-Prince Rupert. The existing AMHS southeast route network currently links these four areas together with mainline ferry service from Prince Rupert to Skagway. Under the proposed plan, conventional mainline ferry service would continue, serving the demand for regional through service, and linking communities in southeast Alaska to each other and to areas outside of southeast Alaska. This would continue "one seat" through service as an overlay to the new regional and community routes. A combination of conventional vessels and new high speed vessels would provide semi-independent ferry service within the four zones with frequent regional service linking the four zones.

Four distinct levels of service are provided on ferry routes in the plan. These include (1) mainline service, (2) regional (zone) service, (3) community service, and (4) shuttle service. Mainline service will be operated on a 24 hour basis, similar to the existing mainline service, and would provide a one-seat ride from Bellingham to major terminals throughout southeast Alaska, terminating in either Juneau or Haines/Skagway. Regional zone service would be operated with both conventional and high speed RoPax vessels as dayboat service within a given zone, with service operated on an 8 or 16 hour daily schedule as seasonal demand warrants. Community service would consist of both dayboat service and 24 hour service using smaller existing vessels or new T-class vessels, which would require smaller crews and lower state operating support. Shuttle service would operate as dayboat RoPax service in a point-to-point route configuration, with vessels beginning and ending service days at the same terminal, which would allow crews to stay overnight at their home residences.

The plan anticipates the reuse of existing ferry vessels and terminals to the greatest extent possible, however some new routes and ferry terminals would be established in order to operate the new zoned service, with TEA-21 funds help to fund the acquisition of new vessels and the construction of new ferry terminals where necessary.

Southeast Alaska Route Segments Selected for Case Study Analysis

The Lynn Canal ferry service between Juneau and Haines/Skagway is selected here for further detailed case study analysis for a variety of reasons. First, because of the extensive number of individual route segments that currently receive some level of either passenger or vehicle service from the AMHS, it is beyond the scope of this analysis to study the AMHS southeast system in detail in its entirety. Also, as noted earlier, the vast majority of these routes experience relatively limited patronage throughout the year, and would likely be ill-suited for vessels having the capacity and high speed of those reviewed in this report. The existing route segments operated on Lynn Canal between Juneau - Haines and Haines - Skagway were, however, the two most heavily patronized in the entire AMHS ferry system in 1997.

Secondly, elsewhere in the southeast Alaska region, navigational difficulties related primarily to channel draft restrictions (e.g., Wrangell Narrows, Scrgius Narrows) pose significant operational difficulties, even in relation to the 17 foot draft of the existing AMHS mainline vessels. The much deeper 28.5 foot draft of the SLICE 600 would far exceed these physical restrictions found throughout many of the southeast route segments currently served by the AMHS. Depths along Lynn Canal are more than adequate even for the SLICE 600, although the controlling depths alongside at the existing ferry terminal berths at all three locations would be inadequate for

the SLICE 600. This is true of most other AMHS ferry terminals as well. Finally, the possible use of high speed RoPax vessels on Lynn Canal is consistent with plans for improved ferry service reviewed in both the recently published *Southeast Alaska Transportation Plan* and the *Juneau Access DEIS*, and with previous studies of high speed ferry service in southeast Alaska such as that conducted in June 1995 by Art Anderson Associates.⁵⁷

9.3 Existing and Proposed Vessels

The existing RoPax ferry service on the AMHS southeast routes is provided by seven of the nine conventional monohull RoPax vessels that make up the AMHS fleet. Vessel particulars for these seven existing baseline vessels are presented in Table 9-9. The SLICE 600 is selected as the primary SLICE variant for this case study, primarily because it is a RoPax design, and is of a generally similar passenger and vehicle capacity as the baseline and comparative high speed vessels. Finally, a 78 meter Incat RoPax high speed wave piercing catamaran is selected as a comparative high speed vessel type. Vessel particulars for the Incat 78 meter WPC and the SLICE 600 are presented in Table 9-10.

Existing Baseline Vessels

Because of the relative protection afforded by the Inside Passage, and the service history of the AMHS in southeast Alaska, all AMHS southeast vessels are certified for service on lakes, bays, and sounds by the U.S. Coast Guard. Also, mainline vessels must meet the international SOLAS (Safety of Life at Sea) requirements. The newest addition to the AMHS fleet is the MV Kennicott, which was introduced into service during the summer of 1998, and is ocean certified, which allowed the AMHS to introduce a new "Inter-Tie" service, connecting the southeast and southwest systems between Juneau and Valdez. Loaded drafts of the existing vessels range from between 13.9 feet up to 17.6 feet, and service speeds range from between 14.5 to 17.3 knots. None of the AMHS vessels are equipped with motion dampening systems, and are sometimes forced to take refuge from heavy weather, or make several tacks across the trackline to prevent excessive rolling. Passenger amenities on-board these vessels generally include food service, gift shop, observation lounges and solariums, and all but the MV LeConte and MV Aurora, private passenger cabins.

The generally long route segment travel times and the provision of overnight accommodations on most of the existing vessels results in larger crew sizes than would otherwise be necessary. The operation of ferry routes as "day boats" can contribute significantly to a reduced crew size, largely as a result of the lack of overnight accommodation services. Studies by the Alaska Marine Highway System suggest that reductions of between one-half to two-thirds over existing crew sizes could be achieved with the use of high speed vessels and day boat operations in southeast Alaska.⁵⁸

All of the existing vessels in the AMHS fleet are in excess of 20 years old, with the exception of the *MV Kennicott*. Total cost for this vessel was \$81 million, with an additional \$5.3 million in general program costs. Approximately \$65 million of the total cost was provided by the Federal Highway Administration from Federal Aid Highway funds under the Innovative Financing Program and Special Experimental Program No. 14. The remainder of the project costs provided by the State of Alaska as federal aid matching funds, Alaska Marine Highway System ferry system discretionary funds, and from the Alaska Department of Environmental Conservation. The *MV Kennicott* was designed to satisfy diverse missions, including (1) to operate as a mainline ferry from Bellingham and Prince Rupert to Skagway, with the ability to transit Wrangell Narrows and Sergius Narrows, (2) substitute for the *MV Tustumena* on the AMHS southwest routes, (3) establish a new service transiting the Gulf of Alaska and connecting the AMHS southeast and southwest service areas, and (4) serve as a logistics,

⁵⁷ Art Anderson Associates. *Study of Marketing Possibilities for Two Variants of the SLICE Design*. June 1995. Pages 4-7.

⁵⁸ State of Alaska Department of Transportation and Facilities. *Technical Memorandum 3: Potential Implications of Technological Improvements*. September 29, 1997. Page 12.

TABLE 9-9: SOUTHEAST ALASKA CASE STUDY - BASELINE VESSEL PARTICULARS

Particulars	Vessel Name						
	MV Columbia	MV Malaspina	MV Matanuska	MV Taku	MV LeConte	MV Aurora	MV Kennicott
Vessel Builder	Lockheed Shipbuilding	Lockheed Shipbuilding	Puget Sound Bridge & Drydock Co.	Puget Sound Bridge & Drydock Co.	Peterson Shipbuilders	Peterson Shipbuilders	Halter Marine
Vessel Type	RoPax	RoPax	RoPax	RoPax	RoPax	RoPax	RoPax
Hull Construction	Steel	Steel	Steel	Steel	Steel	Steel	Steel
Year Entered Service	1974	1963	1963	1963	1974	1977	1998
Original Purchase Price ⁽¹⁾	\$22,000,000	\$5,000,000	\$5,000,000	\$5,000,000	\$5,600,000	\$7,700,000	\$81,000,000
Annual Maintenance Cost ⁽²⁾	\$1,402,366	\$1,446,947	\$1,371,787	\$1,429,283	\$1,446,148	\$1,368,548	\$900,000
Principal Dimensions (feet)							
Length Overall	418.0	408.0	408.0	352.0	235.0	235.0	382.0
Beam Overall	85.0	74.0	74.0	74.0	57.0	57.0	85.0
Full Load Draft	17.6	17.0	17.0	16.9	13.9	13.9	17.5
Vehicle Deck Freeboard (max.) ⁽³⁾	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Capacities							
Passenger Capacity	625	500	500	450	250	250	748
Vehicle Capacity (AEU) ⁽⁴⁾	134	88	88	69	34	34	120
Maximum No. of Tractor Trailers	16	18	11	2	13	10	20
Vessel Manning							
Deck Crew Officers	8	6	6	5	3	3	7
General Deck Crew	15	11	11	10	5	5	13
Engineering Officers	5	4	4	3	2	2	4
Engine Crew	9	7	7	6	3	3	8
Onboard Passenger Service	29	22	22	18	11	11	24
Total Crew Complement	66	50	50	42	24	24	56
Weights (long tons)							
Displacement	3,946	2,928	3,029	2,458	1,328	1,281	6,757
Total Deadweight ⁽⁵⁾	134.0	94.6	88.4	72.3	42.0	42.0	178.5
Propulsion							
Total Installed Horsepower	12,350	8,000	7,200	8,000	4,300	4,300	13,380
Service Speed (knots)	17.3	16.5	16.5	16.5	14.5	14.5	16.8
Fuel Consumption (gallons per hour at indicated speed)							
GPH at service speed	400	270	240	215	250	250	290
GPH at 10.0 knots	167	120	106	95	132	132	126
GPH at 7.0 knots	125	89	79	71	98	98	94
GPH at 3.5 knots	76	53	47	42	52	52	56
GPH at idle	60	41	36	32	38	38	44
Service Route							
Service Route	Southeast Alaska Mainline	Southeast Alaska Mainline	Southeast Alaska Mainline	Southeast Alaska Mainline	Northern Panhandle Feeder	Southern Panhandle Feeder	Southeast Alaska Mainline & Trans Gulf

Sources:
 (1) Current (then-year) dollars. State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 2: Existing Transportation Conditions and Travel Characteristics in SE Alaska*, June 1997, Page 11.
 (2) Includes labor and materials expense for the annual "six-week" overhaul, as well as expenses for major upgrades that each vessel undergoes approximately every three years.
 (3) In Southeast Alaska, maximum vessel freeboard height at the main vehicle deck is 8 feet.
 (4) Automobile equivalent unit (AEU), typically a minimum of a 17' x 8.5' space on the vehicle deck.
 (5) U.S. Army Corps of Engineers, *Waterborne Transportation Lines of the United States, Vessel File*, data for the full load capacity of the vessel, transformed here from short tons to long tons.

communications, and command center for emergency responses to oil spills and natural disasters. General arrangements for the MV Kennicott are presented in Figure 9-3.

Alternative High Speed Vessels

In studying various options for improved road and/or ferry access to Juneau, the state of Alaska has reviewed the possible use of a high speed wave piercing RoPax catamaran to service the route between Juneau and Haines/Skagway along the Lynn Canal.⁵⁹ Also, during 1999, requests for proposals (RFPs) were let by AMHS for two upcoming studies. The first study is the *Vessel Suitability Study*, which is to review vessel requirements and vessel types suitable for a redesigned ferry network in southeast Alaska. The second study is the *Fast Vehicle Ferry Study*, which is to review different high speed vessel designs and determine which is best suited for

⁵⁹ Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997.

service in Alaska. Both studies are not anticipated to be completed until late 2000. By the end of the year 2000, Alaska hopes to put out a design and build contract for the selected high speed vessel design, and hopes to place the vessel into service by late 2002.

TABLE 9-10: SOUTHEAST ALASKA CASE STUDY - HIGH SPEED VESSEL PARTICULARS

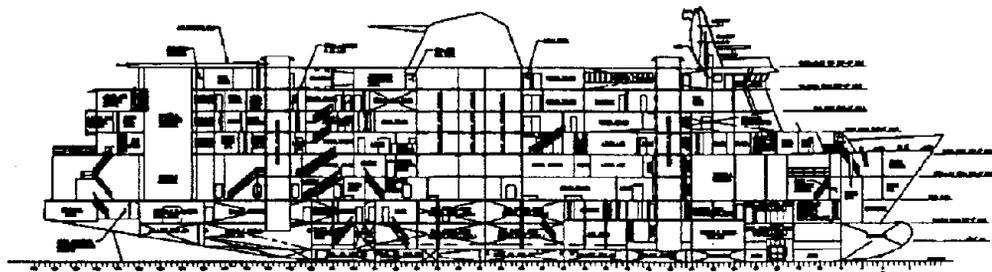
Particulars	SLICE Variant	Comparative High Speed RoPax Vessel
	SLICE 600 ⁽¹⁾	Incat 78m ⁽²⁾
Vessel Designer	Lockheed Marine Systems	Incat
Vessel Type	RoPax	RoPax
Hull Construction	Steel	Aluminum
Purchase Price (1997 US\$)	\$37,000,000	\$32,000,000
Annual Maintenance Cost ⁽³⁾	\$1,295,000	\$1,120,000
Principal Dimensions (feet)		
Length Overall	213.2	254.0
Beam Overall	105.0	85.3
Full Load Draft	28.5	11.5
Main Passenger Deck Freeboard	31.0	data not available
Vehicle Deck Freeboard	21.5	data not available
Capacities		
Passenger Capacity	600	600
Vehicle Capacity (AEU) ⁽⁴⁾	90	150
Fuel Capacity (gallons)	39,087	9,858
Vessel Manning		
Deck Crew Officers	2	2
General Deck Crew	5	5
Engineering Officers	2	2
Engine Crew	3	3
Onboard Passenger Service	8	10
Total Crew Complement	20	22
Weights (long tons)		
Payload	177.9	207.5
Total Deadweight	355.0	252.0
Displacement	1,500.0	865.0
Propulsion		
Main Engines	(2) RLM1600 gas turbines or equivalent	(4) Ruston 16 RK270 marine diesel engines
Total Installed Horsepower	36,000	23,494
Service Speed (knots)	30	34
Range at Service Speed (nmi)	620	370
Fuel Consumption (gallons per hour at indicated speed)		
GPH at service speed	1,891	898
GPH at 30.0 knots	1,891	804
GPH at 15.0 knots	1,757	310
GPH at 7.0 knots	484	176
GPH at 3.5 knots	450	144
GPH at idle	284	135

Sources:

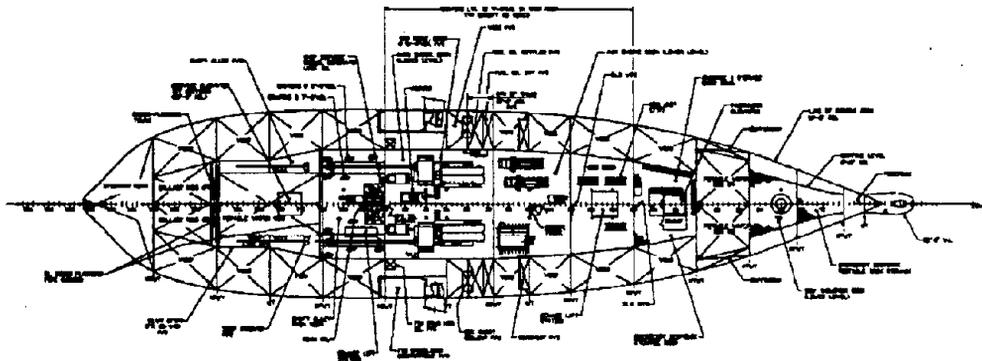
- (1) Lockheed Marine Systems. SLICE 600 Passenger Vehicle Ferry. Technical Data Package. April 1995.
- (2) Incat Designs. Also, *Jane's High-Speed Marine Transportation 1998-1999*. Also, Volvo Center estimates for some data elements, as per discussion in Chapter 8.
- (3) For a nominal vessel operating hours of 3,000 annually.
- (4) Automobile equivalent unit (AEU), typically a minimum of a 17' x 8.5' space on the vehicle deck.

FIGURE 9-3: MV KENNICOTT GENERAL ARRANGEMENTS

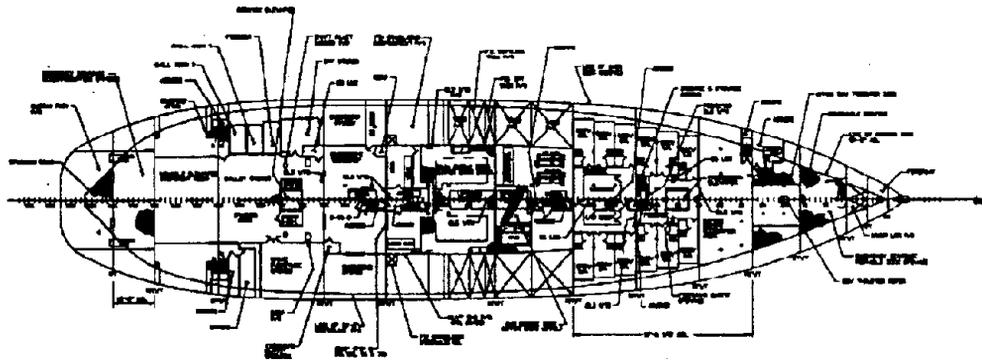
MV KENNICOTT: INBOARD PROFILE



MV KENNICOTT: HOLD



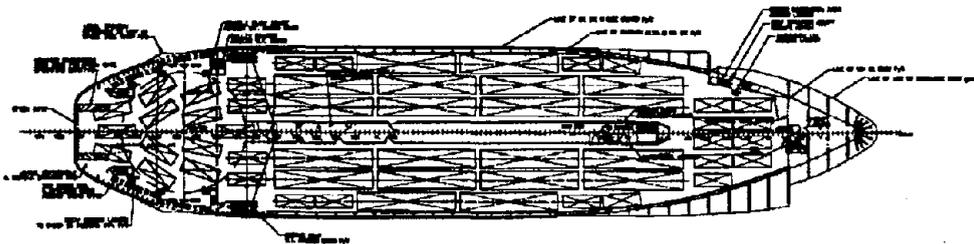
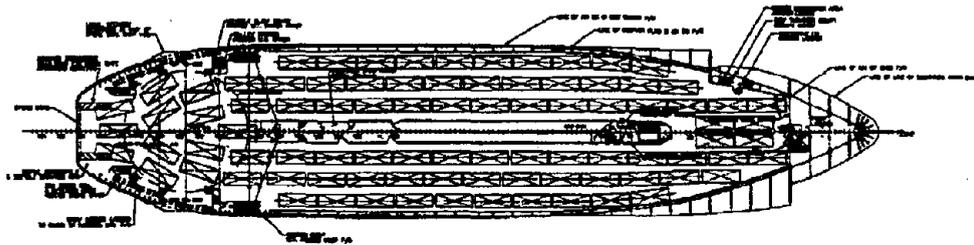
MV KENNICOTT: SECOND DECK



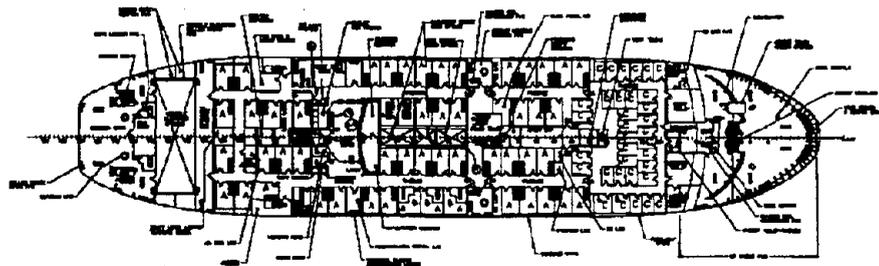
Source: Hutchinson, Bruce L. "Introduction to the Alaska Marine Highway System's New Ocean Class Vessel." *Marine Technology*, January 1998, pp. 32-34.

MV KENNICOTT GENERAL ARRANGEMENTS (CONTINUED)

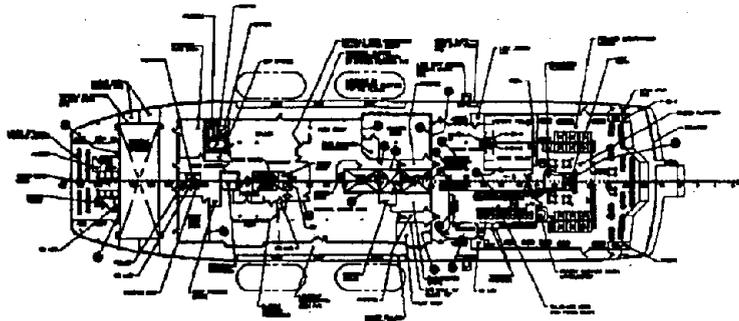
MV KENNICOTT: MAIN VEHICLE DECK AND MEZZANINE VEHICLE DECK



MV KENNICOTT: CABIN DECK



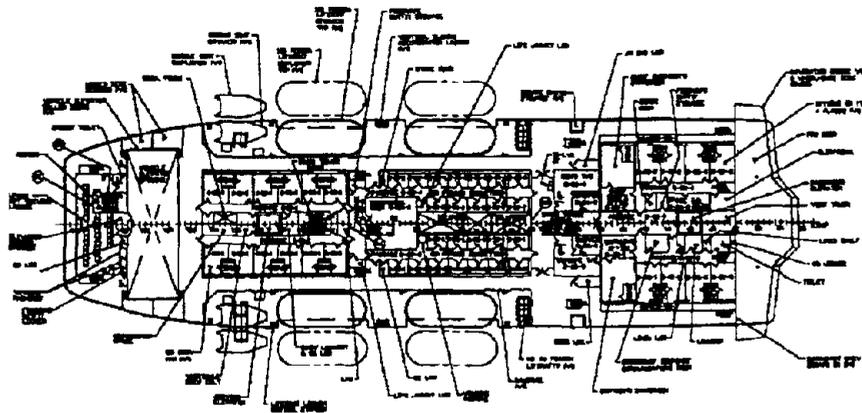
MV KENNICOTT: BOAT DECK



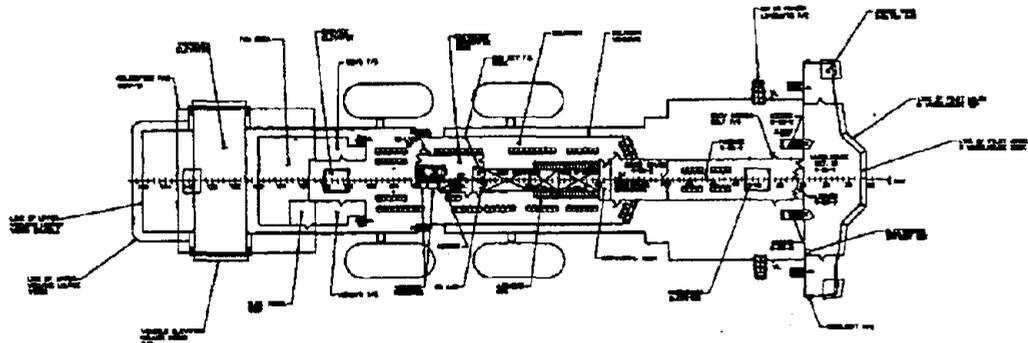
Source: Hutchison, Bruce L. "Introduction to the Alaska Marine Highway System's New Ocean Class Vessel." *Marine Technology* January 1998 pp. 32-34

MV KENNICOTT GENERAL ARRANGEMENTS (CONTINUED)

MV KENNICOTT: SUN DECK



MV KENNICOTT: SOLARIUM DECK



Source: Hutchinson, Bruce L. "Introduction to the Alaska Marine Highway System's New Ocean Class Vessel." *Marine Technology*, January 1998, pp. 22-24.

In developing the requirements for the acquisition of the new ocean class ferry the *MV Kennicott*, in addition to monohull designs, catamarans and SWATH hull forms were also reviewed.⁶⁰ At the time the study was conducted in 1992, it was felt that existing catamaran designs at the time provided neither the required cargo capacity nor suitable seakeeping characteristics. A SWATH concept design with a 1700 long ton displacement and a design draft of 25 feet was also evaluated.

The alternative hull type study concluded that a monohull design would be better suited for AMHS service than a SWATH design because of the draft restrictions found through the AMHS route system, the maximum free-board height of existing AMHS ferry terminal facilities of 8 feet, and the greater operating cost and possibly greater acquisition cost of a SWATH ocean class vessel. It was felt that modifications to the SWATH design, such as the use of a ballasting system and altering the strut and lower hull geometries, might reduce both its 25

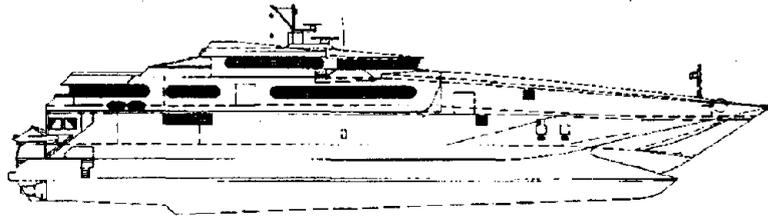
⁶⁰ *Decision Paper #1. Alternative Hull Types. AMHS Ocean Class Ferry.* MT-759/Agreement No. 37-003-21. Submittal to State of Alaska, Department of Transportation and Public Facilities, Alaska Marine Highway System. Revision A. September 23, 1992.

The Incat 78 meter is an aluminum hulled high speed wave piercing catamaran, with capacities ranging between 600 and 700 passengers, and 126 and 151 automobiles. The specific design evaluated here is assumed to have a passenger capacity of 600 and a vehicle capacity of 150 AEU. The design of the Incat 78 meter wave piercing catamaran evolved directly from the Incat 74 meter wave piercing catamaran that preceded it. A total of three 78 meter WPCs were delivered between 1994 and 1995, after which the somewhat larger 81 meter and 86 meter class of Incat WPC came into service. Powered by four marine diesel engines, the Incat 78 meter WPC has an operating speed of 34 knots. Passengers are accommodated on two decks, with approximately 420 on the main passenger deck, and approximately 180 on an upper passenger deck and lounge area. Restrooms and a gift shop are located on the main passenger deck, and a bar and snack area are located on each passenger deck. Typical general arrangements for the Incat 78 meter WPC are presented in Figure 9-4.

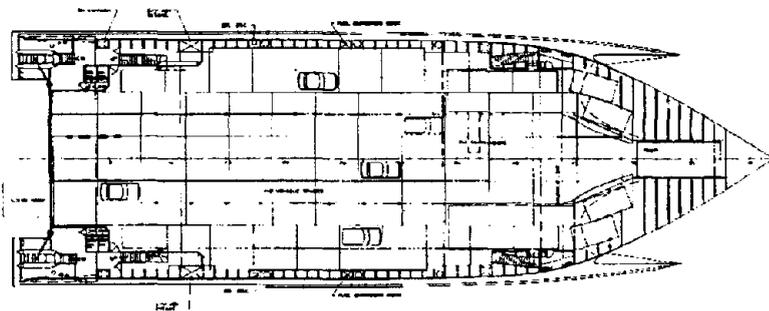
The SLICE 600 is a conceptual design of a steel hulled 65 meter SLICE RoPax ferry. The vessel would accommodate approximately 600 passengers and 90 automobiles, or a combination of 4 motorcoaches and 75 automobiles, with access to the vehicle deck from stern. Passengers are accommodated on two decks, with approximately 422 in economy class seating in two separate compartments on the gallery deck, with each compartment having its own restroom and snack bar. An additional 178 passengers are accommodated on the upper deck in first class or lounge type seating. Two gas turbine engines are to deliver an operating speed of 30 knots. General arrangements for the SLICE 600 are presented earlier in Chapter 4.

FIGURE 9-4: INCAT 78 METER WPC GENERAL ARRANGEMENTS

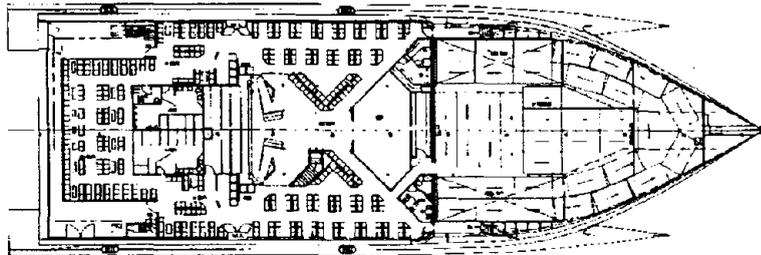
INCAT 78 METER WPC: OUTBOARD PROFILE



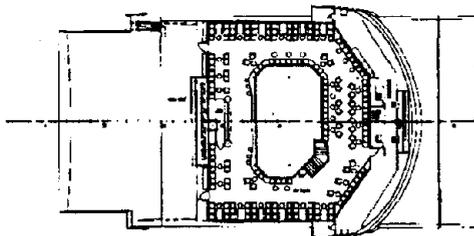
INCAT 78 METER WPC: VEHICLE DECK



INCAT 78 METER WPC: MAIN PASSENGER DECK



INCAT 78 METER WPC: UPPER PASSENGER DECK



9.4 Related Infrastructure and Facilities

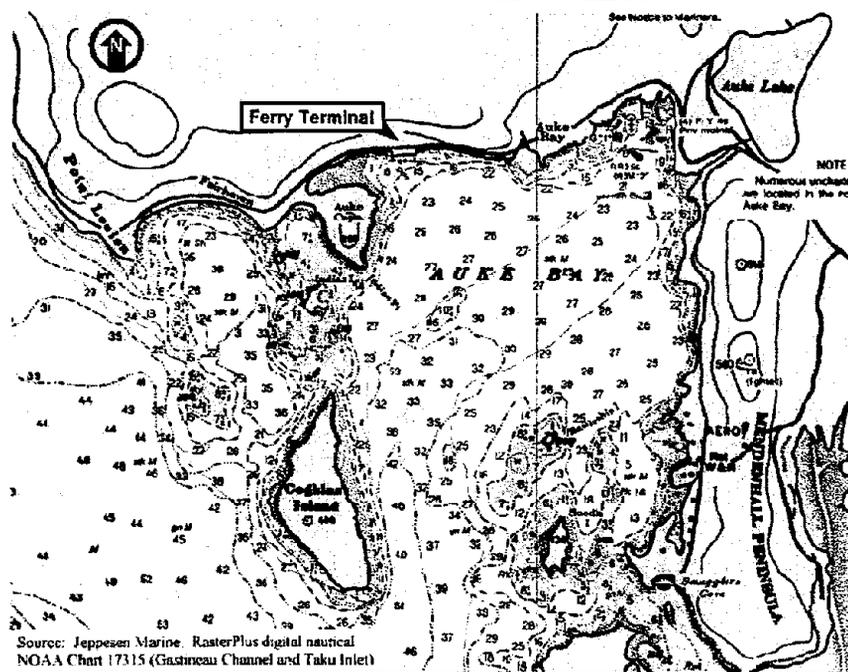
Apart from the terminals leased from the local communities in Bellingham, Prince Rupert, Hyder (at Stewart, British Columbia), and Pelican, the Alaska Marine Highway System owns and maintains its own terminal facilities. AMHS terminal facilities typically consist of a fendered mooring system, a transfer system, a vehicle parking and staging area, and a waiting shelter or terminal building for passengers and ticket sales. Terminal attendants are responsible for reservations, sales of tickets, handling mooring lines upon vessel arrival and departure, controlling parking, and lining up vehicles for loading.

9.4.1 Juneau

Juneau is located east of Douglas Island, at the base of the Coast Mountains on the northeast side of Gastineau Channel eight miles north of Stephens Passage. Juneau is a major distribution center for products moving to smaller communities in northern southeast Alaska. As the state capital and largest city in the region, the local economy is diverse, but centers on government, shipping, fishing and fish products, tourism, and commercial services. In 1997, the City and Borough of Juneau had a resident population of 30,396. As noted earlier, Juneau is not connected to the continental road system, and is highly dependent upon ferry and air service for connections to the rest of Alaska and Canada.

The Auke Bay Ferry Terminal at Juneau is located approximately 14 miles northwest of downtown Juneau (see Figure 9-5). The location at Auke Bay allows AMHS vessels to enter Auke Bay from around the west end of Douglas Island from the deeper waters of Stephens Passage, avoiding the shallow waters of the northern end of Gastineau Channel at Mendenhall Bar. These shallow depths, in combination with a 5 mph (4.4 knot) speed limit in Gastineau Channel between Juneau Isle and Buoy 7, would make ferry access to locations closer to the

FIGURE 9-5: AUKE BAY (JUNEAU) - NAUTICAL CHART



city of Juneau difficult.

The Auke Bay ferry terminal has two berths, an east berth 425 feet long with a controlling depth alongside of 26 feet, and west berth 425 feet long with a controlling depth alongside of 26 feet.⁶¹ These controlling depths are marginal relative to the 28.5 foot draft of the SLICE 600, but would be more than adequate for the 11.5 foot draft of the 78 meter Incat WPC. With a mean range of tide of 13.5 feet in the vicinity of Auke Bay, the SLICE 600 could be adequately accommodated at high tide, however this would impose operational restrictions similar to those that are currently present throughout other areas of southeast Alaska with the existing AMHS vessels.⁶² At present, AMHS vessels depart many ports throughout a 24 hour period on an inconsistent schedule due to tidal restrictions. There are other port facilities near downtown Juneau that have controlling depths of 30 feet or greater, including a number of cruise ship and cargo facilities. However the use of these facilities in order to accommodate the deeper draft of the SLICE 600 would require a more circuitous routing from Juneau south through Gastineau Channel, and through Stephens Passage to the west of Douglas Island, adding a distance of approximately 32 nautical miles to the existing trip length of 66 nautical miles between the Auke Bay ferry terminal and the Haines ferry terminal. Also, moving the ferry terminal from Auke Bay to Juneau would likely require the modification or construction of additional facilities to accommodate the additional passengers and vehicles.

In addition to these controlling depth restrictions at Auke Bay for the SLICE 600, throughout southeast Alaska the maximum freeboard at the vessel main vehicle deck entrance/exit is currently 8 feet with existing ferry terminal facilities and transfer systems. With a freeboard of 21.5 feet at the vehicle deck, the SLICE 600 would be incompatible with the existing AMHS ferry terminal facilities at Auke Bay.

Fuel is not available at the Auke Bay AMHS ferry terminal.⁶³ The ferry terminal building at Auke Bay has 6,160 square feet of space, and a passenger waiting capacity of 205 passengers. During 1997, there were a total of 67,823 embarking passengers and 68,552 disembarking passengers on AMHS vessels at Auke Bay. A total of 17,319 vehicles embarked from Auke Bay, and 17,306 vehicles disembarked at Auke Bay on AMHS vessels.

9.4.2 Haines

Haines is located on the shore of the Lynn Canal on the Chilkat Peninsula between the Chilkoot and Chilkat Rivers. The town is bordered by the Chilkat Mountain Range on the west and the Coast Range on the east. In 1997, Haines had a resident population of 1,429, with an additional 973 people living in the surrounding Haines Borough. Haines is one of the few communities in southeast Alaska connected to the continental road system. The Haines Highway (State Routes 7 and 3) extends north from Haines and connects with the Alaska Highway in the Yukon Territory.

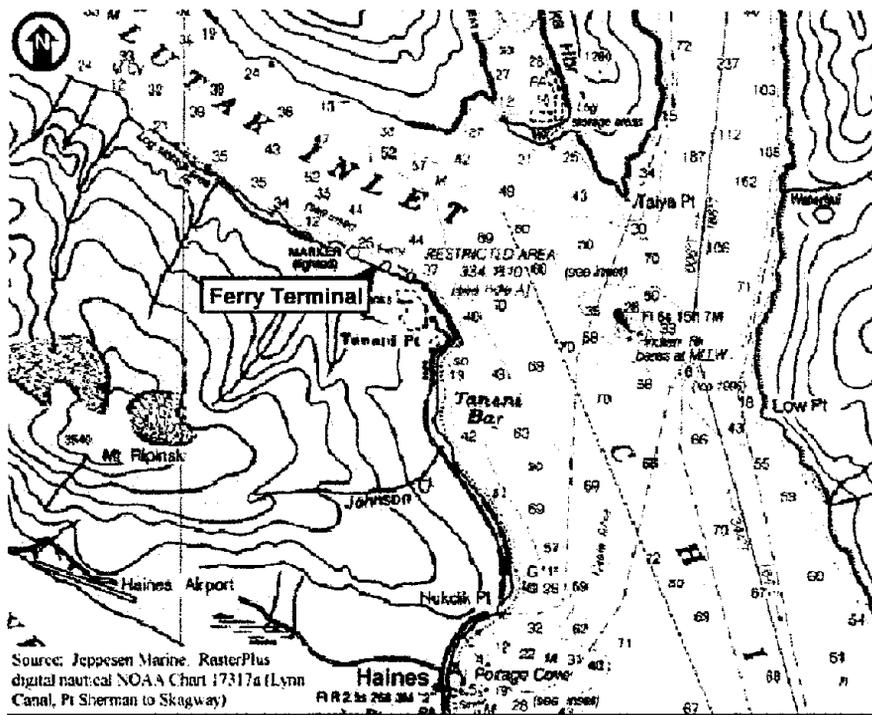
The AMHS ferry terminal in Haines is located approximately 5 miles north of downtown, on the south side of Lutak Inlet (see Figure 9-6). The ferry terminal dock has a berth 640 feet long, with a 35-ton adjustable transfer bridge and a controlling depth alongside of 23 feet. This depth is inadequate relative to the 28.5 foot draft of the SLICE 600, but would be more than adequate for the 11.5 foot draft of the 78 meter Incat WPC. With a mean range of tide of 15.8 feet, the SLICE 600 could be adequately accommodated at high tide, however this would impose operational restrictions similar to those that are currently present throughout other areas of southeast Alaska with the existing AMHS vessels. At present, AMHS vessels depart many ports throughout a 24 hour period on an inconsistent schedule due to tidal restrictions.

⁶¹ State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 2: Existing Transportation Conditions and Travel Characteristics in SE Alaska. Final Memorandum.* June 3, 1997. Appendix B. Inventory of Existing Harbor Facilities in Southeast Alaska. Page 4.

⁶² The mean range of tide is the difference in height between the mean high water and the mean low water. At Fritz Cove near Auke Bay, the mean high water is 15.0 feet above the local datum of mean lower low water, and mean low water is 1.5 feet above the local datum of mean lower low water.

⁶³ State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 2: Existing Transportation Conditions and Travel Characteristics in SE Alaska. Final Memorandum.* June 3, 1997. Appendix B. Inventory of Existing Harbor Facilities in Southeast Alaska. Table B-1.

FIGURE 9-6: HAINES - NAUTICAL CHART



There is only one port facility at Haines that has a controlling depth in excess of 28.5 feet. The Haines Terminal P.O.L. dock is located on the south shore of Lutak Inlet, and is owned by the U.S. federal government and operated by the U.S. Army. However, even if moving the ferry terminal to this other location were possible, it would likely require the modification or construction of additional facilities to accommodate the AMHS passengers and vehicles.

In addition to these controlling depth restrictions at Haines for the SLICE 600, throughout southeast Alaska the maximum freeboard at the vessel main vehicle deck entrance/exit is currently 8 feet with existing ferry terminal facilities and transfer systems. With a freeboard of 21.5 feet at the vehicle deck, the SLICE 600 would be incompatible with the existing AMHS ferry terminal facilities at Haines.

Fuel is available at the Haines AMHS ferry terminal.⁶⁴ The ferry terminal building at Haines has 4,220 square feet of space, and a passenger waiting capacity of 140 passengers. During 1997, there were a total of 38,463 embarking passengers and 38,948 disembarking passengers on AMHS vessels at Haines. A total of 13,457 vehicles embarked and 13,884 vehicles disembarked at Haines on AMHS vessels.

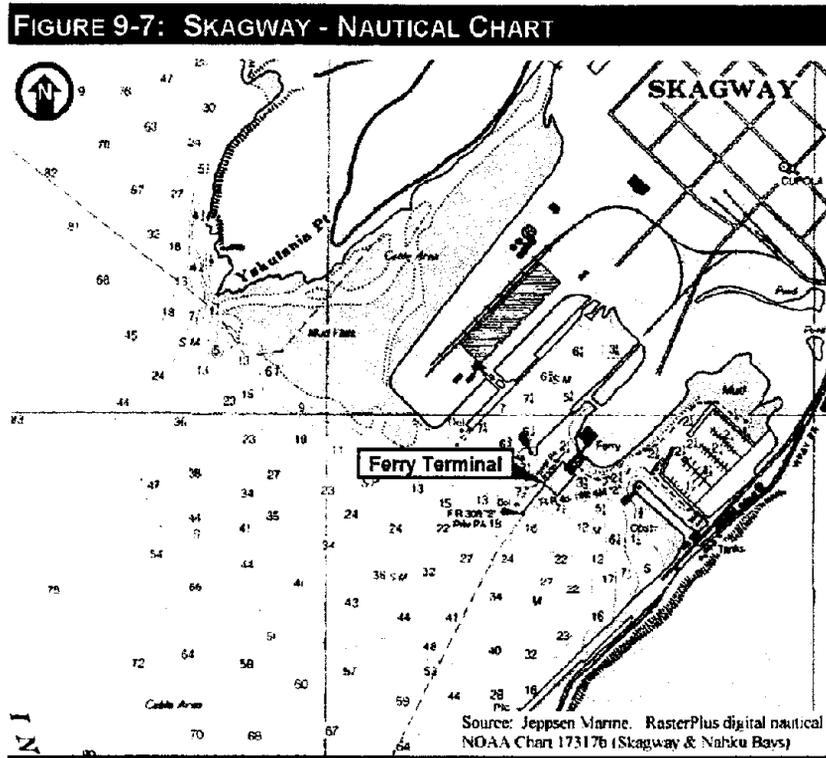
9.4.3 Skagway

Skagway is located at the northern terminus of the Inland Passage at the north end of Taiya Inlet on the delta of the Skagway River. Located approximately 13 nautical miles north of Haines, Skagway is also one of the few

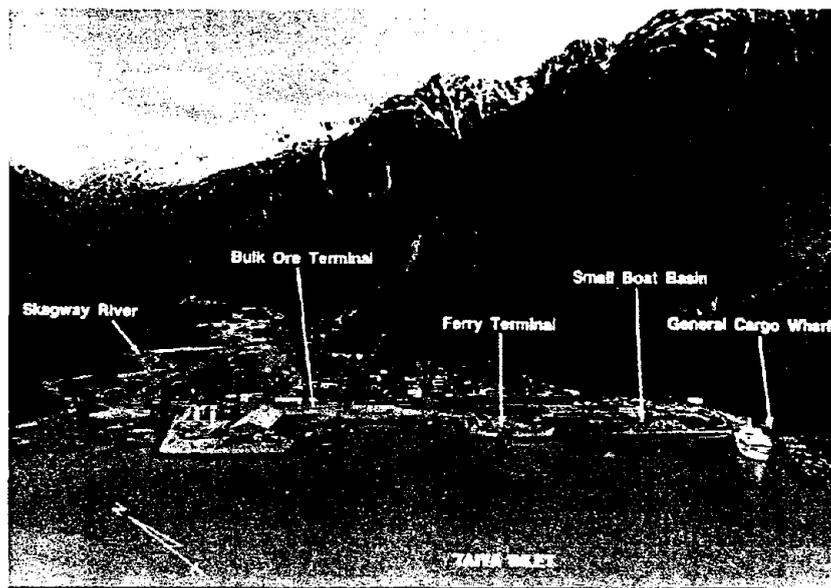
⁶⁴ State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 2: Existing Transportation Conditions and Travel Characteristics in SE Alaska. Final Memorandum.* June 3, 1997. Appendix B. Inventory of Existing Harbor Facilities in Southeast Alaska. Table B-1.

communities in southeast Alaska connected to the continental road system. The Klondike Highway (State Routes 98 and 2) extends north from Skagway and connects with the Alaska Highway in the Yukon Territory. Skagway is also a transfer point between water and rail shipping routes, with the White Pass and Yukon Railway operating 28 miles of a line that operates from Skagway to Fraser, British Columbia, for summer-only tourist excursions.

The AMHS ferry terminal at Skagway is located three blocks south of downtown on the east side of Taiya Inlet (see Figure 9-7 and Figure 9-8). The ferry terminal dock has a berth 385 feet long with dolphins, with a controlling depth alongside of 17 feet. This depth is inadequate relative to the 28.5 foot draft of the SLICE 600, but would be more than adequate for the 11.5 foot draft of the 78 meter Incat WPC. With a mean range of tide of 14.1 feet, the SLICE 600 could be adequately accommodated at high tide, however this would impose operational restrictions similar to those that are currently present throughout other areas of southeast Alaska with the existing AMHS vessels. At present, AMHS vessels depart many ports throughout a 24 hour period on an inconsistent schedule due to tidal restrictions.



There are three other port facilities at Skagway that have controlling depths in excess of 28.5 feet. The Skagway Terminal Company Ore Wharf, located 600 feet northwest of the existing ferry terminal, has a controlling depth of 37 feet, and is used for cruise ships, the receipt of petroleum products, and occasionally to ship lead and zinc ores mined in the Yukon Territory. The White Pass and Yukon Corporation Wharf, located 750 feet southeast of the existing ferry terminal, has a reported depth alongside of 21 to 33 feet, and also accommodates cruise ships, petroleum products and cargo. The Broadway Dock, located 360 feet southeast of the Skagway Terminal Company Ore Wharf, has a reported depth alongside of 30 feet. However, even if moving the ferry terminal to one of these other locations were possible, it would likely require the modification or construction of additional facilities to accommodate the AMHS passengers and vehicles.

FIGURE 9-8: SKAGWAY AERIAL PHOTO

In addition to these controlling depth restrictions at Skagway for the SLICE 600, throughout southeast Alaska the maximum freeboard at the vessel main vehicle deck entrance/exit is currently 8 feet with existing ferry terminal facilities and transfer systems. With a freeboard of 21.5 feet at the vehicle deck, the SLICE 600 would be incompatible with the existing AMHS ferry terminal facilities at Skagway.

Fuel is available at the Skagway AMHS ferry terminal.⁶⁵ The ferry terminal building has 1,872 square feet of space, and a passenger waiting capacity of 130 passengers. During 1997, there were a total of 32,451 embarking passengers and 35,057 disembarking passengers on AMHS vessels at Skagway. A total of 8,258 vehicles embarked and 8,988 vehicles disembarked at Skagway on AMHS vessels.

9.5 Weather and Wave Climate

Throughout coastal areas of southeast Alaska in general, a maritime influence prevails. Between Juneau and Skagway, vessels traverse Lynn Canal, which is an 71 nautical mile long, 4.25 nautical mile wide, deep fjord walled in by steep mountains rising to 7,000 feet on either side. The climate in the southern portion of Lynn Canal in the vicinity of Juneau generally consists of prevailing winds from the southeast throughout the year, although during the winter winds are more variable and may be out of the northeast as well. Southeast gales are more frequent in the winter than in summer, and fog is most likely occur during the winter. Further north, the high shores of Lynn Canal tend to guide winds along its north-south axis, while the narrowing at the northern end of Lynn Canal tends to intensify winds blowing from the south. Temperatures generally range from a low of 8° F during winter to highs in the mid 60's during July. From December through March, an average of 9 to 19 inches of snow per month falls. The southern part of Lynn Canal in the vicinity of Juneau is in the path of most storms that cross the Gulf of Alaska, and Lynn Canal as a whole has moderate temperatures, little sunshine, and abundant precipitation.

⁶⁵ State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 2: Existing Transportation Conditions and Travel Characteristics in SE Alaska. Final Memorandum. June 3, 1997. Appendix B. Inventory of Existing Harbor Facilities in Southeast Alaska. Table B-1.*

The long straight length of Lynn Canal provides for an unusually long fetch. Winter winds are known to reach 70 knots, driving steep waves usually on the order of 12 feet or higher for extended periods of time. The maximum winter sea condition reported in Lynn Canal by the NOAA station in Juneau was 22 feet in the vicinity of Whitestone Harbor on the south side of Icy Strait.⁶⁶ These climate and wave conditions are somewhat more difficult than in many other areas of southeast Alaska in which the AMHS operates. For example, throughout most of the journey from Bellingham to Skagway via the Inside Passage, vessels are generally protected from the open Pacific Ocean. In addition to Lynn Canal, other areas of relatively difficult sea states in southeast Alaska include part of the route between Prince Rupert and Ketchikan⁶⁷, in which vessels are exposed to open ocean waves while traversing Dixon Entrance, and Clarence Strait between Ketchikan and Wrangell, which although protected from the open ocean for much of its length can experience significant wave heights of 6 feet during the winter months due to its long north south fetch.

As discussed earlier in Chapter 8, the Volpe Center conducted a detailed wave climate analysis of each case study region. Unfortunately, southeast Alaska was one of the few regions for which either measured wave data sources or modeled hindcast data sources were unavailable.⁶⁸ As an alternative source of reliable wave climate information, quantitative wave climate data for the southeast Alaska region as a whole were obtained from the Owner's Requirements document developed during the acquisition process of the ocean class RoRo vessel the *MV Kennicott*.⁶⁹ Based on the operating profile throughout southeast Alaska of the ocean class vessel, a distribution of annual vessel hours by sea state was developed. The results of this analysis, presented in Figure 9-9, reveal that significant wave heights in sea state 4 and above (4.1 to 8.2 feet) would be experienced approximately 2.5% of vessel operating hours. These findings are generally consistent with the wave height data presented in the U.S. Coast Pilot, which indicates that waves of 10 feet or more are reported approximately 13.1% of the time for the area off Sitka (see Table 9-11), which is open to the open Pacific Ocean and would experience a more difficult wave climate than the Inside Passage routes making up much of the operating profile for the ocean class vessel. Because the data presented in Figure 9-9 represents operations throughout southeast Alaska, which includes areas which experience less difficult wave climates than Lynn Canal, when calculating estimates of the impact of vessel seakeeping upon patronage, these wave climate data are adjusted upward somewhat.⁷⁰ This results in an estimate that significant wave heights in excess of sea state 4 (4.1 to 8.2 feet) would be experienced approximately 2.5% of vessel operating hours.

⁶⁶ Art Anderson Associates. *Study of Marketing Possibilities for Two Variants of the SLICE Design*. June 1995. Page 5.

⁶⁷ One on occasion in the past, the MV Malaspina encountered seas so difficult in this area that the vessel rolled excessively, and tractor trailer vans on the car deck tipped over, heavily damaging six automobiles. State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 2: Existing Transportation Conditions and Travel Characteristics in SE Alaska*. Final Memorandum. June 3, 1997. Pg. 14.

⁶⁸ The Alaska Marine Highway System is currently planning to outfit one of its vessels with instrumentation capable of recording quantitative measurements of sea state conditions along the routes operated by the AMHS.

⁶⁹ Alaska Department of Transportation and Public Facilities. Alaska Marine Highway System. *Owner's Requirements. Ocean Class RO-RO Passenger Vessel*. Project No. 75409/NH-9500(44). Section 1A, Table 1A-1, "Southeast Alaska Operating Profile." April 1996.

⁷⁰ A total of 10% of annual vessel operating hours are shifted from sea states 0-1 and 2 to sea states 5 and greater than 5.

FIGURE 9-9: ESTIMATED DISTRIBUTION OF ANNUAL VESSEL OPERATING HOURS BY SEA STATE (SOUTHEAST ALASKA)

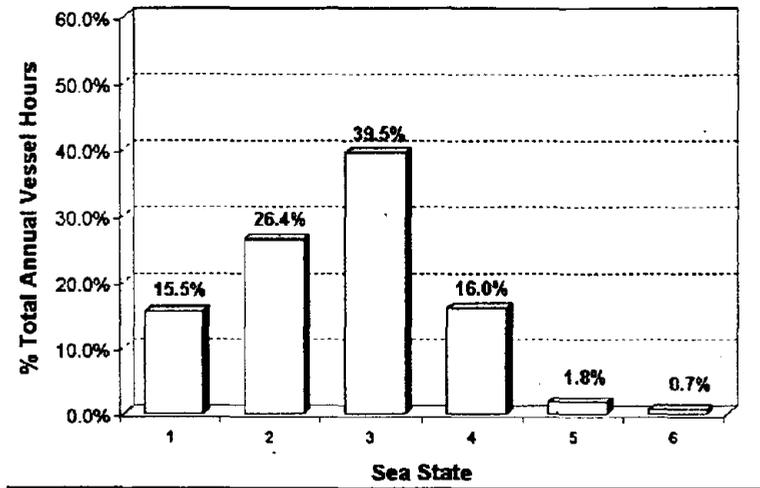


TABLE 9-11: METEOROLOGICAL TABLE FOR COASTAL AREA OFF SITKA

METEOROLOGICAL TABLE FOR COASTAL AREA OFF SITKA
Boundaries: 56°N. and 60°N., from 140°W. to the coast

Weather Elements	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Wind \geq 34 knots (1)	11.7	10.7	5.3	4.3	1.3	0.6	0	0.7	3.7	12.4
Wave height \geq 10 feet(1)	22.2	31.0	13.3	15.9	8.9	4.2	1.2	4.4	7.6	26.8
Visibility < 2 naut. mi. (1)	6.9	7.6	8.5	1.8	4.1	12.3	10.6	11.8	3.9	3.5
Precipitation (1)	23.6	19.9	21.5	19.4	18.8	24.9	26.6	23.4	16.2	19.0
Temperature \geq 85°F (1)	0	0	0	0	0	0	0	0	0	0
Mean Temperature (°F)	35.7	38.2	38.5	41.4	46.1	51.8	55.2	56.5	54.0	47.3
Temperature \leq 32°F (1)	20.3	7.1	6.6	0	0	0	0	0	0	0
Mean relative humidity (%)	87	87	85	81	84	84	85	87	87	84
Sky overcast or obscured (1)	48.3	60.4	47.7	39.0	48.1	55.7	60.4	57.2	45.1	43.7
Mean cloud cover (eighths)	5.6	6.1	5.7	5.2	6.0	6.5	6.8	6.6	6.0	6.0
Mean sea-level pressure (2)	1,009	1,010	1,011	1,011	1,016	1,015	1,017	1,015	1,012	1,004
Extreme max. sea-level pressure (2)	1,037	1,035	1,034	1,032	1,034	1,034	1,032	1,030	1,031	1,031
Extreme min. sea-level pressure (2)	982	980	980	985	988	986	1,000	992	987	974
Prevailing wind direction	E	E	SE							
Thunder and lightning (1)	0	0	0	0	0	0	0	0	0	0

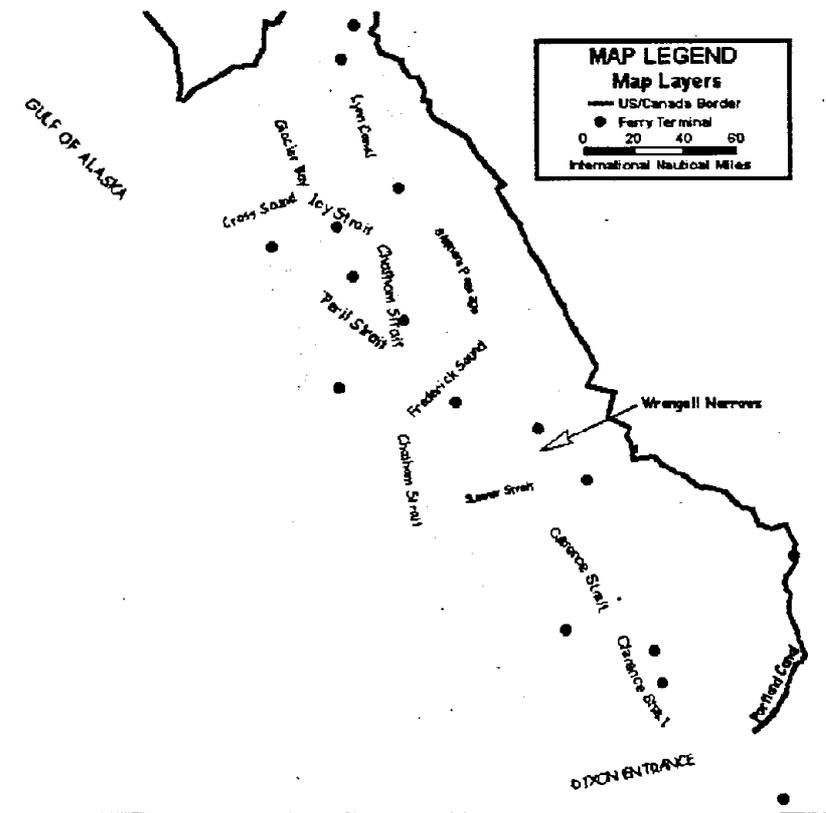
(1) Percentages frequency
(2) Millibars
0-85%

These data are based upon observations made by ships in passage. Such ships tend to avoid bad weather when possible, thus leaving the data toward good weather samples

9.6 Navigational Considerations

Between the ferry terminals at Auke Bay, Haines and Skagway, the navigable waters of Auke Bay, Favorite Channel, Lynn Canal, Chilkoot Inlet, Lutak Inlet and Taiya Inlet are relatively deep, and can easily accommodate the deep draft of the SLICE 600. Only at and in the immediate vicinity of the ferry terminal berths themselves are there any significant controlling depth constraints along these routes. This is in distinct contrast to other parts of the southeast Alaska ferry route network, which require navigating narrow and draft constrained areas such as Wrangell Narrows and Sergius Narrows. For general reference, the major waterways and channels that are traversed by AMHS vessels throughout the southeast Alaska region are presented in Figure 9-10.

FIGURE 9-10: SOUTHEAST ALASKA WATER FEATURES



Floating logs and other debris are present throughout the year in all the inland waters, channels, passes and inlets in southeast Alaska, and are a danger to navigation both day and night. Floating logs are especially prevalent at the entrance to inlets after high tides and storms. Ice is discharged from glaciers and can be expected in Stephens Passage. In daytime and in clear weather ice is not a serious danger to navigation, however at night or in poor visibility conditions it may pose a threat.

Throughout southeastern Alaska there are considerable inequalities in the heights of the two high waters and the two low waters of each day. These differences average about 2 feet between successive high waters and 3 feet between successive low waters. Because of such differences, the mean lower low water (rather than the mean low water) has been adopted as the plane of reference for NOAA National Ocean Service nautical charts of the region.

Access to Auke Bay is made south of Coghlan Island, where depths are well in excess of 120 feet. After turning north around the southern end of Coghlan Island, Favorite Channel is entered to the east of Shelter Island, again with depths far exceeding the minimum necessary to accommodate the SLICE 600. In upper Lynn Canal, voluntary vessel traffic procedures have been adopted for deep draft vessels. Ferries, cruise ships and other deep draft vessels are requested to announce their presence 30 to 45 minutes prior to entering the area and at regular intervals while transiting through the area, and a safe speed must be maintained. The approach to Skagway from Taiya Inlet is clear and deep.

Utilizing the *MarineMap* electronic charting software, a detailed representation of the two case study route segments between Auke Bay and Haines, and Haines and Skagway were created. The total route distance between the ferry terminals at Auke Bay and Haines is 66.2 nautical miles. This total is comprised of 2.7 nmi in Auke Bay from the Auke Bay ferry terminal, 12.6 nmi in Favorite Channel east of Shelter Island, 34.2 nmi in Lynn Canal, 15.3 nmi in Chilkoot Inlet, and 1.4 nmi in Lutak Inlet to the ferry terminal at Haines. The total route distance between Haines and Skagway is 12.8 nautical miles. This total is comprised of 2.2 nmi in Lutak Inlet from the ferry terminal at Haines, and 10.6 nmi in Taiya Inlet to the ferry terminal at Skagway.

Total one-way travel time with the baseline AMHS vessels is currently 4 hours and 30 minutes between Auke Bay and Haines, and 1 hour between Haines and Skagway.

In estimating the total one-way travel time with the SLICE 600 and Incat 78 meter WPC, it is assumed that operating speeds are 7 knots within portions of Auke Bay and Lutak Inlet, 15 knots in portions of Favorite Channel and Chilkoot Inlet, and that the main portion of the trip in Favorite Channel and Lynn Canal is accomplished at the vessel service speed. Therefore, the total trip time with the Incat 78 meter WPC from the Auke Bay ferry terminal to the Haines ferry terminal is 2 hours and 25 minutes, with an operating speed of 34 knots. With the SLICE 600, the total trip time on the same route is 2 hours and 40 minutes, with an operating speed of 30 knots. Between Haines and Skagway, the total trip time with the Incat 78 meter WPC is 37 minutes, and with the SLICE 600 is 40 minutes.

9.7 Environmental Considerations

The pattern of whale migration generally follows a simple routine of feeding at high latitudes during the summer months, and breeding in warmer latitudes during the winter months. This pattern applies for both northern hemisphere and southern hemisphere whale species. The Alaskan coast sees a great variety of whale species during the summer months from April to September. Humpback whales, killer whales, beluga and gray whales are common during this time of year. Other species include bowhead, minke, sperm, and fin whales, as well as narwhals and blue whales. Humpback whales are found throughout Lynn Canal, and in April and May concentrations of adult herring and eulachon bring humpback whales into Berners Bay, on the eastern side of Lynn Canal, to feed.⁷¹

The material contained with the Juneau Access DEIS would seem to suggest that despite what possible environmental impacts might result from improved or increased ferry service in Lynn Canal, these impacts would likely be relatively less than those that would result from the development of any of the road or highway options for the corridor that are discussed in the DEIS.

⁷¹ Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Section 4.3.6.

9.8 Market Forecasts and Financial Analysis

The historical patronage data for 1997 for AMHS service throughout southeast Alaska was reviewed earlier in Table 9-6. For Lynn Canal ferry service between Auke Bay, Haines and Skagway Calendar, somewhat more recent calendar year 1998 passenger and vehicle origin-destination data, reflecting the summer 1998 introduction of the *MV Kennicott* to southeast mainline service, is presented below in Table 9-12.

TABLE 9-12: AMHS 1998 LYNN CANAL PASSENGER AND VEHICLE ORIGIN-DESTINATION DATA

Passengers				
Passengers Embarking	Passengers Disembarking			
Ports	Skagway	Haines	Juneau	Totals
Skagway		9,143	17,257	26,400
Haines	10,732		20,980	31,712
Juneau	18,255	20,524		38,779
Totals	28,987	29,667	38,237	96,891
Vehicles				
Vehicles Embarking	Vehicles Disembarking			
Ports	Skagway	Haines	Juneau	Totals
Skagway		3,727	3,721	7,448
Haines	4,499		6,466	10,965
Juneau	3,794	6,605		10,399
Totals	8,293	10,332	10,187	28,812

Table 9-13 presents 1998 AMHS vessel trips by directional route segment, season and vessel, that correspond to the observed patronage data presented in Table 9-12. As noted earlier, the one-way dock-to-dock travel time is currently 4 hours and 30 minutes between Auke Bay and Haines, and 1 hour between Haines and Skagway. Including staging, loading and unloading times at each terminal, the time to travel between Auke Bay and Haines is approximately 7 hours, with travel on to Skagway adding an additional 2 hours.⁷² The Juneau Access DEIS reports that the annual operating and maintenance cost for the existing Lynn Canal AMHS ferry service is approximately \$8,400,000 annually, and that passenger and vehicle fares are approximately \$6,500,000.⁷³

As noted earlier, capital costs for transportation projects, including ferry acquisition and ferry terminal construction, are covered largely with federal funds, and therefore do not impact the operating budget of the state of Alaska to the same extent as operating expenses. Operating and maintenance costs, however, are especially important since these costs are financed with state funds. Because of declining state revenues, the Alaska State Legislature has called for significant reductions in funding for the AMHS operating budget and the level of state support required for the AMHS. Therefore, the financial performance of any AMHS routes using a different

⁷² Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Section 2.3.

⁷³ Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Section 3.2.1

TABLE 9-13: 1998 AMHS SOUTHEAST VESSEL TRIPS BY DIRECTIONAL ROUTE SEGMENT, SEASON AND VESSEL

Summer Season					
Vessel	Juneau to Haines	Haines to Juneau	Skagway to Haines	Haines to Skagway	Totals by Vessel
MV Aurora	3	4	4	3	14
MV Columbia	20	20	20	20	80
MV Kennicott	8	8	8	8	32
MV LeConte	6	5	3	4	18
MV Malaspina	81	81	81	81	324
MV Matanuska	23	23	24	24	94
MV Taku	24	24	24	24	96
Summer Totals by Route Segment	165	165	164	164	658
Winter Season					
MV Aurora	11	10	10	11	42
MV Columbia	4	4	4	4	16
MV Kennicott	9	9	9	9	36
MV LeConte	17	19	19	17	72
MV Malaspina	0	0	0	0	0
MV Matanuska	26	26	23	23	98
MV Taku	51	51	51	51	204
Winter Totals by Route Segment	118	119	116	115	468
Calendar Year 1998 Totals					
MV Aurora	14	14	14	14	56
MV Columbia	24	24	24	24	96
MV Kennicott	17	17	17	17	68
MV LeConte	23	24	22	21	90
MV Malaspina	81	81	81	81	324
MV Matanuska	49	49	47	47	192
MV Taku	75	75	75	75	300
1998 Totals by Route Segment	283	284	280	279	1,126

Source: AMHS 1998 Annual Traffic Volume Report. 1998 Link Volume Summary Reports. Pages 27, 75-82.

vessel such as SLICE or another comparative high speed vessel would likely be of paramount importance, with the goal of reducing long term operating and maintenance costs for transportation in the region.

Primarily for these reasons, the approach taken here for the analysis of the financial performance of the Lynn Canal service is to focus on operating and maintenance expenses and revenues. The purchase price of \$37 million for SLICE 600 compares favorably to the *MV Kennicott* which cost \$81 million, \$65 million of which was provided by the FHWA. The *MV Kennicott*, however, was designed to meet various missions, and to be certified for open ocean operation, thus likely increasing its cost over what might otherwise have been the case.

⁷⁵ Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Section 2.4.

High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

Even so, it would appear that some benefits could be realized with the purchase of high speed vessels as compared to conventional monohull vessels, however most of these gains would be realized by the federal rather than the state government.

As part of the Juneau Access DEIS, in 1994 the Alaska Department of Transportation and Public Facilities recorded the number of travelers whose request for a vehicle reservation to travel between Juneau and Haines/Skagway was denied because of a lack of ferry space. For the first three months of 1994, immediately after the spring/summer state ferry system schedule was published, reservation requests for 1,135 vehicles and 4,825 passengers to travel among these three communities were denied.⁷⁵

The Juneau Access DEIS reviewed a marine transportation alternative, with four possible options (referred to as Options A, B, C, and D). All four options involved the use of high speed RoPax ferries on Lynn Canal. The high speed RoPax vessel reviewed in the Juneau Access DEIS was an Incat 84 meter WPC, with a passenger capacity of 777 persons, a vehicle capacity 105 AEU, and an operating speed of 25 knots.⁷⁶

Of the four marine transportation options explored in the Juneau Access DEIS, Option B and Option D involved the construction of new ferry terminal at Berners Bay on the east side of Lynn Canal, further north of the existing ferry terminal at Auke Bay. Option A consisted of the continuation of conventional mainline ferry service on Lynn Canal from the existing ferry terminal at Auke Bay, with supplemental high speed RoPax service on the same route. Finally, Option C consisted of the elimination of conventional mainline ferry service on Lynn Canal, with replacement high speed RoPax service operating from the existing ferry terminal at Auke Bay. Because Option C does not involve the construction of a new ferry terminal at Berners Bay, and because it eliminates the baseline conventional mainline ferry service on Lynn Canal, it serves as a convenient baseline against which current AMHS operations on Lynn Canal can be compared. Therefore, a proposed operating profile similar to that reviewed in Option C is selected for review in this case study.

TABLE 9-14: JUNEAU ACCESS DEIS - ALTERNATIVE 4, OPTION C PROPOSED DAILY OPERATING SCHEDULE

Vessel	Depart Auke Bay	Arrive Haines	Depart Haines	Arrive Skagway	Depart Skagway	Arrive Haines	Depart Haines	Arrive Auke Bay
May to September								
Vessel #1							7:00 AM	9:38 AM
Vessel #2	6:00 AM	8:38 AM	9:00 AM	9:38 AM	10:00 AM	10:38 AM	11:00 AM	1:38 PM
Vessel #1	10:00 AM	12:38 PM	1:00 PM	1:38 PM	2:00 PM	2:38 PM	3:00 PM	5:38 PM
Vessel #2	2:00 PM	4:38 PM	5:00 PM	5:38 PM	6:00 PM	6:38 PM	7:00 PM	9:38 PM
Vessel #1	6:00 AM	8:38 PM						
October to April								
Vessel #1							7:00 PM	9:38 PM
Vessel #1	10:00 AM	12:38 PM	1:00 PM	1:38 PM	2:00 PM	2:38 PM	3:00 PM	5:38 PM
Vessel #1	6:00 PM	8:38 PM						

Source: Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Section 3.2.3 (c). Table 3-6.

This proposed operating schedule is presented in Table 9-14. On the Auke Bay - Haines route segment, between May and September, this schedule calls for two vessels, each operating two round trips daily. Between October and April, one vessel is called for, operating two round trips daily. On the Haines - Skagway route segment, between May and September this schedule calls for two vessels, the first operating a single round trip daily, and

⁷⁶ Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Table 3-3.

the second operating two round trips daily. Between October and April, one vessel is called for, operating a single round trip daily.

In developing patronage estimates for Alternative 4, Option C, the Juneau Access DEIS assumed the use of two 84 meter Incat WPCs, each having a capacity of 777 passengers and 105 AEU. If operated according to the schedule presented in Table 9-14, the Juneau Access DEIS estimates that the number of total vehicle boardings on the Lynn Canal routes will increase to 77,000 annually from the current baseline level of approximately 30,000 noted in the Juneau Access DEIS.⁷⁷ As noted earlier in Table 9-12, actual 1998 passenger boardings on the three Lynn Canal routes totaled 28,812.

This estimate of 77,000 annual vehicles is in excess of that which would be estimated based on the changes in the level of service parameters compared to the current baseline conventional RoPax service, and the demand elasticities with respect to travel time, fare and frequency of service reviewed earlier in Chapter 8. However, this higher estimate of 77,000 vehicle boardings still appears reasonable given the sizeable unmet demand on these routes, as shown by the Juneau Access DEIS analysis of denied reservations requests, and the lack of other transportation alternatives, such as highway, on these routes.

The DEIS estimate of 77,000 vehicle boardings serves as the basis upon which patronage estimates for the scenarios evaluated in this case study, utilizing the 78 meter WPC and the SLICE 600, are made. Although estimates of the number of passenger boardings corresponding to the estimate of 77,000 vehicle boardings are not directly made in the Juneau Access DEIS, such an estimate can be made by reviewing the relationship of 1998 passengers boardings to 1998 vehicle boardings on the three routes served in Lynn Canal. Given the existing 1998 origin-destination passenger and vehicle data presented in Table 9-12, a corresponding estimate of passen-

TABLE 9-15: LYNN CANAL CURRENT BASELINE PATRONAGE AND FUTURE HIGH SPEED BASELINE PATRONAGE

Non-Directional Market Segment	1998 Observed Actual Baseline		Juneau Access "Improved Marine" Option Baseline	
	Passengers	Vehicles	Passengers	Vehicles
Auke Bay - Haines	41,504	13,071	106,527	33,549
Haines - Skagway	19,875	8,226	51,013	21,113
Auke Bay - Skagway	35,512	7,515	91,147	19,289
Lynn Canal Total	96,891	28,812	248,687	73,951

ger demand is estimated based on the estimated of 77,000 annual vehicles. These aggregate passenger boarding and vehicle boarding forecasts for the Lynn Canal routes in total are then distributed among the three origin-destination route segments in proportion to currently observed 1998 traffic. The resulting non-directional route segment patronage totals are presented in Table 9-15, and serve as the basis for the patronage forecasts made in this case study for the Incat 78 meter WPC and the SLICE 600.

Table 9-16 and Table 9-17 present the findings for the use of the Incat 78 meter WPC and the SLICE 600 on Lynn Canal. The Incat 78 meter WPC and the SLICE 600 are of the same general passenger capacity as the Incat 84 meter WPC used in the Juneau Access DEIS. Therefore, the same schedule as that proposed in the Jun-

⁷⁷ Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Table 2-3.

eau Access DEIS and presented earlier in Table 9-14 is assumed here for the Incat 78 meter WPC and the SLICE 600. Passenger and vehicle fares are assumed to stay at current levels.

For both the alternative high speed vessels evaluated, total travel times improve only slightly compared with the Incat 84 meter baseline case studied in the Juneau Access DEIS. The SLICE 600 travel times are virtually unchanged from the baseline, and therefore there is no corresponding change from the baseline patronage resulting from an improvement in travel time. The Incat 78 meter WPC, however, returns a travel time that is 9% less than the baseline for the Auke Bay - Haines route segment, and 7% less than the baseline for the Auke Bay - Skagway route. These travel time improvements for the 78 meter WPC result in an estimated overall increase in passenger boardings of 14,275, and an increase in vehicle boardings of 4,300 annually.

It is assumed that the seakeeping performance of the Incat 78 meter WPC is similar to that of the Incat 84 meter WPC, and that there would be no increase in patronage resulting from improved seakeeping and ride quality resulting from the use of the Incat 78 meter WPC. However, based on the seakeeping analysis presented in Chapter 5 and the methodology presented in Chapter 8 regarding the impact of seakeeping performance on patronage, it is estimated that an increase of 3,000 passenger boardings over the baseline would result from the improved seakeeping ability of the SLICE 600. It is further estimated that an additional 6,900 passenger boardings over the baseline would result from an improvement in operational reliability resulting from the better seakeeping ability of the SLICE 600.

The resulting annual operating costs and revenues for the two scenarios are presented in Table 9-17. The annual operating costs for the Incat 78 meter WPC of \$20,314,764 are similar to those estimated in the Juneau Access DEIS for the Incat 84 meter WPC, which were estimated at \$17,800,000 annually.⁷⁸ The Incat 78 meter WPC returns the best economic performance, with an annual net loss of \$7,878,872, compared to an annual net loss of \$17,775,617 with the SLICE 600. On a per passenger boarding basis, the net loss of \$7,878,872 for the Incat 78 meter is equivalent to \$29.96 per passenger boarding, and the net loss of \$17,775,617 for the SLICE 600 is equivalent to \$68.05 per passenger boarding. As noted earlier, the Juneau Access DEIS reports that the annual operating and maintenance cost for the existing Lynn Canal AMHS ferry service is approximately \$8,400,000 annually, and that passenger and vehicle fares are approximately \$6,500,000, resulting in an annual net loss of \$1.9 million, or at baseline 1998 patronage levels totaling 96,891 passengers, \$19.60 per passenger boarding.⁷⁹

It is clear from these findings that although use of either the 78 meter WPC or SLICE 600 would improve travel conditions in the Lynn Canal corridor, the financial impact upon the state of Alaska would increase both in absolute terms and in terms of the per passenger net loss. Although the 78 meter WPC returns an economic performance that is superior to the SLICE 600, both the 78 meter WPC and the SLICE 600 would result in an increase in the required financial support from the state of Alaska, which does not meet the stated goals of the Alaska Marine Highway System and the state of Alaska to reduce the financial burden upon the state by reducing the operating costs of AMHS ferry services.

There are very limited alternatives for travel between the Lynn Canal communities reviewed here, and any attempt to increase fares to improve the financial position of the Lynn Canal ferry service would place an economic burden upon ferry users that would likely be politically unacceptable at the state level. Also, increasing fares in order to improve the financial performance of the Lynn Canal service would be at odds with one the

⁷⁸ Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Section 3.2.3.

⁷⁹ Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Section 3.2.1

⁸¹ Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997. Section 2.1.

stated goals of the Juneau Access DEIS, which is to reduced user costs for travel in the Lynn Canal corridor.⁸¹ For these reasons, no "profit maximizing" fare scenarios were carried out for this case study.

TABLE 9-16: LYNN CANAL IMPROVED MARINE ALTERNATIVE 4,
TABLE 9-17: LYNN CANAL IMPROVED MARINE ALTERNATIVE 4,
OPTION C, WITH BASELINE FARE - OPERATING PROFILES

ANNUAL	vessel type	Scenarios	
		lnca7 78m	SLICE 600
Passenger Capacity Per Vessel			
		lnca7 78m	SLICE 600
CASH EXPENSES			
Direct Operating Costs			
	Salaries Wages and Benefits	\$3,230,463	\$3,517,744
OPERATING PROFILE: LYNN CANAL (TOTAL)			
	Total Annual One-Way Vessel Trip Permits	\$5,188,714	\$11,343,327
	Total Annual One-Way Vessel Trip Permits	\$2,216,543	\$2,662,899
	Total Annual One-Way Vessel Trip Permits	\$1,660,000	\$1,850,000
	Total Annual One-Way Vessel Trip Permits	\$12,536,724	\$22,565,669
Indirect Operating Costs			
OPERATING PROFILE: LYNN CANAL (TOTAL)			
	One-Way Vessel Travel Time	2 hrs. 18 min.	2 hrs. 39 min.
	Total Annual One-Way Vessel Trip Permits	\$452,033	\$493,818
	Adult One-Way Passenger Fare including 21 Sales	\$383,307	\$358,870
	Total Annual One-Way Passenger Boardings	113,626	110,749
	Passenger Capacity Utilization	16.8%	16.8%
	Protection Automobile One-Way Fare	\$55,000	\$75,500
	Total Annual One-Way Vehicle Boardings	\$2,125,765	\$2,159,408
	Vehicle Capacity Utilization	\$242,704	\$260,000
OPERATING PROFILE: HAINES-SKAGWAY			
	One-Way Vessel Travel Time	27 min.	30 min.
	Total Annual One-Way Vessel Trip Permits	\$7,729,036	\$7,542,900
ANNUAL REVENUES			
	Total Annual One-Way Passenger Fare	\$6,344,081	\$6,292,386
	Passenger Capacity Utilization	\$3,987,524	\$3,950,000
	Auxiliary Sales - Onboard and Beverage	\$1,312,533	\$1,300,000
	Total Annual One-Way Vehicle Boardings	\$788,279	\$782,000
	Vehicle Capacity Utilization	21.1%	33.6%
OPERATING PROFILE: AUKE BAY-SKAGWAY or Local			
	Operating Expenses per Trip Subsidy	4 hrs. 2 min.	4 hrs. 18 min.
	Total Annual One-Way Vessel Trip Permits	\$12,435,645	\$12,332,953
NET CASH FLOW			
	Total Annual One-Way Fare	\$7,838,878	\$17,775,617
	Automobile One-Way Fare	\$72.00	\$72.00
	Total Annual One-Way Vehicle Boardings	20,236	20,155

Notes:
 (1) Includes one hour for vessel stopover at Haines.

9.9 Conclusions

Of the mainline AMHS southeast route segments, the SLICE 600 would be best suited for the Juneau to Skagway route, which is well patronized, experiences relatively difficult sea states despite its location protected from the open ocean, and has fewer navigational issues related to controlling depths of channels and at berths than some of the other route segments in southeast Alaska. Although most channel depths in the area are suitable for

the SLICE 600, the controlling depths along side of 26 feet at Juneau (Auke Bay), 23 to 25 feet at Haines, and 17 feet at Skagway are marginal with respect to the SLICE 600, but would be more than adequate for the 78 meter WPC or other WPC designs being evaluated by AMHS. The deep draft of the SLICE 600 would, however, pose additional operational constraints if the vessel were to be utilized elsewhere in the southeast Alaska ferry route system currently operated by AMHS. Although it is unclear at this time on which specific routes high speed ferry service will be implemented by AMHS, the inability to utilize the SLICE 600 elsewhere in the AMHS system is a definite shortcoming that other catamaran designs do not face.

In addition to draft constraints, operational difficulties are also likely to be encountered with the SLICE 600 because of the deck heights at the existing ferry terminals throughout southeast Alaska, which allow a maximum freeboard height at the main vehicle deck entrance/exit of 8 feet. The SLICE 600 main vehicle deck freeboard height of 21.5 feet would be incompatible with existing southeast Alaska ferry terminal facilities.

Finally, although the 78 meter WPC returns an economic performance that is superior to the SLICE 600, both the 78 meter WPC and the SLICE 600 would result in an increase in the required financial support from the state of Alaska, which does not meet the stated goals of the Alaska Marine Highway System and the state of Alaska to reduce the financial burden upon the state by reducing the operating costs of AMHS ferry services.

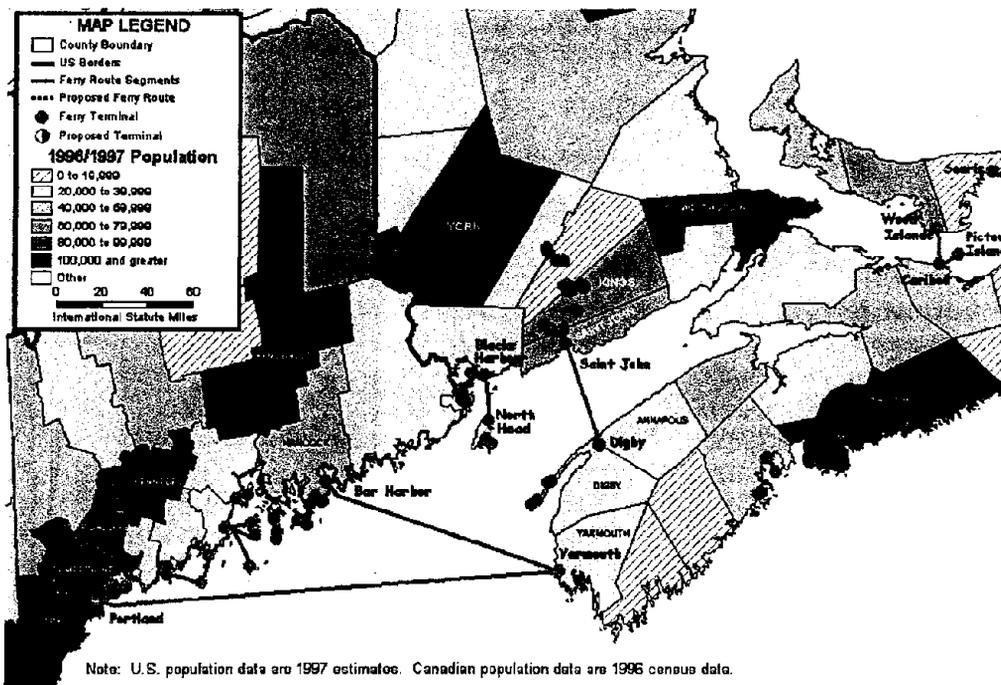
Chapter 10: Case Study #2 - Bay of Fundy (Saint John – Digby)

This case study is an existing conventional RoPax service operated across the Bay of Fundy between Saint John, New Brunswick, and Digby, Nova Scotia, a route length of 39 nautical miles. The service is currently operated year round by Bay Ferries, Ltd. of Canada, who was granted the contract to operate this service in November, 1996. It was formerly operated by Marine Atlantic, a Canadian federal government agency. Conventional RoPax services from both Maine and New Brunswick to Nova Scotia have been operated in various incarnations for many years, and in the spring of 1998, conventional RoPax ferry service on the route from Bay Harbor, Maine to Yarmouth, Nova Scotia, was underwent a dramatic change with the introduction of a high speed 91 meter Incat RoPax vessel, *The Cat*, to replace the former conventional RoPax vessel, the *MV Bluenose*. This case study evaluates the potential for similar improvements on the Saint John to Digby route, with the use of SLICE and other comparative high speed vessels.

10.1 Introduction and Regional Overview

The area reviewed for this case study consists of the region surrounding the Bay of Fundy, extending northward from Maine, into New Brunswick, and east to Nova Scotia (see Figure 10-1). This area is referred to collectively here as the Bay of Fundy region. Important cities and towns in this region include Yarmouth, Digby, and further to the east, Halifax in Nova Scotia, and Saint John, Moncton (in Westmorland County), and Fredericton (in

FIGURE 10-1: MAINE AND ATLANTIC PROVINCES POPULATION DISTRIBUTION (1996/1997) AND EXISTING FERRY ROUTES



High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

York County) in New Brunswick.

The province of Nova Scotia consists of an extensive peninsula connected to the mainland of New Brunswick by the Isthmus of Chignecto, and the adjoining island of Cape Breton, which is separated from the rest of Nova Scotia by the Strait of Canso. The Northumberland Strait separates Nova Scotia from Prince Edward Island to the north. A ridge of low mountains runs lengthwise along much of the Nova Scotia, separating the province into one area that faces the Atlantic Ocean and is generally barren and windswept, and a second area facing the Bay of Fundy and Gulf of St. Lawrence that is generally arable, with fertile plains and river valleys.

The province of New Brunswick is bounded by the state of Maine on the west, the Province of Quebec to the north, the Bay of Fundy and Nova Scotia to the south, and the Northumberland Strait and the Gulf of St. Lawrence on the east. The geography of New Brunswick consists largely of undulating topography, with the Saint John River valley the major lowland area in the province.

Table 10-1 presents a general overview of the population in the Bay of Fundy region. During the last decade, the population of this region has been stable, increasing only slightly. In 1996, New Brunswick had a resident population of 738,133, with most living along the coasts and in the various river valleys.⁸² Nearly 33% of the resident population of New Brunswick are French-speaking, and New Brunswick is Canada's only officially bilingual province. Saint John is the largest city in the province, with a population of 72,494. Moncton has a

TABLE 10-1: MAINE AND ATLANTIC PROVINCES POPULATION

State, Province, or County	Year	
	1990 ⁽¹⁾ /1991 ⁽²⁾	1996 ⁽³⁾ /1997 ⁽⁴⁾
New Brunswick		
York County	82,326	85,719
Westmorland County	114,745	120,531
Kings County	62,122	64,724
Saint John County	81,462	79,302
New Brunswick Total	723,900	738,133
Nova Scotia		
Annapolis County	23,641	22,324
Digby County	21,250	20,500
Yarmouth County	27,891	27,310
Halifax County	330,846	342,966
Nova Scotia Total	899,942	909,282
Maine		
Hancock County	46,948	49,797
Penobscot County	146,601	145,911
Kennebec County	115,904	116,993
York County	164,587	172,589
Cumberland County	243,135	252,758
Androscoggin County	105,259	102,434
Maine Total	1,227,928	1,251,433
Regional Total	2,851,770	2,898,848

Sources:

- (1) U.S. Department of Commerce, Bureau of the Census.
- (2) Statistics Canada. 1991 Census.
- (3) Statistics Canada. 1996 Census.
- (4) U.S. Census Block Groups with Estimates and Projections. Caliper Corporation, and Applied Geographic Solutions.

⁸² Statistics Canada. 1996 Census.

population of 59,313 and Fredericton, the capital, has a population of about 47,154. In 1996, Nova Scotia had a resident population of 909,282.⁸³ Halifax is the largest city in the province, with a population of 113,910.

Major industries in Nova Scotia include fishing, agriculture, forestry, and mineral and energy resources. In 1997, the community/business/personal services sector of the economy in Nova Scotia represented nearly 40% of total employment in the province, with wholesale and retail trade representing 18.5% and manufacturing an additional 11.5%.⁸⁴ Tourism is also an important element of the Nova Scotia economy, with a total of 1,314,800 non-resident visitors to the province between May 15 and October 31 in 1997.⁸⁵ In New Brunswick, in 1998 employment in the service sector of the economy accounted for 38% of total employment in the province, with trade/commerce representing 18% and manufacturing a further 12.6%.⁸⁶

10.2 Ferry Market Overview and Operational Profiles

There are three primary RoPax ferry services connecting Nova Scotia to New Brunswick and to Maine. These include the Digby to Saint John route that is the focus of this case study, as well as a route between Bar Harbor, Maine and Yarmouth, Nova Scotia, and a route between Portland, Maine and Yarmouth, Nova Scotia.

The Saint John to Digby and the Bar Harbor to Yarmouth routes were formerly operated by Marine Atlantic, a Federal Crown Corporation. At one time, Marine Atlantic operated as many as 16 vessels on 8 routes throughout Atlantic Canada. Beginning in 1993, the Canadian Federal Government and Marine Atlantic shed many of these routes, beginning with the former route between New Brunswick and Prince Edward Island, now linked by the Confederation Bridge since May 1997. Many of the coastal routes in Newfoundland and Labrador were assumed by the provincial government, and then, in late 1996, the Bay of Fundy routes were awarded to Bay Ferries, Ltd., who continue to operate these routes as of 1999.

The route between Portland, Maine and Yarmouth, Nova Scotia, a distance of 182 nautical miles, is currently operated by Prince of Fundy Cruises. This route is serviced by the *Scotia Prince*, a conventional monohull RoPax ferry with a passenger capacity of 630 persons and a vehicle capacity of 220 AEU. Service is seasonal only, with daily overnight cruises during the summer season from early May to late October. Total one-way trip time is 11 hours, with departures from Portland at 9:00PM eastern time, and departures from Yarmouth at 9:00AM eastern time.⁸⁷ In 1997, a total of 322 one-way vessel trips were performed between May 1 and October 26, with a total of and 159,546 passenger boardings, 29,824 automobile boardings, and 274 tractor trailer boardings.⁸⁸ Adult fares during the 1999 seasons were \$80 one-way during the peak season of June 18 to September 15, and \$60 one-way during the remainder of the season.⁸⁹ Fares for children were \$40 and \$30 during the same time periods, and overnight cabin accommodations range in price from \$32 to \$165 one-way in addition to passenger fares. Automobile fares are \$98 one-way and 80\$ during the same time period.

In 1997, Bay Ferries took over the RoPax ferry route between Bar Harbor, Maine and Yarmouth, Nova Scotia, a route distance of 97 nautical miles. Service on this route was previously provided by the conventional RoPax ferry *MV Bluenose*. Using the *MV Bluenose*, the one-way trip time was 6 hours. When Bay Ferries was granted

⁸³ Statistics Canada. 1996 Census.

⁸⁴ Nova Scotia, Department of Finance, Statistics Division. *Nova Scotia Facts at a Glance*. WWW at URL <http://www.gov.ns.ca/fina/publish/pub08.htm>.

⁸⁵ Nova Scotia, Department of Finance, Statistics Division. *Nova Scotia Facts at a Glance*. WWW at URL <http://www.gov.ns.ca/fina/publish/pub08.htm>.

⁸⁶ New Brunswick. *The New Brunswick Economy. A Report to the Legislative Assembly*. 1999. Table 15, pg. 53.

⁸⁷ Yarmouth is located in the Atlantic time zone, and local departure time is at 10:00AM.

⁸⁸ Atlantic Provinces Transportation Commission. *1997 Annual Transportation Review*. WWW at URL <http://www.aptc.nb.ca/vwebsite/report/1997/97ferry.html>

⁸⁹ Unless otherwise noted, all monetary values are expressed in U.S. dollars throughout this chapter, with a Canadian dollar to U.S. dollar exchange rate of 0.7333 used.

the contract to operate this route in late 1996, an investment of approximately \$20 would have been required to update the *MV Bluenose*. Instead, Bay Ferries acquired *The Cat*, a 91 meter high speed RoPax catamaran which began operating on this route in 1998. Launched in September 1997, *The Cat* has a passenger capacity of 877 persons, a vehicle capacity of 240 automobile equivalent units (AEU) or a combination of automobiles and up to four motorcoaches, and an operating speed of 43 knots. With *The Cat*, one-way trip time is 2 hours and 45 minutes.

Service is seasonal between late May and late September, with a single round trip operated daily from late May to July 1, after which two round trips are provided daily until August 31, except for Wednesday when a single round trip is provided. For the month of September, a single round trip daily is provided, except for Sundays and Tuesdays when two round trips are provided. In 1998, approximately 424 one-way vessel trips were performed, providing a total capacity of about 370,000 seats. It is the company policy of Bay Ferries not to disclose patronage data. Assuming an average 60% load factor for the season, it is estimated that annual ridership is approximately 223,000 passenger boardings and 61,000 AEU.

Adult fares during 1999 were \$46.00 one-way during the peak season of June 20 to September 15, and \$29.00 one-way during the remainder of the season. For children fares were \$23.00 one-way and \$14.50 one-way for the same time periods, and for seniors were \$41.00 one-way and \$25.00. Up to 2 adults, 4 dependents and one automobile can obtain a discount fare of \$198.00 one-way and \$137.00 one-way during the same time periods.

It is notable that fares for the 1998 season when *The Cat* was introduced were kept at the same levels as the previous season when the *MV Bluenose* serviced this route. With fare levels remaining the same, and a total travel time reduced from 6 hours to 2 hours and 45 minutes, Bay Ferries reports that ridership during the 1998 season on *The Cat* approximately doubled over the previous year. It is estimated by one the number of vessel trips performed by *The Cat*, its capacity and an assumed average capacity utilization rate of 50% that patronage increased from approximately 95,500 annually to 191,000 annually. This suggests a demand elasticity with respect to travel time of about -0.89, meaning, for example, that a 10% reduction in travel time will result in a 8.9% increase in travel demand. This is generally consistent with the demand elasticity with respect to travel time observed in southeast Alaska by the Alaska Marine Highway System.⁹⁰

The 39 nautical mile RoPax ferry route between Saint John and Digby, also operated by Bay Ferries, is the focus of this case study and the remainder of this chapter. The conventional RoPax vessel *MV Princess of Acadia* serves this route. This vessel has a passenger capacity of 650 persons and a vehicle capacity of 260 AEU. Additional vessel particulars and general arrangements for the *MV Princess of Acadia* are presented in the following section of this chapter. With an operating speed of just over 13 knots, total one-way trip time on this route is currently 3 hours; however, the ferry saves what would otherwise be approximately 7 hours of driving time between Saint John and Digby. Formerly operated by Marine Atlantic, this route was awarded to Bay Ferries in late 1996. Current plans are for the Canadian government to phase out the annual subsidy for this route over the next four or five years. This subsidy ranged between \$3.1 million and \$6.5 million annually between 1993 and 1996. Therefore, the financial performance of this route with a different vessel such as SLICE or another comparative high speed vessel would likely be of paramount concern to Bay Ferries.

The number of annual one-way vessel trips performed on this route has been stable for several years, averaging approximately 1,460 one-way vessel trips per year (see Table 10-2). Service is provided year round on this route, with between one and three round trips offered daily depending upon the season (see Table 10-3).

⁹⁰ State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 10: Existing and Future Demand for Inter-Community Travel in Southeast Alaska*. May 14, 1998. Appendix B.

TABLE 10-2: SAINT JOHN - DIGBY HISTORICAL OPERATING AND FINANCIAL DATA (MARINE ATLANTIC)

	Calendar Year						
	1990	1991	1992	1993	1994	1995	1996
Operating Expenses (thousands of U.S. dollars)							
Terminal Operations	\$2,076	\$2,138	\$2,169	\$2,194	\$2,239	\$2,234	\$2,121
Terminal Maintenance	\$342	\$274	\$339	\$499	\$347	\$397	\$222
Vessel Operations	\$5,043	\$5,884	\$5,562	\$5,897	\$5,657	\$5,991	\$5,889
Vessel Maintenance	\$476	\$2,412	\$496	\$2,293	\$667	\$1,789	\$521
Vessel Services	\$59	\$0	\$0	\$0	\$0	\$0	\$0
Marine Shore	\$145	\$136	\$117	\$0	\$0	\$0	\$0
Operating Administration	\$138	\$164	\$235	\$256	\$332	\$302	\$155
Total Operating Expenses	\$8,880	\$11,008	\$8,918	\$11,139	\$9,243	\$10,713	\$8,909
Corporate Expenses	\$1,318	\$1,420	\$1,200	\$1,540	\$1,481	\$1,933	\$1,427
TOTAL EXPENSES	\$10,197	\$12,428	\$10,118	\$12,679	\$10,723	\$12,646	\$10,336
Vessel Operations and Passenger Boardings							
One-Way Vessel Trips	1,506	1,410	1,428	1,372	1,478	1,473	1,478
Total Vessel Hours	4,518	4,230	4,284	4,116	4,434	4,419	4,434
Total Non-Commercial Vehicle Boardings	60,504	54,287	50,580	57,374	60,217	60,988	56,952
Total Commercial Vehicle Boardings	21,132	17,937	19,560	20,273	23,216	23,679	22,487
Total Passenger Boardings	213,667	196,219	183,791	195,513	208,450	207,419	195,952

Source: Transport Canada - Marine Policy & Programs - Yearly financial statement 1990 to 1996 for Princess of Acadia operations by Marine Atlantic between Saint John and Digby.

Notes:
 A Canadian dollar to U.S. dollar exchange rate of 0.7333 is used (the CY1996 average)
 All dollar values are current ("then-year") dollars.

As with their Bar Harbor to Yarmouth route, it is the company policy of Bay Ferries not to disclose patronage data, and despite the contribution of federal operating and non-operating subsidies to Bay Ferries by Transport Canada, there is no requirement by either organization to release operating and performance data into the public

TABLE 10-3: SAINT JOHN - DIGBY 1999 OPERATING SCHEDULE

Saint John to Digby 1999 Operating Schedule (Departure Times from Saint John)							
1999 Date	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
January 1 - May 15	12:15	12:15	12:15	12:15	12:15	12:15	23:00
		23:00	23:00	23:00	23:00	23:00	
May 16 - June 19	12:15	12:15	12:15	12:15	12:15	12:15	12:15
	23:00	23:00	23:00	23:00	23:00	23:00	23:00
June 20 - October 16	09:00	00:45	00:45	00:45	00:45	00:45	00:45
	16:45	09:00	09:00	09:00	09:00	09:00	09:00
		16:45	16:45	16:45	16:45	16:45	16:45
October 17 - December 31	12:15	12:15	12:15	12:15	12:15	12:15	23:00
		23:00	23:00	23:00	23:00	23:00	
Digby to Saint John 1999 Operating Schedule (Departure Times from Digby)							
1999 Date	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
January 1 - May 15	08:00	16:30	08:00	08:00	08:00	08:00	12:00
	16:30		16:30	16:30	16:30	16:30	
May 16 - June 19	08:00	08:00	08:00	08:00	08:00	08:00	08:00
	16:30	16:30	16:30	16:30	16:30	16:30	16:30
June 20 - October 16	13:00	05:00	05:00	05:00	05:00	05:00	05:00
	20:45	13:00	13:00	13:00	13:00	13:00	13:00
		20:45	20:45	20:45	20:45	20:45	20:45
October 17 - December 31	08:00	16:30	08:00	08:00	08:00	08:00	12:00
	16:30		16:30	16:30	16:30	16:30	

Notes:
 All times are Atlantic time, 24 hour clock

High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

domain. However, data from the full calendar year 1996 and prior years are available, since at that time Marine Atlantic operated the route with the same vessel and with the same vessel and schedule very similar to the current schedule. These data reveal that for calendar year 1996, total passenger boardings on this route were 195,952, total non-commercial vehicle boardings were 56,952, and total commercial vehicle boardings were 22,487.

As is the case with fares on the Bar Harbor to Yarmouth route, passenger and vehicle fares on the Saint John to Digby route vary during the operating season, with the highest fares during the peak summer months. The 1999

TABLE 10-2: SAINT JOHN - DIGBY 1999 FARES

1999 Passenger Fares (U.S. dollars)		
Fare Class	Off Season⁽¹⁾ One-Way Fare	Summer Season⁽²⁾ One- Way Fare
Adults 13-64 years	\$14.50	\$18.30
Children 5-12 years	\$7.30	\$9.20
Children under 5 years	free	free
Senior Citizens 65 years +	\$12.80	\$16.10
Family Fare ⁽³⁾	\$77.00	\$95.30
Non-Commercial Vehicle Fares		
Vehicle & Trailer, Single or Combination to 20'	\$33.00	\$40.30
Vehicle & Trailer, Single or Combination to 20' to 30'	\$57.20	\$66.00
Vehicle & Trailer, Single or Combination to 30' to 40'	\$76.30	\$91.70
Vehicles Over 40'	\$110.00	\$132.00
Mini Buses to 20'	\$33.00	\$40.30
Mini Buses 20' to 30'	\$57.20	\$66.00
Motorcoaches	\$102.70	\$124.70
Motorcycle	\$18.30	\$22.00
Commercial Vehicle Fares (Truck/Tractor Trailers)		
Over 20' to 30'	\$57.20	\$57.20
Over 30' to 40'	\$76.30	\$76.30
Over 40' to 50'	\$110.00	\$110.00
Over 50' to 60'	\$132.00	\$132.00
Over 60' to 70'	\$148.90	\$148.90
Over 70' to 80'	\$176.00	\$176.00
Over 80' to 90'	\$198.00	\$198.00
Over 90' to 100'	\$220.00	\$220.00
Commercial Vehicle Fares (Drop Trailers)⁽⁴⁾		
Over 20' to 30'	\$57.20	\$57.20
Over 30' to 40'	\$76.30	\$76.30
Over 40' to 50'	\$110.00	\$110.00
Over 50' to 60'	\$132.00	\$132.00
Handling Fees	\$29.30	\$29.30

Notes:

(1) Off Season is September 16 to June 19.

(2) Summer Season is June 20 to September 15.

(3) The "Family Fare" is for an automobile less than 20' in length, plus a maximum of 2 adults and 4 dependents.

(4) "Drop Trailers" are the trailer portion only of tractor trailer, which is left on the vessel, then picked up at the destination by another tractor.

fare schedule for the Saint John - Digby route is present in Table 10-2.

10.3 Existing and Proposed Vessels

The existing baseline RoPax ferry service on the Saint John to Digby route is provided using the vessel *MV Princess of Acadia*. Vessel particulars for the *MV Princess of Acadia* are presented in Table 10-3. The *MV Princess of Acadia* was built in 1971, and has a passenger capacity of 650 persons, and a vehicle capacity of 260 AEU. Passenger amenities include a cafeteria, seating lounges, bar, video arcade, and news stand. Seven cabins

**TABLE 10-3: BAY OF FUNDY CASE STUDY
- PRINCESS OF ACADIA VESSEL
PARTICULARS**

Particulars	MV Princess of Acadia
Vessel Builder	Saint John Shipbuilding
Vessel Type	RoPax
Hull Construction	Steel
Year Entered Service	1971
Annual Maintenance Cost ⁽¹⁾	\$1,338,070
Principal Dimensions (feet)	
Length Overall	480.0
Beam Overall	67.3
Full Load Draft	15.0
Capacities	
Passenger Capacity	650
Vehicle Capacity (AEU) ⁽²⁾	260
Fuel Capacity (gallons)	80,696
Vessel Manning	
Deck Crew Officers	5
General Deck Crew	9
Engineering Officers	3
Engine Crew	6
Onboard Passenger Service	16
Total Crew Complement	39
Weights (long tons)	
Gross Tonnage ⁽³⁾	10,050
Propulsion	
Total Installed Horsepower ⁽⁴⁾	9,000
Service Speed (knots)	13.5
Fuel Consumption (gal. per hour at indicated speed)	
GPH at service speed	283
GPH at 10.0 knots	198
GPH at 7.0 knots	138
GPH at 3.5 knots	66
GPH at idle	43

Sources:

- (1) Transport Canada. Marine Policy & Programs. Yearly financial statement 1989 to 1996 for Princess of Acadia operations by Marine Atlantic between Saint John and Digby.
- (2) Automobile equivalent unit (AEU), typically a minimum of a 17' x 8.5' space on the vehicle deck.
- (3) Gross tonnage or "gross register tonnage" refers to the total measured cubic volume (100 cubic feet per ton of 2,240 lbs.), based on varying formulas.
- (4) Estimate based on comparison with Alaska Marine Highway Vessels, and accounting for differences in operating speed and displacement.

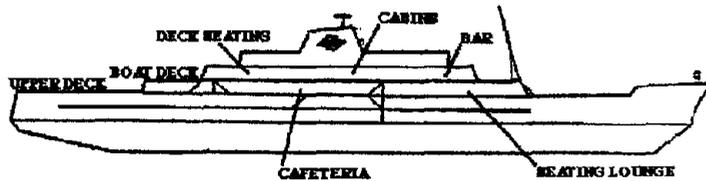
are also available that include private showers and bunks. The vehicle deck can accommodate motorcoaches and tractor trailers, as well as automobiles, and vehicles can be loaded from both the bow and the stern. Figure 10-2 contains a recent photograph of the *MV Princess of Acadia*, in its Bay Ferries paint scheme. General arrangements for the *MV Princess of Acadia* are presented in Figure 10-3.

FIGURE 10-2: MV PRINCESS OF ACADIA

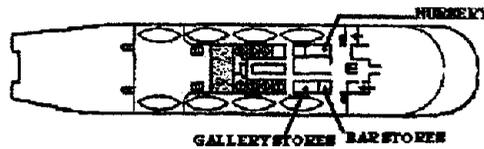


FIGURE 10-3: MV PRINCESS OF ACADIA GENERAL ARRANGEMENTS

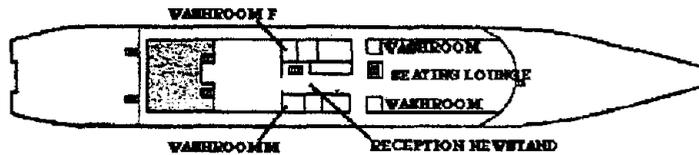
MV PRINCESS OF ACADIA: OUTBOARD PROFILE



MV PRINCESS OF ACADIA: BOAT DECK



MV PRINCESS OF ACADIA: UPPER DECK



Source: WWW at URL <http://www.gaxcities.com/TheTropics/Bay/8898/index.html>

TABLE 10-4: BAY OF FUNDY CASE STUDY - HIGH SPEED VESSELS PARTICULARS

Particulars	SLICE Variant	Comparative High Speed Vessels	
	SLICE 600 ⁽¹⁾	AMD K50 ⁽²⁾	Incat 74m ⁽³⁾
Vessel Designer	Lockheed Marine Systems	Advanced Multihull Designs / Incat	Incat
Vessel Type	RoPax	RoPax	RoPax
Hull Construction	Steel	Aluminum	Aluminum
Purchase Price (1997 US\$)	\$37,000,000	\$30,000,000	\$28,900,000
Annual Maintenance Cost ⁽⁴⁾	\$1,295,000	\$1,050,000	\$1,011,500
Principal Dimensions (feet)			
Length Overall	213.2	262.7	243.2
Beam Overall	105.0	62.3	85.3
Full Load Draft	28.5	7.1	9.6
Main Passenger Deck Freeboard	31.0	21.0	data not available
Vehicle Deck Freeboard	21.5	11.0	data not available
Capacities			
Passenger Capacity	600	400	597
Vehicle Capacity (AEU) ⁽⁵⁾	90	89	84
Fuel Capacity (gallons)	39,067	12,680	10,067
Vessel Manning			
Deck Crew Officers	2	2	2
General Deck Crew	5	4	5
Engineering Officers	2	1	2
Engine Crew	3	2	3
Onboard Passenger Service	8	7	8
Total Crew Complement	20	16	20
Weights (long tons)			
Payload	177.9	138.9	154.6
Total Deadweight	355.0	174.0	199.0
Displacement	1,500.0	612.0	700.0
Propulsion			
Main Engines	(2) RLM1600 gas turbines or equivalent	(4) Ruston 16 RK270 marine diesel engines	(4) Ruston 16 RK270 marine diesel engines
Total Installed Horsepower	36,000	29,476	22,025
Service Speed (knots)	30	45	39
Range at Service Speed (nmi)	620	390	390
Fuel Consumption (gallons per hour at indicated speed)			
GPH at service speed	1,891	1,439	933
GPH at 30.0 knots	1,891	590	557
GPH at 15.0 knots	1,757	344	270
GPH at 7.0 knots	484	246	177
GPH at 3.5 knots	450	222	155
GPH at idle	284	216	149

n/a (not applicable)

Sources:

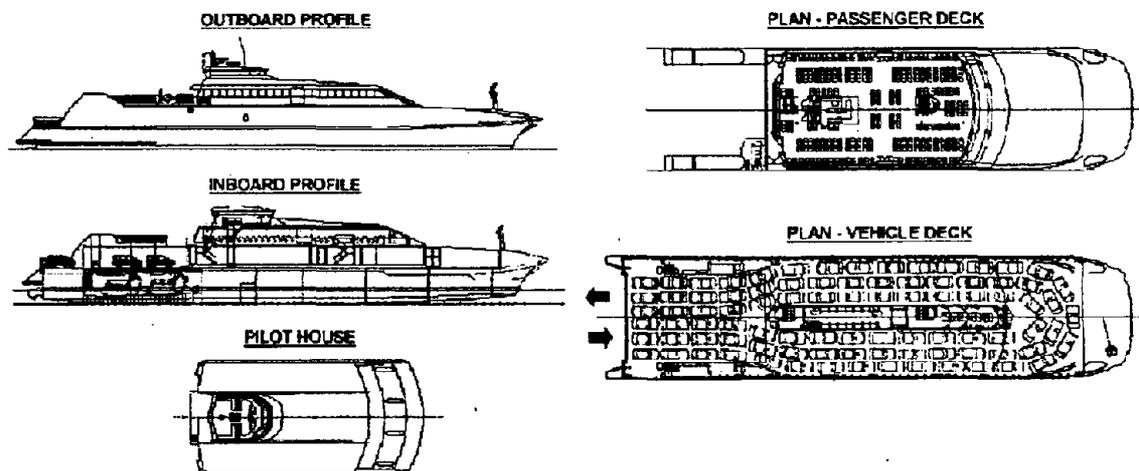
- (1) Lockheed Marine Systems. SLICE 600 Passenger Vehicle Ferry. Technical Data Package. April 1995.
(2) Advanced Multihull Designs. Also, *Fast Ferry International*, October 1998, pp. 21-24. Also, *Jane's High-Speed Marine Transportation*, 1998-1999. Also, Volpe Center estimates for some data elements, as per discussion in Chapter 8.
(3) Gladding, Hearn Shipbuilding, the Duclos Corporation. Also, Volpe Center estimates for some data elements, as per discussion in Ch.
(4) For a nominal vessel operating hours of 3,000 annually, as per discussion in Chapter 8.
(5) Automobile equivalent unit (AEU), typically a minimum of a 17' x 8.5' space on the vehicle deck.

The SLICE 600 is selected as the primary SLICE variant for this case study, primarily because it is a RoPax design, and is of a generally similar passenger and vehicle capacity as the baseline and comparative high speed vessels. The AMD K50 RoPax high speed catamaran and the 74 meter Incat RoPax high speed catamaran are also reviewed as comparative high speed vessel types. Vessel particulars for the SLICE 600, AMD K50, and Incat 74 meter WPC are presented in Table 10-4.

The SLICE 600 is a conceptual design of a steel hulled 65 meter SLICE RoPax ferry. The vessel would accommodate approximately 600 passengers and 90 automobiles, or a combination of 4 motorcoaches and 75 automobiles, with access to the vehicle deck from stern. Passengers are accommodated on two decks, with approximately 422 in economy class seating in two separate compartments on the gallery deck, with each compartment having its own restroom and snack bar. An additional 178 passengers are accommodated on the upper deck in first class or lounge type seating. Two gas turbine engines are to deliver an operating speed of 30 knots. General arrangements for the SLICE 600 are presented earlier in Chapter 4.

The AMD K50 is an aluminum hulled 80 meter high speed conventional catamaran, with a typical capacity of 400 passengers and 89 automobiles, or a combination of up to 4 motorcoaches and 46 automobiles. Although generally referred to as the AMD K50, Incat is also jointly involved in the design of the K50, with AMD responsible for the design of the main structure and propulsion system, while Incat is responsible for the design of the superstructure and engineering. The first AMD K50 to be built was delivered to the Dae A Gosh Ferry Company in South Korea in 1995 by Incat Tasmania. An additional three K50 vessels are to be built under license in China by Afai Ships. The first of these three, designated *Afai08*, was launched in mid 1998. Powered by four marine diesel engines, the AMD K50 has an operating speed of 45 knots. Passengers are accommodated on a single passenger deck, divided into two lounge areas with a bar and snack facilities. A gift shop and other passenger amenities are located in the center of the vehicle deck. As can be seen in the general arrangements presented in Figure 10-4, the vehicle deck is arranged to provide for simultaneous loading and unloading of vehicles.

FIGURE 10-4: AMD K50 GENERAL ARRANGEMENTS



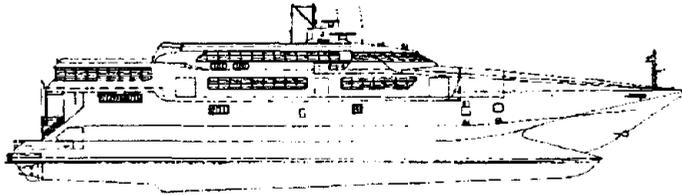
Source: Advanced Multihull Designs (AMD). WWW at URL <http://www.amd.com.au/designs/nf08/nf08.html>

The Incat 74 meter is an aluminum hulled 74 meter high speed wave piercing catamaran, with a typical capacity of between 350 to 600 passengers and 84 to 106 automobiles. The specific design evaluated here is assumed to have a passenger capacity of 597 and a vehicle capacity of 84 AEU. The Incat 74 meter wave piercing catamaran is generally considered the first large, high speed RoPax catamaran to be designed and built, with a total of nine delivered between 1990 and 1994. These vessels have operated around the world, including Europe, South America, New Zealand, and as of the fall of 1999, the United States and Caribbean, and have served as the basis for the further development of larger vessels in the line of Incat 74, 78, 81, 86, 91 and 96 meter wave piercing catamarans. Powered by four marine diesel engines, the Incat 74 meter WPC has an operating speed of 39

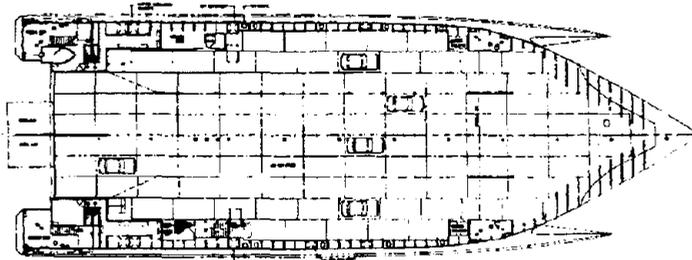
knots. For the 74 meter WPC assumed for this case study, passengers are accommodated on two decks, with approximately 500 on the main passenger deck in a mix of economy and first class seating, and approximately 100 on an upper passenger deck in a lounge area. Restrooms, and a bar and snack area are located on each passenger deck, and a gift shop is located on the main passenger deck. Typical general arrangements for the Incat 74 meter WPC are presented in Figure 10-5.

FIGURE 10-5: INCAT 74 METER WPC GENERAL ARRANGEMENTS

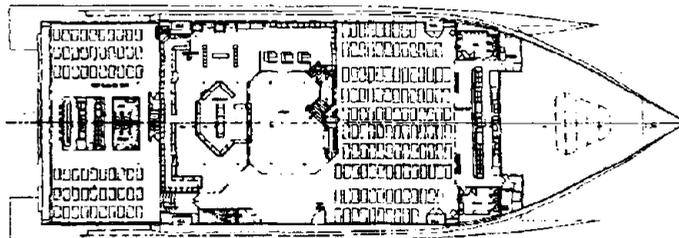
INCAT 74 METER WPC: OUTBOARD PROFILE



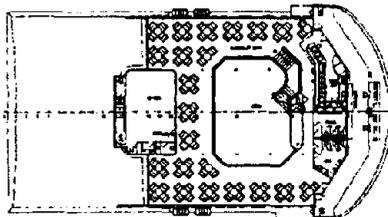
INCAT 74 METER WPC: MAIN VEHICLE DECK



INCAT 74 METER WPC: MAIN PASSENGER DECK



INCAT 74 METER WPC: UPPER PASSENGER DECK



10.4 Related Infrastructure and Facilities

Because Bay Ferries currently operates RoPax ferry service serving Saint John and Digby, both ports currently have existing RoPax ferry terminal facilities that would be suitable for many of the alternative vessel types analyzed later in this chapter.

10.4.1 Saint John

Saint John is one of the most important ports in eastern North America. The port is located at the mouth of the Saint John River, on the north shore of the Bay of Fundy. It is administered by the Saint John Port Authority, and is adequately served by road and rail connections to the rest of New Brunswick and beyond. The port handles approximately 15 million tons of cargo annually, and in recent years cruise ship traffic has also been on the increase, with more than 39,000 cruise ship passengers expected during 1999. Cruise ships have historically docked at Rodney Terminal on the west side of the harbor, but since mid 1999, virtually all cruise ships have docked at newly developed facilities on the east side of the harbor.

The port is well sheltered, and open to shipping year round. The main channel, which is located to the east of Partridge Island, is dredged to a depth of 27 feet, and there are many wharves having berths with depths in excess of 33 feet. A breakwater joins Partridge Island to Negro Point on the mainland, just south of the ferry terminal. Berthing accommodations in Saint John Harbor extend along both sides of the main harbor, and in Courtenay Bay just east of the main harbor (see Figure 10-6). The existing ferry terminal is located at the south end of the west side of the harbor, just under one mile from Partridge Island (see Figure 10-6 and Figure 10-7). The ferry terminal wharf is 830 feet long, with a depth alongside of approximately 16 feet, and a deck height of approximately 10 feet. These depths are marginal relative to the 28.5 foot draft of the SLICE 600, but would,

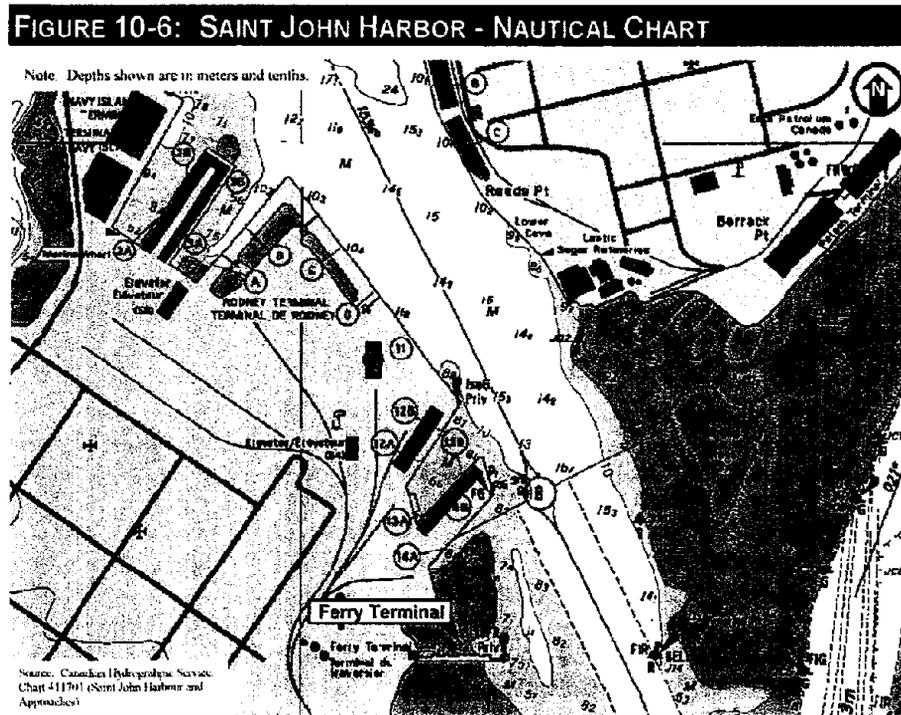


FIGURE 10-7: SAINT JOHN HARBOR AERIAL PHOTO

Source: Sailing Directions: Nova Scotia (Atlantic Coast) and Bay of Fundy. First Edition 1990. Canadian Hydrographic Service. Page 274.

however, be suitable for the AMD K50 and the Incat 74 meter WPC. Fuel and supplies of all kinds are available in Saint John. For the period 1989 to 1996, expenditures by Marine Atlantic on "Terminal Operations" and "Terminal Maintenance" ranged from between \$9.50 and \$13.80 per passenger boarding.⁹¹ It is expected that similar expenses would be experienced regardless of the type of vessel being used.

10.4.2 Digby

The town of Digby, with a population of approximately 2,650, is located at the southwest end of Annapolis Basin, an estuary of the Annapolis River. Digby Gut is a deep water passage from the Bay of Fundy into Annapolis Basin. Major local industries include commercial fishing, with Digby home to the world's largest scallop fleet, as well as lumber and farming. At Digby, the controlling depth is 20 feet in the narrow approach channel leading to the wharves. The old ferry wharf, which extends in a southeast direction from the town, is now a public wharf and has a berth of 336 feet and a controlling depth of 13 feet. South of the old ferry wharf is the Digby Public Wharf, which has a controlling depth of 20 feet along its 328 foot outer east face, and a deck height of 10 feet. Most ship stores are available in Digby, as well as diesel oil and a small boat repair facility.

The current ferry terminal is located approximately 2 miles north of the town itself and its public wharf facilities at Rattling Beach, on the west side of Digby Gut near the entrance to Annapolis Basin (see Figure 10-8 and Figure 10-9). The current ferry terminal wharf is 460 feet long with the berth having a controlling depth of 16 feet.⁹² This depth is unsuitable for the 28.5 foot draft of the SLICE 600, however the AMD K50 and Incat 74 meter WPC could be easily accommodated. As in the case of Saint John, typical expenditures between 1989 and 1996 by Marine Atlantic on terminal operations and maintenance suggest terminal related costs of between \$9.50 and \$13.80 per passenger boarding.

⁹¹ Transport Canada. Marine Policy and Programs. Yearly financial statement 1990 to 1996 for Princess of Acadia operations by Marine Atlantic between Saint John and Digby.

⁹² Sailing Directions: Nova Scotia (Atlantic Coast) and Bay of Fundy. First Edition 1990. Canadian Hydrographic Service. Page 274.

FIGURE 10-8: DIGBY NAUTICAL CHART

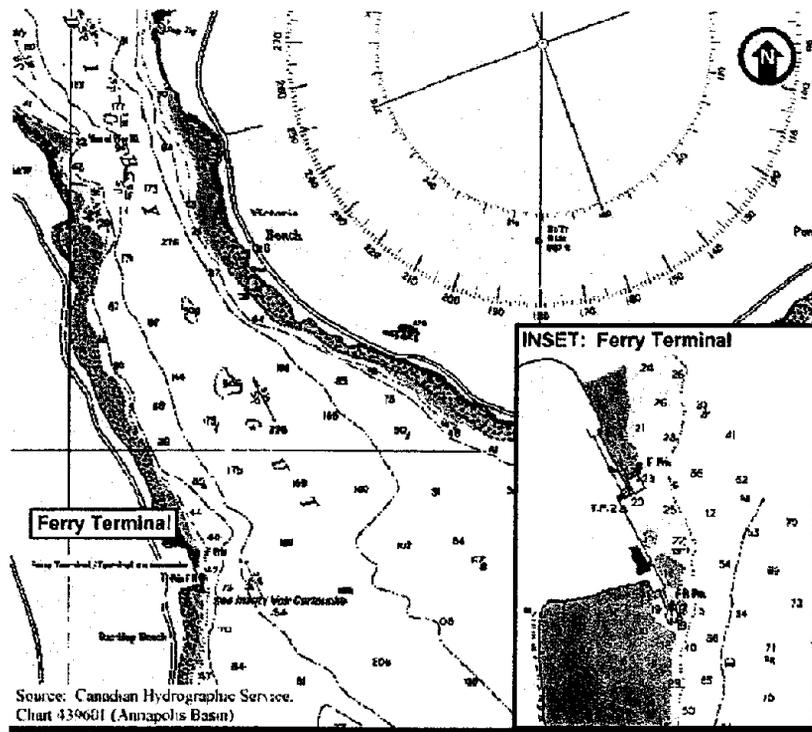
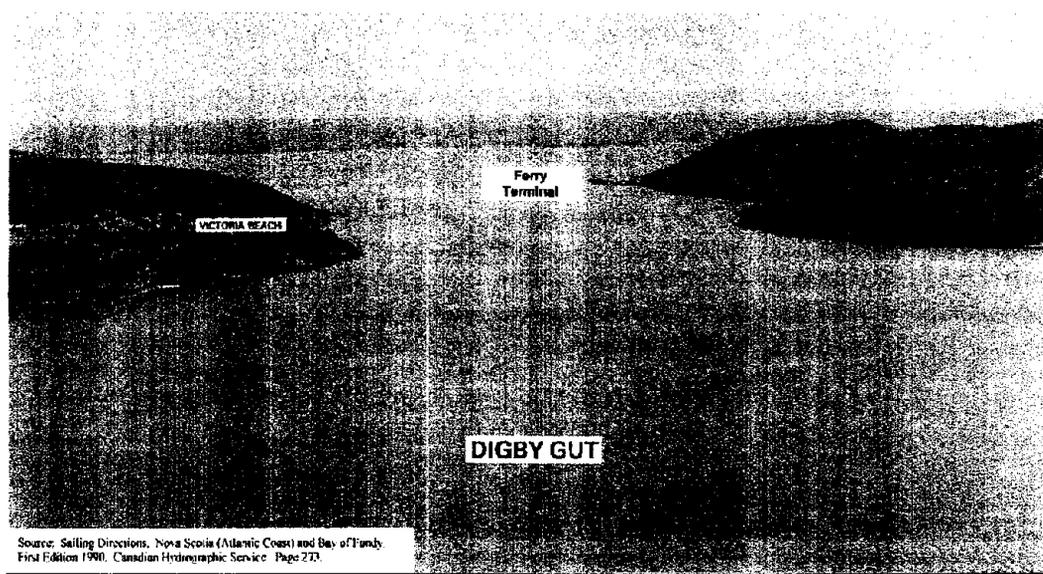


FIGURE 10-9: DIGBY (DIGBY GUT) AERIAL PHOTO



10.5 Weather and Wave Climate

Nova Scotia and New Brunswick are subject to both continental air masses from the west, as well as the maritime influence of the Atlantic Ocean. These provinces therefore experience a relatively wide fluctuation in temperatures on both a day to day and season to season basis. Fog occurs frequently in the Bay of Fundy, particularly in the spring and summer, as noted in the historical meteorological data that is presented in Table 10-7 for the ferry route area. Coastal areas are generally cooler than interior areas in the summer, while in the winter temperatures are milder nearer the coast than inland. The first significant amounts of snow usually arrive between mid November and mid December. During the winter months, winds are generally from the northwest, while in the summer prevailing winds tend to be from the south and southwest. Fog is usually associated with winds from the southeast to southwest. Winds of over 20 knots are relatively frequent except from late May to early September, when winds over 20 knots occur less than 10% of the time.

Fog is probably the greatest impediment to visibility. In winter, fog and low visibility occur at sea only 2 to 4 days per month, but in late spring and early summer fog can be frequent and persistent. July is the month with

TABLE 10-7: METEOROLOGICAL TABLES FOR SAINT JOHN - DIGBY ROUTE

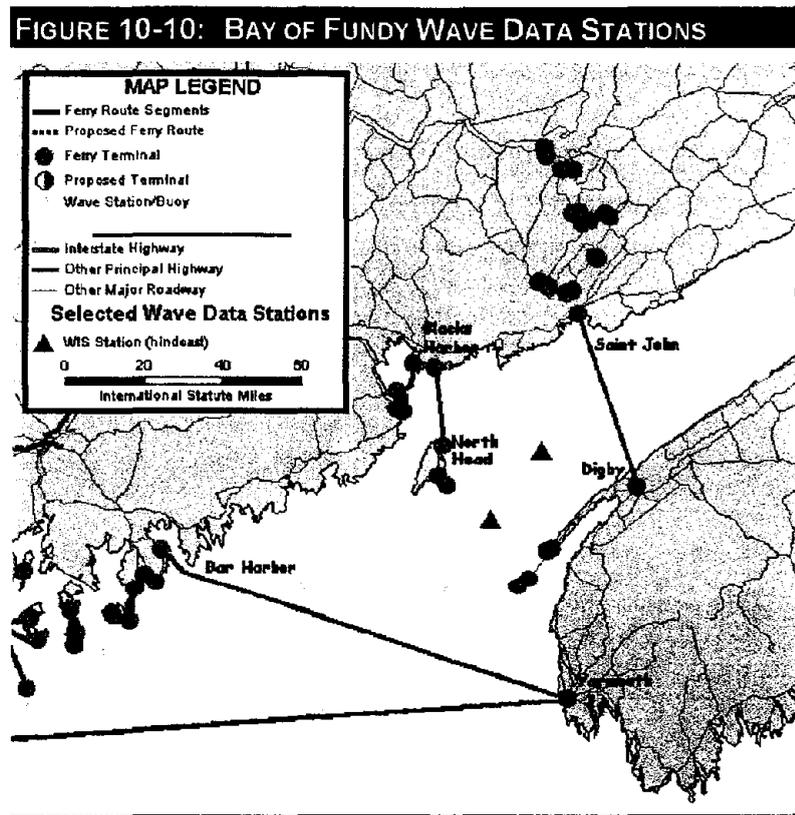
Month	Mean Sea Level Pressure	Temperature					Relative Humidity	Cloud Amount Scale 0-10	Precipitation		Days with					Wind Direction									
		Average	Mean Daily		Extreme				Total	Max. In 24 Hrs.	Rain	Snow	Precipitation	Fog	Thunder	% of Observations From									
			Max.	Min.	Max.	Min.										N	NE	E	SE	S	SW				
	kPa	°C	°C	°C	°C	°C	%	mm	mm																
January	101.3	7.8	2.6	-12.9	14.0	-31.7	77	6.4	148.8	83.0	6	13	16	3	0.1	23	9	6	5	5	6				
February	101.2	7.5	-2.2	12.8	11.1	36.7	75	5.9	115.7	95.0	5	12	14	3	0.1	20	9	7	5	7	8				
March	101.2	2.5	2.1	7.1	13.9	-30.0	76	6.3	114.1	74.0	7	11	14	5	0.3	19	11	8	6	9	10				
April	101.3	3.2	7.9	1.5	22.8	16.7	74	6.5	107.3	125.5	10	5	13	6	0.4	18	10	8	8	13	13				
May	101.4	9.0	14.4	3.6	30.0	7.8	74	6.8	107.7	66.5	13	1	13	10	1.2	12	7	9	9	20	18				
June	101.4	13.8	19.2	8.4	31.7	2.2	79	7.0	94.2	54.1	14	0	14	12	2.4	9	7	7	8	26	23				
July	101.4	16.9	22.2	11.6	32.8	1.1	81	6.5	103.4	72.6	12	0	12	17	2.9	7	3	4	7	31	24				
August	101.5	16.6	21.7	11.4	34.5	-0.6	81	6.0	102.0	125.2	12	0	12	14	2.3	9	5	5	6	26	21				
September	101.7	12.7	17.6	7.7	28.9	6.7	81	5.7	111.8	74.9	12	0	12	13	1.1	13	7	6	6	18	19				
October	101.6	7.6	12.1	3.1	25.6	-10.6	80	5.7	127.7	85.3	12	1	12	9	0.5	15	7	5	6	15	16				
November	101.5	2.3	6.3	1.6	21.7	15.3	81	6.8	145.7	154.4	13	4	14	5	0.2	18	9	6	7	11	10				
December	101.4	-4.8	0.1	-9.3	16.1	-30.9	79	6.2	166.0	105.7	8	12	17	3	0.1	21	9	5	6	7	7				
Means	101.4	5.0	9.9	0.1			78									15.2	7.7	6.2	6.3	15.6	14.5				
Totals									1444.4	154.4	124	59	163	100	11.6										
Extremes					34.5	36.7																			
No. of Years of Observations	28	32	32	32	32	32	28	13	32	32	32	32	32	30	24	26	26	26	26	26	26	26	26	26	26

Source: Sailing Direction, Nova Scotia (Atlantic Coast) and Bay of Fundy, First Edition 1990. Canadian Hydrographic Service. Page 65. Climate data for Saint John, NB.

the most frequent fogs, which historically have been reported in about 40% of ship reports for this month. In the period of May to August, some 10 to 14 days per month are foggy, while in April and September the average range is 5 to 10 days per month. Visibility can also be impaired by snow, which falls on about 10 days per month from December to March.

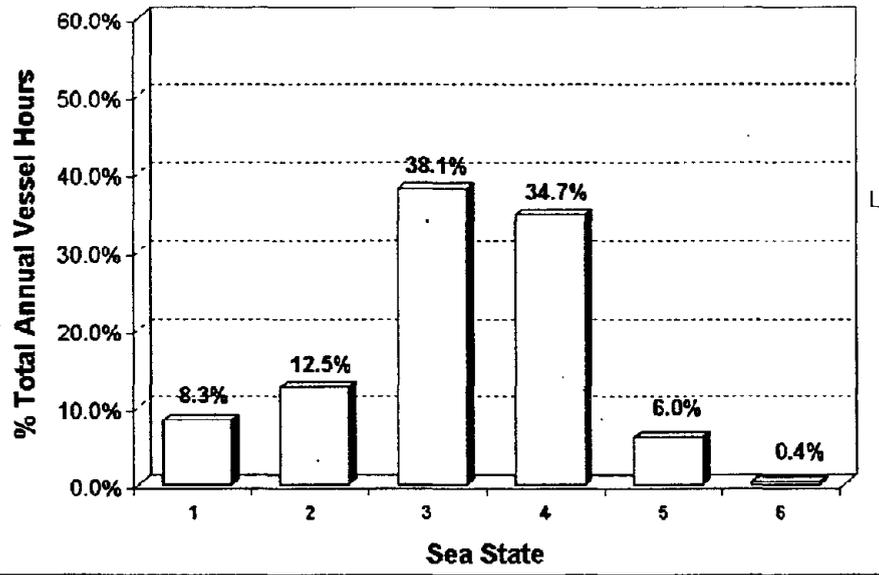
The Bay of Fundy is generally considered ice free, due in large part to strong tidal action and mixing. During extreme winters, some ice can be found in Annapolis Basin near Digby, but usually only briefly and in the most extreme winter conditions.

As discussed earlier in Chapter 8, the Volpe Center conducted a detailed wave climate analysis of each case study region. Sources used for this region consisted of hindcast data obtained from the U.S. Army Corps of Engineers, Wave Information Study (WIS). A total of 116,880 data records were utilized, spanning a period of approximately 20 years between 1976 and 1995. Figure 10-10 presents the location of the particular WIS stations from which data were obtained. Based on the actual baseline 1997 operating schedule for the Saint John to Digby route, and a detailed definition of the location and operating speed on each segment of the route, a distribution of annual vessel operating hours by sea state was developed. The results of this analysis, presented in Figure 10-11, reveal that significant wave heights in excess of sea state 4 (4.1 to 8.2 feet) are experienced 6.4% of vessel operating hours. These findings are also generally consistent with the wave height data presented in the U.S. Coast Pilot, which indicates that wave heights of 10 feet or greater are reported approximately 6.4%



percent of the time in the Gulf of Maine. Bay Ferries reports that typically there are only about 5 to 10 trips annually cancelled due to poor weather or sea state conditions, out of the total of 1,450 or more one-way vessel trips typically performed annually.

FIGURE 10-11: DISTRIBUTION OF ANNUAL VESSEL OPERATING HOURS BY SEA STATE (SAINT JOHN - DIGBY ROUTE)



10.6 Navigational Considerations

In Saint John, regulations require that no vessel shall move in the harbor at a rate of speed that may endanger life or property. For vessels arriving or leaving Saint John Harbor, a traffic separation scheme is in effect, and a vessel traffic services system is in operation for the approaches to and in Saint John Harbor.⁹³ The main channel into Saint John Harbor is dredged to a depth of 27 feet, however silting is a problem and depths are subject to change. Relative to the 28.5 foot draft of the SLICE 600, the controlling depth in the main channel is therefore not adequate. Depth alongside at the ferry terminal is approximately 16 feet, which is also inadequate for the SLICE 600, but suitable for the other comparable high speed vessels analyzed in this case study. The harbor has extremely high tides however, with the range at spring tides being 29 feet, and strong currents that are caused by the inflow and outflow of water from the Saint John River. The operational and scheduling constraints that would be imposed by tide restricted operations would likely be unacceptable, however. There are other wharves in the harbor that have berths with depths in excess of 33 feet, however these are primarily cargo related facilities that do not have suitable facilities to accommodate passengers and vehicles.

The tides in the Bay of Fundy are considered among the highest in the world. Because the Bay of Fundy has a funnel shape, tidal variations are amplified more than would otherwise be the case, with tidal differences in excess of 48 feet experienced in the upper parts of the bay. Tide related currents in the Bay of Fundy can reach a speed of 5 to 6 knots.

⁹³ *Sailing Directions: Nova Scotia (Atlantic Coast) and Bay of Fundy*. First Edition 1990. Canadian Hydrographic Service. Page 325.

Although controlling depths in Digby Gut and approaching the existing Digby ferry terminal are well in excess of 40 feet, the controlling depth alongside at the ferry terminal berth is 16 feet, again inadequate for the SLICE 600, but suitable for the other comparable high speed vessels analyzed in this case study.

Utilizing the *MarineMap* electronic charting software, a detailed representation of the planned route was created. The total route distance between the existing ferry terminals in Saint John and Digby is 39 nautical miles. This total is comprised of approximately 4 nautical miles from the Saint John ferry terminal to a point approximately 2.5 miles south of Partridge Island, 32 nautical miles in the Bay of Fundy, and 3 nautical miles from a point about 0.8 nautical miles outside of Digby Cut in the Bay of Fundy, to the ferry terminal at Rattling Beach.

Given this operating profile, total one-way trip time from terminal to terminal is 3 hours using the *MV Princess of Acadia*. With the SLICE 600, total one-way trip time would be 1 hour and 32 minutes, with an operating speed of 30 knots in the Bay of Fundy, and 15 knots for the 4 nmi and 3 nmi legs in the approaches to and within Saint John Harbor and at Digby. With the AMD K50, total one-way trip time would be 1 hour and 11 minutes, with an operating speed of 45 knots in the Bay of Fundy, and 15 knots for the 4 nmi and 3 nmi legs in the approaches to and within Saint John Harbor and at Digby. Finally, with the Incat 74 meter WPC, total one-way trip time would be 1 hour and 17 minutes, with an operating speed of 39 knots in the Bay of Fundy, and 15 knots for the 4 nmi and 3 nmi legs in the approaches to and within Saint John Harbor and at Digby.

10.7 Environmental Considerations

Possible environmental issues concerning the use of high speed vessels including SLICE in the Bay of Fundy include both possible impacts upon marine mammals, as well as possible impacts from wake and wash. During the summer months, many species of whales live in the Bay of Fundy. Most of the whales are in the Bay of Fundy from June until October, and migrate here to feed primarily upon herring, krill and other schooling fish. The lower Bay of Fundy is designated one of the critical habitats for the northern right whale. During the summer and fall months it is a feeding and nursery area for this and other species of whales. Other common species in this area include the beluga, humpback and minke whales, with occasional blue whale sightings. Harbour seals are also a common marine animal living in the bay.

In addition to possible impacts upon marine mammals in the region, wake wash impacts could be a potential issue for the catamaran vessels. When the 91 meter WPC vessel *The Cat* was introduced by Bay Ferries onto the Bar Harbor to Yarmouth route, the harbor master in Bar Harbor brought charges of "imprudent speed" against two of captains of *The Cat* in late 1998, indicating that *The Cat* was getting too close to the harbor before slowing down, causing wakes which damaged the town floats, banged boats against docks and even resulted in some minor injuries to boaters.²⁴ The SLICE 600 would likely have an advantage in this respect, because of the low wake signature of the SLICE design as measured in the Fox Associates study during the spring of 1999.

²⁴ Porter, Anne. "Seasons Ends Friday for High Speed Cat." The Ellsworth American, Ellsworth American.com, WWW at URL http://www.ellsworthamerican.com/archive/10-29-98/ea_story3_10-29-98.html. October 29, 1998.

Although controlling depths in Digby Gut and approaching the existing Digby ferry terminal are well in excess of 40 feet, the controlling depth alongside at the ferry terminal berth is 16 feet, again inadequate for the SLICE 600, but suitable for the other comparable high speed vessels analyzed in this case study.

Utilizing the *MarineMap* electronic charting software, a detailed representation of the planned route was created. The total route distance between the existing ferry terminals in Saint John and Digby is 39 nautical miles. This total is comprised of approximately 4 nautical miles from the Saint John ferry terminal to a point approximately 2.5 miles south of Partridge Island, 32 nautical miles in the Bay of Fundy, and 3 nautical miles from a point about 0.8 nautical miles outside of Digby Cut in the Bay of Fundy, to the ferry terminal at Rattling Beach.

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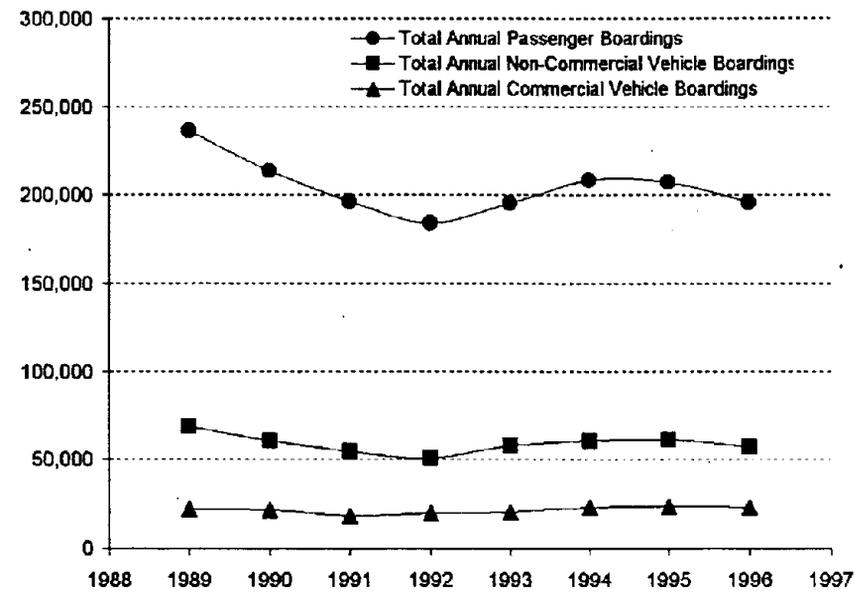
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⁹⁴ Porter, Anne. "Seasons Ends Friday for High Speed Cat." The Ellsworth American, Ellsworth American.com, WWW at URL http://www.ellsworthamerican.com/archive/10-29-98/ea_story3_10-29-98.html. October 29, 1998.

10.8 Market Forecasts and Financial Analysis

Historical patronage data obtained from Transport Canada indicate that both passenger patronage and vehicle patronage have been relatively stable on this route over the last several years (see Figure 10-12). In particular, the Saint John to Digby route experiences a consistent and relatively high level of commercial vehicle traffic year round.

FIGURE 10-12: SAINT JOHN - DIGBY HISTORICAL RIDERSHIP DATA



Based on observed annual ridership data by month and season for calendar year 1996, 53% of total annual passenger boardings and 38% of total annual AEU vehicle boardings occur during the peak months of July, August and September (see Table 10-8). Overall, passenger load factors are relatively low, ranging from between 9.4% in January up to 35.9% in August, with an annual average of 20.4%. Vehicle load factors are somewhat higher overall than passenger load factors, and also vary less during the year, due in part to consistent demand throughout the year from commercial vehicles.

For steel monohull vessels such as the *Princess of Acadia*, a service life expectancy of 50 to 60 years, with periodic upgrades and overhauls, is not uncommon. As of 1999, the *Princess of Acadia* was 28 years old, and as such, it is assumed here that this vessel could be maintained on this route for an additional 25 years, which is the project life-cycle over which the discounted cash flow analyses are performed.

As noted earlier, the Canadian federal government provides both operating and non-operating subsidies, currently totaling about \$3.1 million, to the operator of this route. It is the intent of the federal government to reduce, and ultimately phase out completely, this subsidy. The commercialization of this route in late 1996, with its transition from operation by the federal crown corporation Marine Atlantic to operation by the private operator Bay Ferries, was intended to help in achieving this goal of reducing and ultimately eliminating the required subsidy.

TABLE 10-6: SAINT JOHN - DIGBY 1996 RIDERSHIP DATA BY MONTH AND SEASON

Month or Season	Number of One-Way Vessel Trips	Passengers			Vehicles				
		Passenger Boardings	Available Passenger Seats	Passenger Load Factor	Non-Commercial Vehicle Boardings	Commercial Vehicle Boardings	Total Vehicle Boardings (AEU)	Available AEU Vehicle Spaces	AEU Vehicle Load Factor
January	94	5,754	61,100	9.4%	1,456	1,548	6,874	24,440	28.1%
February	100	5,709	65,000	8.8%	1,530	1,647	7,295	26,000	28.1%
March	104	9,398	67,600	13.9%	2,293	1,773	8,499	27,040	31.4%
April	98	9,286	63,700	14.6%	2,651	1,629	3,353	25,480	32.8%
May	108	12,003	70,200	17.1%	3,527	2,064	10,751	28,080	38.3%
June	122	19,155	79,300	24.2%	5,808	1,848	12,276	31,720	38.7%
July	178	37,894	115,700	32.8%	11,233	1,992	18,205	46,280	39.3%
August	178	41,593	115,700	35.9%	12,460	2,135	19,933	46,280	43.1%
September	164	24,005	106,600	22.5%	7,403	2,031	14,512	42,640	34.0%
October	136	15,030	88,400	17.0%	6,386	2,045	13,544	35,360	38.3%
November	104	7,709	67,600	11.4%	2,141	2,090	9,456	27,040	35.0%
December	92	8,416	59,800	14.1%	2,064	1,685	7,962	23,920	33.3%
Peak Season ⁽¹⁾	520	103,492	338,000	30.6%	31,096	6,158	52,649	135,200	38.9%
Off-Peak Season ⁽²⁾	958	92,460	622,700	14.8%	27,856	16,329	85,008	249,080	34.1%
Annual Total	1,478	195,952	960,700	20.4%	56,952	22,787	136,707	384,280	35.6%

Notes:

AEU is an "automobile equivalent unit," generally an area of vehicle deck space 9' x 20'. Oversize commercial vehicles such as tractor trailers and motorcoaches are assumed here to be 3.5 AEU on average.

(1) Peak season is mid-June to mid-September, approximated here as July through September.

(2) Off-peak season is mid-September to mid-June, approximated here as October through June.

Table 10-7 presents the findings of the baseline scenario, in which the operation of the *Princess of Acadia* is continued for an additional 25 years from the present. The expenses and revenue elements and amounts presented in the table are based on data obtained from Transport Canada for this route between 1989 and 1996. Because variation from year to year during this time historical period for both ridership levels and financial performance was generally limited, it is assumed here that the performance in 1996 would be experienced in the future as well, given use of the same vessel and a similar operating schedule, and barring any other significant exogenous factors.

The item "year zero effective outlay" represented in Table 10-7 is taken as the market value of the existing vessel, the *Princess of Acadia*, because under the baseline scenario, the benefit that could be obtained by selling the vessel at its current market value is foregone. A value of \$5 million is assumed here for the value of the *Princess of Acadia*.

Vessel debt repayment for the existing vessel under the baseline scenario is assumed to be zero. Because it is the company policy of Bay Ferries not to disclose its financial data, it is unclear what financial arrangements were made regarding the vessel when operation of the route was awarded to Bay Ferries from the original operator Marine Atlantic. The maintenance expenses used for the *Princess of Acadia* reflect the fact that this vessel is older and would likely require more overhaul and upgrades than would otherwise be the case with a more recently built vessel. In conducting the discounted cash flow analysis for this baseline scenario, annual vessel maintenance expense for the *Princess of Acadia* is assumed to increase 2% annually over the 25 year baseline project period, reflecting additional expenses for continued upgrades and overhauls as the vessel approaches the end of its useful life.

As might be expected, no meaningful figure can be calculated for the internal rate of return, since no positive annual net cash flows are forecast during any years of the project life cycle. The annual net cash flow deficit of \$3.6 million is approximately equivalent the level of subsidy that would be required from either the federal government or some other source, if the ferry route were to continue operation for any extended period of time.

TABLE 10-7: SAINT JOHN - DIGBY BASELINE SCENARIO WITH BASELINE FARE

Baseline	
Vessel Type	Princess of Acadia
Internal Rate of Return (IRR) ⁽¹⁾	no meaningful figure
Year zero effective outlay ⁽²⁾	-\$5,000,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	\$0
YEARS 1 THROUGH 15 ANNUAL OPERATING PROFILE⁽²⁾	
Vessel Type	Princess of Acadia
Passenger Capacity Per Vessel	650
Vehicle Capacity Per Vessel (Automobile)	260
Number of Vessels	1
One-Way Vessel Travel Time	3 hours
Total Annual One-Way Vessel Trips Performed	1,478
Annual Operating Hours per Vessel	4,434
Adult One-Way Passenger Fare (including pfc's) ⁽³⁾	\$16.40
Total Annual One-Way Passenger Boardings	195,952
Passenger Capacity Utilization Rate	20.4%
Automobile One-Way Fare	\$36.65
Total Annual One-Way Vehicle Boardings	79,739
Vehicle Capacity (AEU) Utilization Rate	35.6%
ANNUAL VESSEL DEBT REPAYMENT	
Vessel Debt Repayment (combined principal and interest)	\$0
ANNUAL CASH EXPENSES (OTHER THAN INTEREST)	
Direct & Indirect Operating Costs	
Terminal Operations	\$2,121,000
Terminal Maintenance	\$222,000
Vessel Operations	\$5,889,000
Vessel Maintenance	\$1,392,128
Operating Administration	\$155,000
Corporate Expenses	\$1,427,000
Operating Costs Subtotal	\$11,206,128
Passenger Fares & Vehicle Fares	\$7,590,000
Total Revenues	\$7,590,000
Net Cash Flow Before Taxes	-\$3,616,128

Notes:

"no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning.

(1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.

(2) The year zero effective outlay is taken as the market value of the existing vessel, the Princess of Acadia, because under this baseline scenario, the benefit that could be obtained by selling the vessel at its current value is foregone.

Under the alternative scenarios in which the SLICE 600 and other alternative high speed vessels are evaluated, it is assumed that the change in ridership that would result from the improved travel time is experienced in full during the first year of the introduction of high speed service. Although this is a somewhat different treatment from the gradual phase in of ridership on completely new routes that is assumed in the Lake Michigan and Florida case studies, it seems a reasonable assumption for the current case study since there is already existing conventional service on the route between Saint John and Digby, and given that the year over year data for the Bay Ferries route between Bar Harbor and Yarmouth revealed a doubling of ridership in the first year that the high speed catamaran *The Cat* was introduced into service.

Because the alternative vessel types evaluated here are of the same approximate passenger capacity as the *Princess of Acadia*, an operating schedule similar to that currently used by the *Princess of Acadia* in the baseline analysis is assumed for the alternative vessel types evaluated here. Although the vehicle capacities of the alternative vessel types are substantially less than that of the *Princess of Acadia*, their inability to accommodate most oversize commercial vehicles would reduce the demand for vehicle deck space on those vessels.

The findings for the discounted cash flow analysis for the alternative high speed vessels, under the baseline fare scenario in which it is assumed that current baseline fares remain the same, are presented in Table 10-8. Under this scenario, it is estimated that for the SLICE 600 there would be an additional 71,849 annual passenger boardings relative to the baseline case (an increase of 37%) because of the substantial improvement in travel time over the baseline case. Based on the seakeeping analysis presented in Chapter 5 and the methodology presented in Chapter 8 regarding the impact of seakeeping performance on patronage, it is estimated that an increase of 3,327 passenger boardings over the baseline would result from the improved seakeeping ability of SLICE. A further increase in patronage of 1,326 passenger boardings is estimated to result from the improved operational reliability in poor weather conditions of the SLICE 600. The net change in vehicle boardings, however, is estimated to be a reduction of almost 39,000 vehicles annually, due in large part to the elimination of oversize commercial vehicles, and the smaller vehicle deck capacity of the SLICE 600 (90 AEU) relative to that of the *Princess of Acadia* (260 AEU).

For the AMD K50 and the Incat 74 meter WPC, it is estimated that there would be an additional 88,995 annual passenger boardings relative to the baseline case (a 45% increase) and 84,096 (a 43% increase), respectively, because of the substantial improvement in travel time provided by both vessels over the baseline case. It is assumed that the seakeeping performance and operational reliability in poor weather for the AMD K50 and the Incat 74 meter WPC would be generally similar to that of the baseline monohull vessel, or at a minimum would not provide the same improvement in seakeeping that the SLICE 600 would relative to the baseline vessel. The net change in vehicle boardings is estimated to be a reduction of almost 16,300 vehicles annually for the AMD K50 and 40,300 for the Incat 74 meter WPC, again due in large part to the elimination of oversize commercial vehicles and the smaller vehicle deck capacity of the AMD K50 (89 AEU) and the Incat 74 meter WPC (84 AEU) relative to that of the *Princess of Acadia* (260 AEU).

As was the case with the baseline analysis, all three scenario vessels also yield no meaningful figure for the internal rate of return. Therefore, a comparison of the relative attractiveness of the baseline scenario and the three alternative vessel scenarios is instead made on the basis of the annual net cash deficit. That amount is approximately equivalent to the level of subsidy that would be required from either the federal government or some other source, if the ferry route were to continue operation for any extended period of time. On this basis, among the high speed craft candidates the AMD K50 returns the best economic performance, with an annual net cash deficit of \$5,915,905. This is followed by the Incat 74 meter WPC with an annual net cash deficit of \$6,463,450, and then by the SLICE 600, with an annual net cash deficit of \$11,827,879.

In Table 10-9, an extension of the baseline fare scenario referred to as the "profit maximizing fare scenario" is presented for the alternative high speed vessel types. Under this scenario, fares for these vessel types were varied to determine if a fare level other than the baseline fare could yield an internal rate of return higher than that under the baseline fare scenario, or an annual net cash deficit less than that under the baseline fare scenario. Therefore, in addition to changes in the baseline patronage resulting from different travel times and seakeeping performance, changes in patronage resulting from different fare levels are also considered in combination with these other level of service parameters.

TABLE 10-8: SAINT JOHN - DIGBY ALTERNATIVE VESSEL SCENARIOS WITH BASELINE FARE

Results from Discounted Cash Flow Analysis (U.S. dollars)			
Vessel Type	Scenarios		
	SLICE 600	AMD K50	Incat 74m
Internal Rate of Return (IRR) ⁽¹⁾	no meaningful figure	no meaningful figure	no meaningful figure
Equity Investment - Vessel Purchase	-\$2,400,000	-\$1,000,000	-\$780,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	\$0	\$0	\$0
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$23,655,757	-\$11,831,810	-\$12,926,901
YEARS 1 THROUGH 15 ANNUAL OPERATING PROFILE ⁽²⁾			
Vessel Type	SLICE 600	AMD K50	Incat 74m
Passenger Capacity Per Vessel	600	400	597
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	90	89	84
Number of Vessels	1	1	1
One-Way Vessel Travel Time	1 hrs, 32 min.	1 hrs, 11 min.	1 hrs, 17 min.
Total Annual One-Way Vessel Trips Performed	1,478	1,478	1,478
Annual Operating Hours per Vessel	2,285	1,749	1,897
Adult One-Way Passenger Fare (including pfc's) ⁽³⁾	\$16.40	\$16.40	\$16.40
Total Annual One-Way Passenger Boardings	272,454	284,947	280,048
Passenger Capacity Utilization Rate	30.7%	48.2%	31.7%
Automobile One-Way Fare	\$36.65	\$36.65	\$36.65
Total Annual One-Way Vehicle Boardings	40,868	63,401	39,404
Vehicle Capacity (AEU) Utilization Rate	31.6%	53.0%	32.7%
ANNUAL VESSEL DEBT REPAYMENT			
Vessel Debt Repayment (combined principal and interest)	\$3,816,997	\$3,084,863	\$2,981,384
EQUILIBRIUM YEARS 1 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)			
Direct Operating Costs			
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$1,252,984	\$731,539	\$1,048,693
Vessel Fuel and Lubricants	\$5,686,894	\$2,410,700	\$1,892,216
Vessel Maintenance Costs	\$1,188,309	\$874,855	\$862,711
Marine Hull Insurance	\$925,000	\$750,000	\$722,500
Direct Operating Costs Subtotal	\$9,033,187	\$4,767,095	\$4,526,120
Indirect Operating Costs			
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$435,821	\$294,297	\$364,763
Marketing and Advertising	\$323,871	\$369,645	\$326,002
Reservations & Sales	\$267,100	\$243,654	\$209,463
Docking Fees / Passenger Facility Charges / Shore Operations	\$2,247,742	\$2,350,812	\$2,310,397
Protection and Indemnity (P&I) Insurance	\$81,736	\$85,484	\$84,014
General Administration	\$2,252,742	\$2,355,812	\$2,315,397
Outside Professional Services	\$272,167	\$284,606	\$279,729
Onboard Food & Beverage Sales - Cost of Sales	\$885,474	\$926,077	\$910,156
Gift Shop - Cost of Sales	\$367,812	\$384,678	\$378,065
Onboard Gaming - Cost of Sales	\$0	\$0	\$0
Indirect Operating Costs Subtotal	\$7,074,466	\$7,295,065	\$7,180,985
EQUILIBRIUM YEARS 1 THROUGH 15 ANNUAL REVENUES			
Passenger Fares	\$4,387,811	\$4,589,012	\$4,510,118
Vehicle Fares	\$1,529,332	\$2,372,530	\$1,474,536
Ancillary Sales - Onboard Food & Beverage Sales	\$1,362,268	\$1,424,734	\$1,400,240
Ancillary Sales - Gift Shop Sales	\$817,361	\$854,841	\$840,144
Ancillary Sales - Onboard Gaming	\$0	\$0	\$0
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0	\$0
Total Revenues	\$8,096,771	\$9,241,117	\$8,225,039
EQUILIBRIUM YEARS 1 THROUGH 15 NET CASH FLOW BEFORE TAXES			
Annual Net Cash Flow Before Taxes	-\$11,827,879	-\$5,915,905	-\$6,463,450

Notes:
 "no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning.

- (1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.
- (2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years. Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years 1 through 15 are presented in the above summary of the discounted cash flow analysis.

TABLE 10-9: SAINT JOHN - DIGBY ALTERNATIVE VESSEL SCENARIOS WITH PROFIT MAXIMIZING FARE

Results from Discounted Cash Flow Analysis (U.S. dollars)			
Vessel Type	Scenarios		
	SLICE 600	AMD K50	Incat 74m
Internal Rate of Return (IRR) ⁽¹⁾	no meaningful figure	no meaningful figure	no meaningful figure
Equity Investment - Vessel Purchase	-\$2,400,000	-\$1,000,000	-\$780,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	\$0	\$0	\$0
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$18,795,817	-\$6,238,154	-\$7,783,291
YEARS 1 THROUGH 15 ANNUAL OPERATING PROFILE ⁽²⁾			
Vessel Type	SLICE 600	AMD K50	Incat 74m
Passenger Capacity Per Vessel	600	400	597
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	90	80	84
Number of Vessels	1	1	1
One-Way Vessel Travel Time	1 hrs, 32 min.	1 hrs, 11 min.	1 hrs, 17 min.
Total Annual One-Way Vessel Trips Performed	1,478	1,478	1,478
Annual Operating Hours per Vessel	2,288	1,748	1,807
Adult One-Way Passenger Fare (including p/c's) ⁽³⁾	\$33.00	\$33.00	\$34.00
Total Annual One-Way Passenger Boardings	151,466	163,956	151,771
Passenger Capacity Utilization Rate	17.1%	27.7%	17.2%
Automobile One-Way Fare	\$73.75	\$73.75	\$75.99
Total Annual One-Way Vehicle Boardings	22,720	36,481	21,355
Vehicle Capacity (AEU) Utilization Rate	17.6%	30.5%	17.7%
ANNUAL VESSEL DEBT REPAYMENT			
Vessel Debt Repayment (combined principal and interest)	\$3,816,997	\$3,094,863	\$2,981,384
EQUILIBRIUM YEARS 1 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)			
Direct Operating Costs			
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$1,252,984	\$731,539	\$1,048,893
Vessel Fuel and Lubricants	\$5,686,894	\$2,410,700	\$1,892,216
Vessel Maintenance Costs	\$1,168,309	\$874,855	\$862,711
Marine Hull Insurance	\$925,000	\$750,000	\$722,500
Direct Operating Costs Subtotal	\$9,033,187	\$4,767,095	\$4,526,120
Indirect Operating Costs			
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$435,821	\$294,297	\$364,763
Marketing and Advertising	\$313,235	\$374,874	\$317,529
Reservations & Sales	\$231,670	\$282,107	\$235,342
Docking Fees / Passenger Facility Charges / Shore Operations	\$1,249,568	\$1,352,657	\$1,252,112
Protection and Indemnity (P&I) Insurance	\$45,440	\$49,188	\$45,531
General Administration	\$1,254,588	\$1,357,657	\$1,257,112
Outside Professional Services	\$151,518	\$183,992	\$151,823
Onboard Food & Beverage Sales - Cost of Sales	\$492,262	\$532,885	\$493,256
Gift Shop - Cost of Sales	\$204,478	\$221,344	\$204,891
Onboard Gaming - Cost of Sales	\$0	\$0	\$0
Indirect Operating Costs Subtotal	\$4,378,599	\$4,628,981	\$4,322,360
EQUILIBRIUM YEARS 1 THROUGH 15 ANNUAL REVENUES			
Passenger Fares	\$4,908,381	\$5,313,238	\$5,067,337
Vehicle Fares	\$1,710,772	\$2,746,956	\$1,656,713
Ancillary Sales - Onboard Food & Beverage Sales	\$757,326	\$819,792	\$758,856
Ancillary Sales - Gift Shop Sales	\$454,396	\$491,875	\$455,314
Ancillary Sales - Onboard Gaming	\$0	\$0	\$0
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0	\$0
Total Revenues	\$7,830,874	\$9,371,862	\$7,938,219
EQUILIBRIUM YEARS 1 THROUGH 15 NET CASH FLOW BEFORE TAXES			
Annual Net Cash Flow Before Taxes	-\$9,397,909	-\$3,119,077	-\$3,891,645

Notes:

"no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning.

- (1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.
 (2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years. Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years 1 through 15 are presented in the above summary of the discounted cash flow analysis.

As can be seen in Table 10-9, fare levels approximately twice those of the baseline case result in an annual net cash deficit of \$9,397,909 for the SLICE 600, about 21% less than for the SLICE 600 in the baseline fare scenario, with passenger ridership declining to 151,465 from 272,454. For the AMD K50, there is an annual net cash deficit of \$3,119,077 under these higher fare levels, about 47% less than for the AMD K50 in the baseline fare scenario, with passenger ridership declining to 163,958 from 284,947. For the Incat 74 meter WPC, there is an annual net cash deficit of \$3,891,645 under these higher fare levels, about 40% less than for the Incat 74 meter WPC in the baseline fare scenario, with passenger ridership declining to 151,771 from 280,048.

Therefore, if passenger demand were to respond to the changes in travel time and fares utilized in this scenario as hypothesized earlier in Chapter 8, it is conceivable based on the analysis conducted here that the annual net cash deficit for the AMD K50 would be an improvement over that in the baseline case with the *Princess of Acadia*. The economic performance of the SLICE 600, however, with an annual net cash deficit of \$9,397,909, is still substantially more inferior to that of the baseline case with the *Princess of Acadia*. The economic performance of the Incat 74 meter WPC is also inferior to the baseline case with the *Princess of Acadia*, but only slightly so. Even though the profit maximizing fare scenario for the AMD K50 may yield a modest improvement in the annual net cash deficit relative to the baseline case with the *Princess of Acadia*, the absolute number of passenger boardings in this case decreases over the baseline by about 16%. Although the reduction in the annual net cash deficit would likely be welcomed by the government agencies providing the required subsidy, the significant reduction in patronage that would result under this scenario might be viewed by some as a reduction in mobility that could negatively affect the economy of New Brunswick and Nova Scotia, and therefore not in the public interest.

10.9 Conclusions

The Canadian federal government would not meet its goal of reducing and phasing out the current subsidy on this route with the SLICE 600, or the other high speed vessels analyzed. The existing baseline operation with the *Princess of Acadia* now operates at an annual net cash deficit that is less than that calculated for the SLICE 600, AMD K50, and the Incat 74 meter WPC. For the baseline fare scenario, the AMD K50 returns the best economic performance, with an annual net cash deficit of \$5,915,905. The Incat 74 meter WPC shows an annual net cash deficit of \$6,463,450, and the SLICE 600 a deficit of \$11,827,879. Fare optimization, while likely not a politically acceptable approach, results in smaller though still significant deficits for all three high speed types, with the SLICE 600 still the worst performer. For the profit maximizing fare scenario, fare levels approximately twice those of the baseline case result in an annual net cash deficit of \$9,397,909 for the SLICE 600, about 21% less than for the SLICE 600 in the baseline fare scenario, with passenger ridership declining to 151,465 from 272,454. For the AMD K50, there is an annual net cash deficit of \$3,119,077 under these higher fare levels, about 47% less than for the AMD K50 in the baseline fare scenario, with passenger ridership declining to 163,958 from 284,947. For the Incat 74 meter WPC, there is an annual net cash deficit of \$3,891,645 under these higher fare levels, about 40% less than for the Incat 74 meter WPC in the baseline fare scenario, with passenger ridership declining to 151,771 from 280,048.

It is likely that the deep draft of the SLICE 600 would impose constraints on vessel operations, with the depth alongside at the existing ferry terminals in Saint John and Digby unsuitable for the SLICE 600 except perhaps during high tides. Some channel depths, such as the main channel into Saint John Harbor, are also of unsuitable or marginal controlling depth with respect to the 28.5 draft of the SLICE 600. Operational difficulties might also be encountered with the SLICE 600 because of the deck heights at the existing ferry terminals, which are approximately 10 feet at both Saint John and Digby, and the SLICE 600 main vehicle deck freeboard height of 21.5 feet.

Although wave climate conditions are more difficult in this region than in some of the other case study regions, it is estimated that the additional patronage of approximately 4,600 passengers and their vehicles that might be realized from the elimination of missed trips due to weather and the improved seakeeping ability and ride qual-

ity of the SLICE 600 is insignificant relative to both the baseline and forecast scenario patronage levels on this route.

Tractor trailers are not accommodated on either the SLICE 600 or the other comparative high speed vessels. This would reduce fare revenues, particularly in light of the consistent and relatively high level of existing commercial vehicle traffic. Also, the exclusion of oversize commercial vehicles from this route would likely be politically unacceptable, since the RoPax ferry services operating in Atlantic Canada are generally felt by the federal government and the provincial governments of New Brunswick and Nova Scotia to be in the public interest and to contribute to the economic well-being of the region.

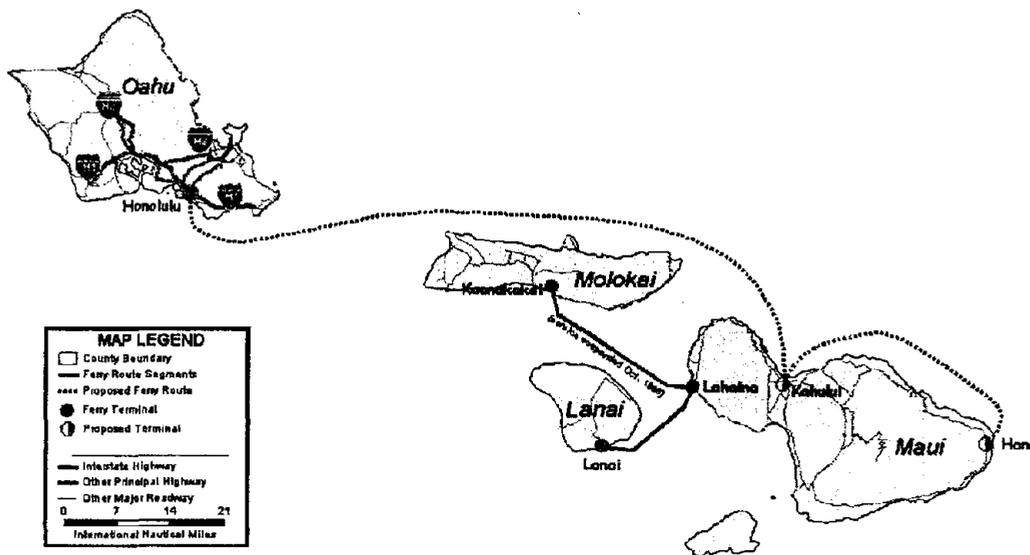
Chapter 11: Case Study #3 - Hawaii

In July of 1995, Pacific Marine & Supply Company, Ltd., completed a SLICE service feasibility study for the Hawaiian Islands entitled *Hawaii Inter-Island Ferry Business Plan, Phase A*. In March of 1999, Pacific Marine and the U.S. Navy Office of Naval Research agreed that the findings of this earlier study should be presented as part of the Volpe Center SLICE commercial feasibility study. The findings of this earlier study are presented here, reorganized to be consistent with the other common carrier SLICE case studies present in the Volpe Center report. This chapter includes information independently developed by the Volpe Center, e.g., weather and wave climate aspects.

11.1 Introduction and Regional Overview

For purposes of the subject business plan, the Phase A market was defined as passenger transportation service between the islands of Oahu and Maui (see Figure 11-1). This route would maximize the competitive advantages of the proposed marine transportation service as it represents the most highly traveled inter-island segment. By providing a comfortable ride with spectacular scenery between these islands, it was believed that a significant share of the inter-island traveler market could be captured. Additionally, Hawaii Department of Transportation estimates placed visitors to Hana at 400,000 to 500,000 per year. The following sections provide general information about the economic environment in which the SLICE inter-island ferry would operate.

FIGURE 11-1: PROPOSED HAWAII FERRY ROUTES



State of Hawaii

The state of Hawaii consists of seven major and 124 minor volcanic and coral islands which form a 1,610 mile long chain in the mid-Pacific ocean. The major islands are, in order of size: Hawaii, Maui, Oahu, Kauai, Molo-

kai, Lanai, and Niihau. Admitted as the 50th State in 1959, the Aloha State, with a total land area of 6,426 square miles, ranks 47th in size and has a coastline of 750 miles. Honolulu, Hawaii's capital and largest city, is situated about 2,400 miles west of the U.S. mainland, on the Island of Oahu.

Economy

Any ferry operation will require a healthy economy as a foundation. It is important, therefore, to look at Hawaii's current economic situation and its ability to support a ferry operation with riders.

Hawaii's economy is built primarily on three major industries. In order of importance, they are tourism, military activity and agriculture. The Hawaiian economy grew at a rapid rate in the 1980s, the year 1989 being the seventh straight year of expansion. Statewide gross business receipts, which measure the volume of business activity in the economy, jumped 13 percent to \$36 billion in 1989 - up from \$32 billion. Adjusted for inflation, growth in gross business receipts amounted to 7 percent in 1989. The unemployment rate during 1989 averaged 2.8 percent, well below the national average. As an economy, Hawaii had repeatedly demonstrated its growth power and resiliency even in the face of national and international economic slowdowns and recessions.

But the 1990s brought a slowdown of the economy. Spectacular tourism growth in the 1980s peaked in 1990 with an annual visitor count of 7 million tourists. Over the next three years, the world and U.S. economies went into recession; visitors from Hawaii's two most important tourism markets, California and Japan, declined as the Japanese economic bubble burst and California slid into a harsh recession; the Gulf War caused tourist cancellations in 1991; mainland airlines excluded Hawaii from their fare-cutting wars in 1992 and Hurricane Iniki caused extensive damage to the island of Kauai that September; and Hawaii began and ended 1993 officially in a shallow recession. By the end of 1993, the annual visitor count had slipped to a little over 6.1 million tourists, the agriculture and defense sectors had contracted and construction had also declined.

Economic performance during 1994 pointed to an end of the recession, a flat overall economy, and a recovery for tourism, Hawaii's most important industry. The 1994 visitor count rose 5.4 percent over 1993. Hotel occupancy rose to 76.5 percent in this period, up from 72 percent a year earlier. Another sign of the emerging recovery is an increase in State general fund tax revenues. They rose 1.4 percent in the fiscal year ending June 30, 1994 after declining 1.7 percent in FY 92-93, and 4.1 percent in FY 91-92.

Throughout this shallow recession, Hawaii's economy declined modestly as measured by real gross state product (GSP). In 1991, it stood at \$19.6 billion; by 1992 it had dropped to \$19.1 billion; and at the end of 1993, the GSP had declined to the \$18.6 billion mark (in 1982 dollars).

U.S. census figures for 1990 show Hawaii with a population of 1,160,000. The majority, 865,000, live on Oahu, in the city of Honolulu. Honolulu is the business capital of the State, the largest city in the State, and the hub of the inter-island transportation network. The Big Island of Hawaii, with four times the land mass as Oahu, has the next highest population count with 131,000 residents. Maui, the most popular visitor destination outside Oahu, has 109,000 local residents, including the island of Molokai which is part of Maui county. The island of Kauai, to the north of Oahu, has the smallest population of the five major islands in the Hawaiian chain with only 55,000 residents.

Unemployment in Hawaii has historically been lower than in the U.S. as a whole. In 1991, its unemployment rate stood at a low 2.8%. Even in 1993, during the middle of the recent recession, Hawaii's unemployment rate stood at only 4.2%, compared to the national average for that year of 6.8%. Statistics for December 1994 indicated that Hawaii unemployment was at 4.7%, compared to 7.5% for the nation as a whole.

The Hawaii Visitor Industry

Tourism is Hawaii's biggest industry. It is supported by an annual, sustained, broad-based multi-million dollar marketing effort funded by the State of Hawaii, the Hawaii Visitors Bureau, and major private sector companies ranging from United Airlines and American Express to individual destination resort associations, tour wholesalers and hotel properties.

Hawaii's tourism industry recorded a gain in its annual visitor count every year except two during the period 1959 -1990. (The only exceptions were 1980, when the tourism count dropped seven-tenths of one percent under the previous year; and 1981 when growth was flat.)

At the start of the 1980s, the annual Hawaii visitor count was approximately 3.9 million and topped the 4 million mark for the first time in 1982. Slower but positive growth continued right through the national recession, a tribute to the strong, global market appeal of the Islands, before exploding again in the mid and late 1980s. For 1990, the Hawaii Visitors Bureau logged a record 6,971,000 tourists staying overnight or longer in Hawaii, marking the peak of the most recent tourism boom.

In the years since, the total visitor count has declined to 6,124,000, but in 1994 has begun to climb once again. Three out of four visitors to Hawaii spend time on Oahu, one in three visits Maui, and one in five visits the Big Island. Kauai hosted about 572,000 visitors in 1993 and Molokai is the least visited of the major islands with only 91,000 tourists spending one night or longer there.

Visitors to the Islands are classified either as "first time" or repeat" visitors. As a tourist destination, Hawaii is a mature market for the westbound visitor from the Mainland U.S. Hawaii is more exotic and less familiar to the eastbound visitors from Asia for whom the islands are often a first time experience. Some 63% of westbound tourists to Hawaii had visited the Islands before while only 42% of the eastbound visitors had vacationed in Hawaii before.

Visitors can also be classed as either part of a "Group Tour" or "Free and Independent" (FIT) travelers who book their own trip and are not part of a packaged program. Again, there is a marked difference between eastbound and westbound visitors in this regard. In 1992, 60 percent of eastbound tourists traveled to Hawaii as part of a Group Tour while only 10 percent of westbound tourists were part of a Group Tour. Asians making their first trip to Hawaii clearly feel more comfortable in a group. Two out of three (68%) also tend to buy a package trip whereas only one in three (36%) westbound travelers does so. Businesses marketing their services to Hawaii tourists routinely market their products and services quite differently to the westbound and eastbound traveler.

Visitor spending kept pace with the visitor count during the late 1980s boom. According to the Hawaii Visitors Bureau, 1986 total visitor expenditures totaled \$6.1 billion. By 1990, that figure was \$9.7 billion. It peaked in 1991 at \$10.6 billion, slipped to \$9.6 billion the next year and again to \$8.7 billion in 1993 as the recession took hold.

The Japanese segment of the visitor market is not as large as the westbound segment in terms of numbers, but the average Japanese tourist spends a lot more per day than his U.S. mainland counterparts. 1993 westbound visitors originating primarily from the U.S. account for 55% of the total visitor count, but only 45% of all visitor spending. Japanese visitors outspend them in every category except transportation and personal services, where the two groups are about even. In 1993, the average Japanese tourist spent \$307 a day in Hawaii while the average visitor from the U.S. Mainland spent only \$116. Consequently, the Japanese visitor is a prime target for all visitor activities, and his patronage of any inter-island ferry system is very important.

The free-spending Japanese visitor segment is expected to provide substantial, quality growth for the foreseeable future, due to the increased buying power of the yen and a steady increase in visitor count. Japanese visitors in 1986 totaled 731,000. By 1993 they had risen to 1,592,000, more than doubling in this period.

Hawaii's visitor industry infrastructure also grew substantially in the second half of the 1980s as the tourism industry responded with major investments in new hotels, upgrading and renovations, and long-term infrastructure improvements in cooperation with the State. Over 5,000 rooms were added to the visitor plant inventory between 1986 and 1990 with the statewide room total increasing from 66,300 to 71,600 during this period. By 1992, that number had risen to 73,779 rooms. These rooms are almost evenly split between Oahu and the Neighbor Islands (Maui, Molokai, Kauai and the Big Island). Oahu's visitor plant totaled 37,000 rooms in 1993; the four Neighbor Islands combined boasted 33,500. Many of the largest, most expensive and most luxurious hotels and resort complexes are found on the Neighbor Islands. Waikiki on average caters to the budget, middle class tourist.

Island of Maui

Maui, the second largest island in the Hawaiian chain, lies midway between Oahu and Hawaii. It is often called the "Valley Isle" because of its valley-like isthmus between two mountain masses. The island measures 48 miles long and 26 miles wide and has a land area of 727 square miles. The western shores of the Island of Maui include approximately 20 miles of white sand beaches, the most noteworthy being Kaanapali Beach fronting the Kaanapali resort area. Wailuku is the headquarters city for Maui County, which includes the islands of Maui, Molokai and Lanai. Kahului, the headquarters of HC&S, the world's largest sugar plantation, is the location of Kahului harbor and most of the industrial and resident oriented retail activity on Maui.

There have been two distinct centers of economic activity on Maui. In the early 19th century, Lahaina, on the west Maui coast, was the main center of activity. Until 1855, Lahaina was the capital city of Hawaii and its leading whaling port. The capital subsequently was moved to Honolulu, following a decline in whaling activity. Agriculture then became the primary activity in the Lahaina district. The growth of large scale agriculture on the island and the development of superior port facilities at Kahului resulted in Wailuku becoming the major town on the island. Lahaina continued to function as a local community business center and tourist attraction.

The Wailuku-Kahului area is now the center of government and business activity on Maui. Although visitor activity has been concentrated on the west Maui coast, the Kihei-Wailea area will likely be the basis for a major amount of future tourism growth. The Wailuku-Kahului area will likely continue in its present role as the seat of county government activity. Kahului is the major port and the location of the primary inter-island airport. Thus, growth and employment not related to the visitor industry will likely continue to be concentrated in Wailuku-Kahului.

Lahaina is located in the west Maui district, the island's best known and most popular visitor destination area. Lahaina town is a major tourist attraction and serves as the current commercial center for the west Maui resort region. In the early 1800's, it was Hawaii's capital and the playground of Hawaiian royalty. For years, whalers used Lahaina as their Pacific headquarters during the winter months. As many as two thousand ships at one time were anchored in the Lahaina roadstead, which is naturally protected from the elements by the neighboring islands of Molokai, Lanai and Kahoolawe.

The Lahaina area enjoys some of the best year-round weather in all Hawaii, due to its geographic location and the protection afforded by nearby islands. The temperature in the Lahaina area averages 71 degrees in February and 78 degrees in August and September. Annual rainfall averages 13.6 inches.

Numerous long-term and short-term visitor accommodations are available in the area through condominium units which have been developed north of Kaanapali to Napili Bay. The Kapalua resort area located 8.5 miles north of Lahaina, consists of a golf course, resort condominiums, shops and hotels. With the exception of the retail shops in the various hotels in Kapalua and Kaanapali, and the visitor oriented Whaler's Village in Kaanapali, all of the commercial activity is concentrated in Lahaina town.

11.2 Ferry Market Overview and Operational Profiles

History of Inter-Island Ferry Transportation

As far back as the mid-1800s, Hawaii had regular steam ferry boat service between the islands. The first inter-island ferry service using steamships was begun in 1853 with the SS Akamai, and by the 1860s \$5.00 could get you passage from Honolulu to Lahaina, Maui, or \$10.00 to ports on the Big island. While many native Hawaiians still continued to travel by outrigger canoe between the islands, by the mid-1880s two steamship companies were plying the inter-island trade. In 1905, the two companies merged their operations, forming the Inter-Island Steam Navigation Co. (IISNC).

A Chamber of Commerce 1976 study entitled "The Inter-Island Ferry Issue", noted that Hawaii's inter-island transportation system has undergone many changes over the decades as technological improvements have been made in the field of transportation, as markets have changed, and as consumer preferences have changed. But until shortly after World War II, the IISNC ferries remained the prime method of moving both people and cargo among the islands. Until the 1930s, its main competition came from barge services, which moved some cargo in direct competition with the ferries. But a greater threat emerged in the 1930s as the airplane turned from an oddity to an industry. After air service was introduced to the islands in 1929, the airplane took increasing amounts of passenger traffic away from the inter-island ferry. The ocean steamboat ferry business had met a foe which would eventually destroy it.

The end of World War II marked the end of the line for the IISNC. When the DC-3 replaced the Sikorsky flying boats just after World War II, the inter-island ferry lost its passenger trade and could not compete with barge service for inter-island cargo trade. The IISNC ferry system folded in 1949.

The authors of the 1976 Chamber study noted that when the Inter-Island Steam Navigation Co. closed down in 1950, it was generally agreed that the inter-island ferry had been displaced by better technology, just as the horse, the passenger train, the dirigible, and the flying boat were replaced.

But ship technology was also improving, including the development of new motion control systems that promised to allow an inter-island ferry to make the trip through Hawaiian waters without the extreme discomfort most passengers experienced on the old steamships. The newer ferry couldn't match an airplane in terms of speed, but it could perhaps provide reasonably comfortable travel between the islands at a lower cost than a plane ticket, and in the years to follow a number of companies as well as the Hawaii State Government, unsuccessfully tried to re establish various forms of inter-island ferry service.

Two of the more recent efforts to develop an inter-island ferry system, SeaFlite and Sea Link, are discussed in more detail below.

SeaFlite

SeaFlite (1975-1978) was undoubtedly the best financially and technologically equipped inter-island ferry venture to emerge in Hawaii since 1949. Consequently, the results of its operations and marketing efforts offer important clues to the market viability of an inter-island ferry in Hawaii and are treated here in some detail. A good summary of SeaFlite's operations can be found in a privately-circulated 1982 report entitled "Inter-Island Sea Transit Feasibility Study".

According to that study, the Boeing company had been engaged in the research, design and manufacturing of submerged hydrofoil boats since 1959 and by 1972 had developed and begun marketing a new 40-knot hydrofoil called the Boeing Model 929 jetfoil. In the early 1970s, officers from a local subsidiary of LTV Aerospace Corp., convinced that the Jetfoil would make a good inter-island ferry, formed a company called PST to bring the technology to Hawaii.

High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

Application for an operating license was filed with the Hawaiian Public Utility Commission in November of 1971 and, after public hearings were held on the various islands, a conditional certificate of convenience and necessity was granted in November 1972.

The principal concerns of PST were ride quality, external and internal noise, speed and endurance. To alleviate these concerns and share the risks, Boeing agreed to participate in the Hawaiian venture. On April 13, 1972, the LTV/ Kentron/ Boeing Agreement on financial support was signed and Boeing acquired a 25% interest in PST. Ultimately, PST received its first Jetfoil, the Kamehameha in May 1975 followed by delivery of the Kalakaua on August 11 and the Kuhio on October 6, 1975.

During the check out phase of the Kamehameha, it was discovered that engine shut-down occurred more often than expected. A wait ensued while the turbine cooled before it could be restarted, and the Jetfoil's ride suffered because the craft cannot stay foil borne on one engine. Until the ship became foil borne again, it wallowed in the seas like a monohull, causing significant seasickness among the passengers. The problem was later corrected by introducing a pressure control system in the suction inlet which detected a decrease in pressure and automatically returned the turbine to idle speed. This system was installed and tested on the third boat delivered to PST, the Kuhio. The system minimized the probability of shutdown during scheduled operations, but increased turbine maintenance.

Despite this series of technical problems, PST inaugurated commercial inter-island service as "SeaFlite" with the Kamehameha on June 15, 1975, with one daily trip from Honolulu to Maalaea, Maui and one from Honolulu to Nawiliwili (on Kauai). With the addition of the Kalakaua in August, service was expanded to two trips daily to these ports. The Kuhio's addition later in the year allowed one trip daily from Honolulu to Kailua-Kona on the Big Island of Hawaii with stops at Maalaea on the outward and return legs. On days when southerly wind conditions hampered landings at Kailua-Kona's unprotected pier (estimated to be fifteen to twenty days a year) the landings were made at Kawaihae harbor a short distance up the coast. The three legs were about the same length, each requiring 2 to 2.5 hours of schedule time.

Within the first six months of operation, the effects of the 40% increased power requirements over design conditions became evident. The entire power train was over stressed, and gear box and thrust bearing failures were commonplace. Rather than maintaining 45 knots speed as publicized, the Jetfoil made about 40.5 knots depending on wind or sea direction. Other operating problems required extensive and expensive dredging operations on Maui and Kauai and the addition of a tug on Maui. All of these problems added voyage time, fuel costs, labor costs and maintenance costs on the equipment.

SeaFlite's credibility with the tourist and travel industry suffered from delays and rescheduling of commercial service necessitated by late delivery of the Jetfoils as well as the numerous operating problems discussed above. Being a new venture and important to the islands, SeaFlite was newsworthy and the Jetfoil breakdowns provided the media with news to report. The problems may have been magnified by the media, but the result was that tour wholesalers and travel agencies were reluctant to include SeaFlite in their packages or recommend it to customers. Consequently, SeaFlite fell short of its projections for passenger bookings and revenue generation.

SeaFlite fare to Kauai or Maui was \$20 (one-way, regular, adult) versus airline fare of \$21.38, and \$25 to Kailua-Kona versus airline fare of \$25.38. This pricing reflected a strategy to position SeaFlite as a form of transportation rather than a unique attraction.

When SeaFlite began operations, the "common air fare" was in use. Because this subsidy was a significant expense to the trunk carriers, these airlines did their best to keep the common fare a secret, and only 30% of the inter-island travelers were knowledgeable about the common fare and purchased tickets prior to leaving the mainland.

Changes in the common fare provisions destroyed SeaFlite's strategy to pursue those travelers who did not know or were ineligible for the common fare. The stopover charge was increased and the number of charges imposed increased from one to two, and sometimes three, per island. The passenger technically traveled at no charge on inter-island flights, but the stopover charges became significantly attractive so that the trunk carriers publicized and promoted the common fare to stimulate travel to Hawaii.

The result of the changes in the common fare was that over 95% of the travelers from the mainland became knowledgeable about the common fare and were pre-ticketed if their trip included neighbor island visits. A major segment of SeaFlite's market disappeared. Instead of having 70% of the mainland traveler market as its target, that segment was reduced to less than 5%.

In its first year, SeaFlite carried approximately 190,000 passengers. This was below projections, but sufficient to give an indication of potentially profitable route segments and to determine passenger reactions. Approximately 35% of the revenues came from local residents and 65% from tourists. To monitor passenger reaction, SeaFlite passed out questionnaires on randomly selected trips. The demographics of the passengers turned out to be very similar to the Hawaii Visitors Bureau ("HVB") demographics of Hawaii visitors generally.

To a question asking whether passengers would travel on SeaFlite again and recommend it to their friends, 97% answered affirmatively. As to the agreeableness of the ride, the ratings were studied based on sea conditions ranging from good to very bad. Even under the worst conditions, over 87% of the passengers ranked the ride "good to excellent". Under the best conditions, 99.2% rated it "good to excellent".

By 1977, a pattern emerged showing that while system-wide load factors remained low, the Oahu-Maui leg was operating at close to a 60% load factor. Trip completion factors had improved to the point where tour operators were booking groups for 1978. SeaFlite's passenger acceptance rating by the Hawaii Visitor Bureau was consistently above that of the competing airlines, ranging from "above average" to "excellent", and the trip was looked upon as a major event in the "Hawaiian experience".

The Oahu-Molokai-Maui market accounted for just over 80% of SeaFlite's traffic. During the first six months of 1977, PST operated four round-trips per day to the Maalaea Bay terminal on Maui from Pier 8 in Honolulu. The early morning and midday trips from Honolulu to Maalaea averaged approximately 70% load factor and the late evening (5 p.m. to 7 p.m.) Maalaea to Honolulu return trip averaged 67.7% load factor. The load factors on the two late morning return trips from Maui to Oahu were low, averaging 31.2% for the earlier and 17.9% for the later trip. The early evening return to Oahu was better, but averaged only 46.9%.

With all of the problems encountered, SeaFlite was able to establish an economically significant share of the Oahu to Maui market. During the first nine months of 1977, it carried over 150,000 passengers between Oahu and Maui and achieved an overall average load factor of 58.4%. This was 8.1% of the total passenger traffic between the two islands.

Even though it appeared that PST had its earlier problems under control and profitable operations could be achieved, PST's parent was suffering from lack of corporate profitability and its management decided to divest the corporation of all resort and tourist related businesses. These operations did not fit with the parent corporation's total business thrust, were small and required a disproportionate share of management's attention. The decision to shut down SeaFlite was made in late 1977 to be effective in January 1978.

Despite the shutdown, the SeaFlite experience provided clear support for the argument that an inter-island ferry which is reliable, comfortable, fast and correctly priced would indeed draw a significant number of both residents and tourists. But all these elements - along with patience and financial staying power from the ferry operator itself - are required to make the product work.

Sea Link

Ten years after SeaFlite shut down, a new inter-island ferry company launched another attempt to capture this market opportunity. In November 1987, Sea Link began inter-island ferry operations on the Oahu-Molokai-Maui route identified by SeaFlite as the most financially viable leg of any inter-island ferry system. Unfortunately, the local company had very limited financial resources and less technologically advanced equipment than SeaFlite.

Sea Link had only one vessel, an 118-foot, 150-passenger monohull called the Maui Princess. Twice a day the ferry left Oahu, crossed the Molokai Channel and made a stop at Kaunakakai, Molokai, then went on to Lahaina, Maui. The return trip traced the same route in reverse. Where the SeaFlite hydrofoil rode above the waves, the Sea Princess found itself pounding through the big channel waves. Sea conditions in the Molokai Channel can be extremely rough; consequently, even with its fin stabilizers the Maui Princess experienced a lot of motion in big waves, and seasickness remained a problem for passengers.

The first six months of operations showed some promise. Monthly passenger counts rose from 1,522 in January to peak at 3,550 before decreasing somewhat. The service averaged slightly over 2,700 a month the first half year of operation. During the same period, revenues averaged \$92,840 a month. Between January and June, Sea Link completed 97.8% of its scheduled runs. Two runs were canceled by storms and two by engine problems.

But the second six months of operations showed a number of weaknesses in the operation. The frequency of sailings and rough ocean route put a lot of hours on the vessel and its engines; travel agents and big tour wholesalers did not deliver the volume of passengers the company had expected from them; and the inter-island airlines saw the ferry as competition and worked hard to protect and retain their customer base.

Solving these problems was going to take some time and Sea Link apparently did not have the financial resources to operate at a loss for an extended period. By the month of October, Sea Link was averaging only 20-30 passengers per day on the 150 seat vessel. In November 1988, approximately one year after launching the service, Sea Link filed a request with the Public Utilities Commission to discontinue its twice-a-day inter-island passenger service between Oahu and Maui. With the help and cooperation of Maui employers and financial support (approximately \$330,000 a year) from the State of Hawaii, the Molokai-Maui ferry leg remains operational, primarily serving as a shuttle for Molokai residents working on Maui. It currently operates seven days a week and serves a small base of approximately 150 active commuters with monthly ridership of approximately 1,600 passengers.

Evaluating the operation, it is clear that Sea Link started out with several disadvantages. The company was under-capitalized and unable to sustain the losses that can be expected from a start-up ferry operation competing against the inter-island airlines; it operated only one vessel, with no backup vessels; the vessel was a conventional monohull and could not consistently deliver the high speeds and comfortable passenger ride in rough channel waters which SeaFlite did; and tour agents and wholesalers, sensitive to possible customer complaints of seasickness, were perhaps wary of recommending the product wholeheartedly to their clients. In the end, Sea Link's financing, technology and marketing efforts all fell short of what was needed for success.

Sea Link represents the most recent company to try and fail at establishing a true inter-island ferry service (passenger only). Since then, an intra-island, Oahu-only commuter ferry shuttle has also started up and shut down. The San Diego-based company, called Hawaii Ocean Transit Systems (HOTS), used a wavepiercer vessel to make daily round trips from Barbers Point on West Oahu to downtown Honolulu. The company planned to operate a dinner cruise with the same vessel during off-hours to provide the profits needed to subsidize the unprofitable commuter ferry trips. But the route was ill-advised, the frequency of service was inadequate, and the company's commitment to the ferry service portion of the project was questionable from the outset.

Proposed SLICE Route Operational Description

The high-speed, low motion characteristics of the SLICE Ferry were thought to allow it to comfortably cruise inter-island and around island routes, opening up sightseeing opportunities not previously available. SLICE Ferry would also provide an alternate means of transportation between islands. Most of all, SLICE Ferry was expected to gain the standing of an attraction in and of itself, eventually becoming as popular and as well known as the Aloha Tower or the Na Pali Coast of Kauai.

Phase A of the SLICE Ferry was to operate between Honolulu, Oahu and Kahului, Maui, a route distance of 96 nautical miles. Additionally, SLICE Ferry would offer mid-day cruises between Kahului, Maui and Hana, Maui, a distance of 40 nautical miles, providing convenient transportation for an estimated 400,000 potential passengers with a 1 hour one-way trip time.

During the first two months of operation, SLICE Ferry would travel between Honolulu and Kahului three days a week, with a one-way trip time of 3 hours. The round trip would begin at 7:00AM in Honolulu and end at 8:00PM in Honolulu. Limiting the schedule to a few days a week would allow for a shake out of any problems in the vessel or operations.

The Honolulu to Kahului SLICE Ferry route would depart and return to Pier 8 at the Aloha Tower Marketplace in Honolulu. During the first two months of operation, the route would be run every Tuesday, Thursday and Saturday. Beginning with the third month of operation, SLICE Ferry would operate between Honolulu and Kahului every day except Monday. Additionally, a mid day cruise between Kahului and Hana on Maui would be added to maximize revenues and vessel utilization. Figure 11-1, presented earlier, shows the location of the proposed routes.

SLICE Ferry would be one of seven wholly-owned subsidiaries involved in the hospitality and ocean transportation business segment of Pacific Marine.. Except for Island Navigation Co., Ltd., which serves primarily as a tour cruise support services company, the companies in this business segment hold berthing and commercial permits and conduct full hospitality operations (service, entertainment, food, liquor, and transportation). They all utilize the trade name "Royal Hawaiian Cruises" for institutional marketing and advertising purposes.

The other tour cruise companies owned by Pacific Marine are: Hawaiian Cruises Ltd.; Seabird Cruises, Inc.; Catamaran Express, Inc.; and Lady Ann Cruises, Inc. Hawaiian Cruises, founded in 1953 and acquired by Pacific Marine in 1988, operates the Navatek I in Honolulu and the passenger vessel Captain Cook VIII in Kona on the island of Hawaii. Seabird Cruises (incorporated in 1986 and acquired by Pacific Marine in 1988) conducts adventure sailing, whale watch and dinner cruises on the island of Maui on the Navatek II vessel, a smaller version of the Navatek I. Catamaran Express (incorporated in 1986 and acquired by Pacific Marine in 1988) conducts adventure sailing and dive tours on the island of Maui. Lady Ann Cruises (incorporated in 1984 and acquired by Pacific Marine in 1988) is located on the island of Kauai, where it also conducts adventure sailing and dive tours.

Island Navigation Co., Ltd. was established in 1987 to provide support services to all Pacific Marine's tour cruise companies and comprises two divisions. The Sales and Marketing Division provides centralized sales and marketing services for all Pacific Marine tour boat subsidiaries under the trade name "Royal Hawaiian Cruises". The Corporate Division is responsible for arranging federal, state and county operating permits; terminal and mooring facilities; joint venture operating agreements; and project financing.

Pacific Marine, founded in 1944, is a privately-held, diversified Hawaii corporation with operations in the tourism, maritime, industrial, and environmental sectors. Consolidated gross revenues for fiscal year ended June 30, 1994 exceeded \$57 million. Today, its hospitality and ocean transportation segment represents roughly 25% of consolidated assets and revenues.

Initially, Pacific Marine's existing staff would be tapped to assist in the development of the SLICE Ferry. As implementation of the business plan progresses, the actual SLICE Ferry organization would begin to fill out.

11.3 Proposed Vessels

The SLICE 250 is a conceptual design for an aluminum hulled 33.7 meter passenger-only ferry. The vessel is planned to accommodate a total of 250 passengers. Although principal particulars for all SLICE variants including the SLICE 250 were presented earlier in Chapter 4, those for the SLICE Advanced Technology Demonstrator (ATD) and the SLICE 250 are presented again here in Table 11-1 for convenience. The SLICE 250 analyzed for this case study is expected to be very similar to the ATD prototype designed by Lockheed and built by Pacific Marine. Powered by two gas turbine engines, the SLICE 250 is planned to have an operating speed of 30 knots. The preliminary general arrangements for the SLICE 250 are presented in Figure 11-2, and the proposed exterior styling in Figure 11-3. The large open spaces in the middle to rear areas of both decks will be used for flexible open seating and will allow passengers to roam about freely, enjoying spectacular views from either the interior of the vessel or from the outside observation deck. The large galley area will be used to prepare food for the snack and beverage bars.

TABLE 11-1: SLICE 250 PRINCIPAL PARTICULARS

Particulars	SLICE Variant	
	SLICE Advanced Technology Demonstrator (ATD) ⁽¹⁾	SLICE 250 ⁽²⁾
Length Overall (LOA) (feet)	104.0	110.5
Beam (feet)	55.0	55.0
Draft (feet)	14.0	14.0
Main Passenger Deck Freeboard (feet)	11.0	11.0
Vehicle Deck Freeboard (feet)	n/a	n/a
Displacement (long tons)	180.0	180.0
Payload (long tons)	35.1	17.9
Passenger Capacity	n/a	250
Main Engines	(2) MTU 16V 396 TB94	(2) TF40 gas turbines
Total Power (hp)	6,850	6,800 ⁽³⁾
Service Speed (knots)	23 to 25 ⁽⁴⁾	30.0

n/a (not applicable)

Sources:

- (1) Lockheed Marine Systems, *SLICE ATD Weights Summary*. Also, U.S. Navy, Office of Naval Research, Industrial Programs.
- (2) Lockheed Marine Systems. Also, *Hawaii Inter-Island Ferry Business Plan Phase A*. Pacific Marine & Supply Company, Ltd. July 1995.
- (3) No data available, but power requirements are inferred from the SLICE ATD and the SLICE 400.
- (3) No data available, but power requirements are inferred from the SLICE ATD and the SLICE 400.
- (4) Although operating speeds of 27 to 28 knots were planned for, in practice speeds of 23 to 25 knots are achieved at 85% mer.

FIGURE 11-2: SLICE 250 GENERAL ARRANGEMENTS

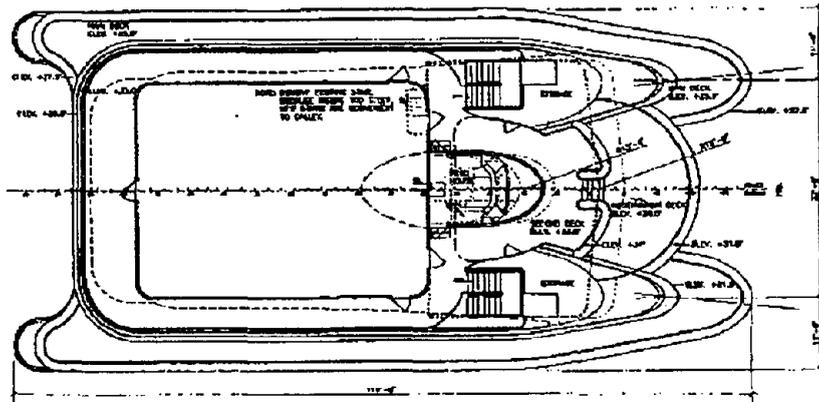
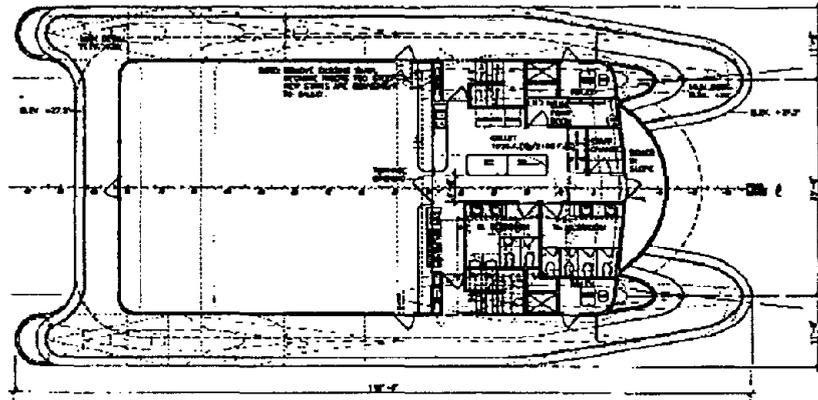
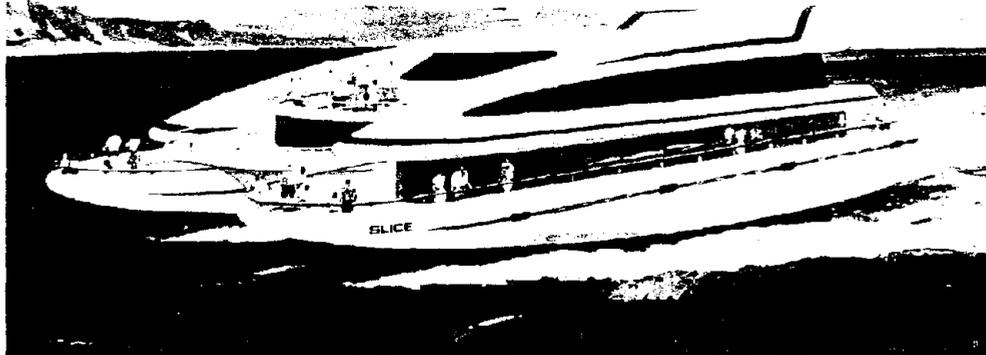


FIGURE 11-3: SLICE 250 PROPOSED EXTERIOR STYLING



11.4 Related Infrastructure and Facilities

Oahu Passenger Terminals - Pier 8

Pier 8 was the Honolulu terminal and main operations headquarters for SeaFlite. This terminal was well laid out and very compatible with the jetfoil operation. However, the facility was incorporated into the Aloha Tower Development, a beautification, restoration and economic development project which has turned that rundown portion of the Honolulu waterfront into a vital area of commerce.

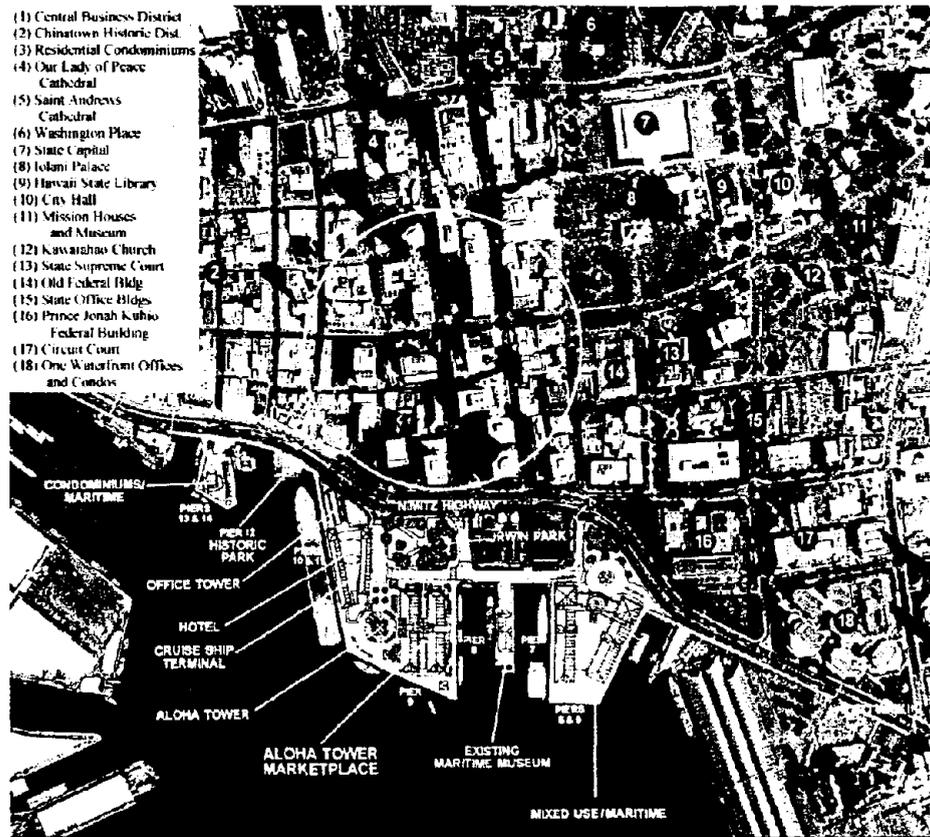
Plans continue to call for the use of Pier 8 as the inter-island ferry space along with approximately 2,000 square feet of office and terminal area (see Figure 11-4). Because of its proven efficiency, central location, sheltered moorage, public visibility and minimum start up effort, every effort will be made to obtain the use of this terminal.

The potential drawbacks to using this area include the lack of parking space, the minimal amount of staging and terminal area and potential traffic problems that may occur given the nature of the surrounding shopping and restaurant complex. The overall ease of staging each cruise could depend on the time of day it departs, the efficiency of the service operations, the amount of activity scheduled for the adjacent loading dock and the availability of parking for ferry passengers.

Oahu Passenger Terminals - Pier 13 and 14

A couple of blocks north of Pier 8, Piers 13 and 14 are currently used as a service area for state vehicles. Although it is not located in a large retail and restaurant complex and so is more isolated than Pier 8, there is an abundance of parking space that can easily be secured. Additionally, there is adequate space to perform nearly all maintenance functions without having to move the SLICE vessel to Pier 41 and its two-block distance from Aloha Tower probably would result in a more manageable traffic situation in that area.

FIGURE 11-4: PROPOSED HONOLULU FERRY TERMINAL FACILITIES (PIER 8 OR PIERS 13 & 14)



If Pier 8 is unavailable or unworkable, Piers 13 and 14 can be converted into a superior integrated maintenance base/passenger terminal providing one-day or multi-day parking for ferry patrons. Passenger and baggage/service operations would be facilitated because there would be enough room to separate the two and to allow for an uninterrupted flow of activity. The large covered parking area of the existing structure has two openings allowing for ease of drop off and loading, entrance and exit.

Passenger Handling

Two distinct areas for departure and arrival would be set up at each terminal. Departing passengers enter the departures area where they purchase tickets and/or check their baggage. A lounge area is provided for the departing passengers until boarding is announced. At this time the passengers exit through the departure gates and board the SLICE ferry. Upon arrival, passengers unload from the SLICE ferry and enter the terminal through the arrival gates. After claiming their baggage, they exit through the terminal doors into the street, bus or parking area.

Baggage Handling

All baggage would be loaded into water tight containers that can easily be loaded and unloaded into the SLICE ferry by a small crane. Full containers would be lifted and placed on a designated deck area of the ferry. The

operation would be much simpler and faster than the conventional conveyor type of operation that airlines use, and would enhance the convenient nature of the SLICE ferry operation.

Administration Offices

Offices to house the operating staff can be set up in the designated office area adjacent to Pier 8. Administrative staff probably would need to be located elsewhere at either Pacific Marine's corporate office two blocks away. If the terminal is located at Piers 13 and 14, there would be sufficient room to house all administrative and operating staff, easing communications and efficiency.

Oahu Maintenance Facility

Some routine maintenance can be accomplished at Pier 8 after completion of each day's operations. However, it is unclear to what extent the maintenance may be completed, given the close proximity of the retail businesses in the area. If maintenance capability is limited, then the SLICE ferry may be taken to Pier 41 for daily maintenance and well as dry dock and major overhauls. Pier 41 is currently occupied by Honolulu Shipyard, Inc. and Island Navigation Co., Ltd., sister companies which would be responsible for all maintenance and repair work on the SLICE ferry.

If Piers 13 and 14 are secured, then there would be sufficient space and security to perform all maintenance functions onsite.

Maui Passenger Terminal

Three locations in the Lahaina-Kaanapali area were investigated as possible west Maui terminals: Black Rock at Kaanapali, Mala Wharf and Lahaina harbor. Other possible locations were rejected as unsuitable due to limited access, coral reef obstructions, shallow water or anticipated political or residential antagonism.

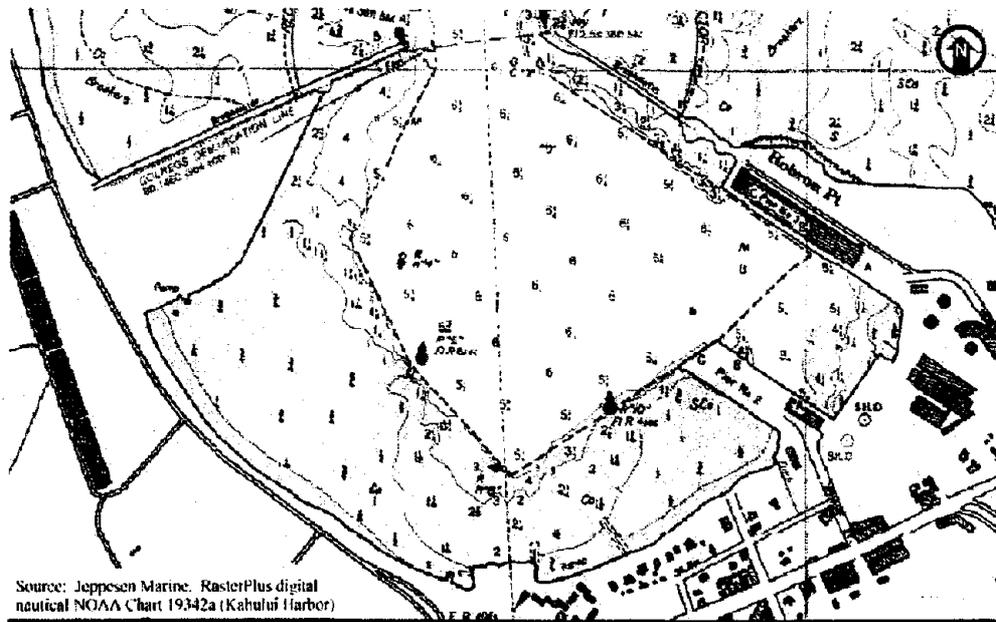
An existing rock jetty at Black Rock appeared to be suitable for establishing a Maui terminal. However, discussions with individuals knowledgeable about conditions on the Maui coast established that storms and heavy seas would destroy any terminal facilities. Furthermore, surge conditions during much of the year would make the location unusable.

Mala Wharf was once considered the only possible location for a West Maui terminal because it appeared that an extension of the existing breakwater could accommodate a large ship. However, since that time, the pier and breakwater have completely disintegrated to the point of being economically unfeasible to repair.

Although Lahaina harbor has several obstacles to overcome - a difficult approach, congestion and lack of sufficient space for terminals, passenger traffic and baggage handling facilities - it is centrally located and would be most convenient for passengers. To avoid problems associated with maneuverability in the harbor itself, a barge could be permanently moored offshore from which passengers would be transferred to and from the SLICE ferry. Smaller shuttle boats would be used to transfer passengers from and to shore.

Because of the numerous problems and issues associated with establishing a ferry terminal in the Lahaina area, this Phase A of the SLICE ferry operation would likely use existing facilities in Kahului. If at a future point of expansion, it is determined that terminal facilities in Lahaina is feasible, then such terminal facilities may be developed.

Kahului Harbor is located on the south side of Kahului Bay, with the commercial deepwater port of Kahului located on the southeast side of the harbor (see Figure 11-5). Controlling depth of the harbor basin is 35 feet. State owned and operated piers are located on the southeast side of the harbor. Pier 1 has 1,350 feet of berthing space along the southwest side, with a controlling depth of 35 feet alongside and a deck height of 9 feet. Pier 2 has 894 feet of berthing space along the northeast side, with a controlling depth of 27 feet alongside and a deck

FIGURE 11-5: KAHULUI HARBOR - NAUTICAL CHART

height of 9 feet. Along the northwest side of Pier 2 there is 290 feet of berthing space, with a controlling depth of 30 feet alongside. Pier 3 extends northeast from the foot of Pier 2, and has 500 feet of berthing space along the northwest side, with a controlling depth of 17 feet alongside and a deck height of 9 feet.⁹⁵

Hana Bay is located at the east end of Maui. A state owned T-pier at Hana provides 300 feet of berthing space, with a controlling depth alongside of 20 to 23 feet, but the pier is no longer maintained and in poor condition (see Figure 11-6).⁹⁶

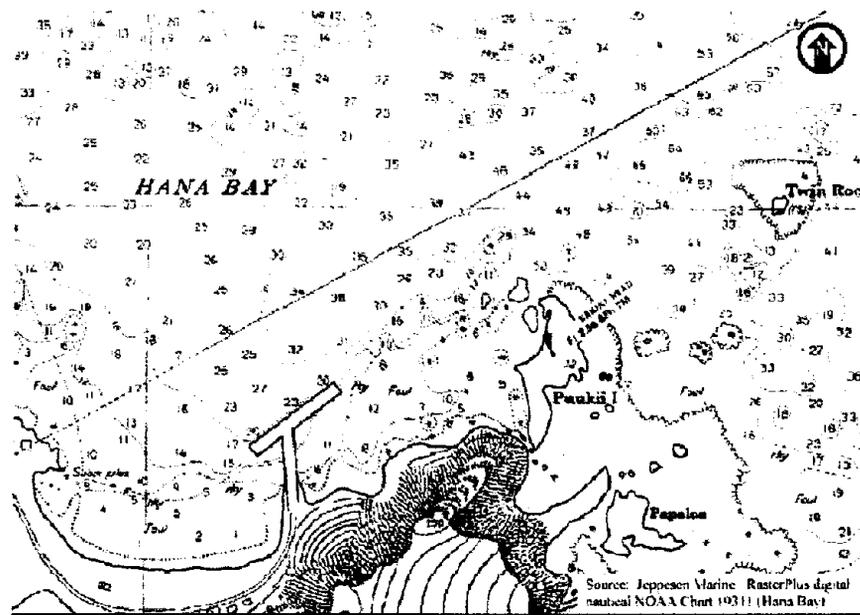
11.5 Weather and Wave Climate

Although a tropical area, the climate of the Hawaiian Islands is unusually pleasant due in large part to the marine influence and the persistent trade winds. The primary climatic feature of the islands is the dominant trade wind influence throughout all seasons, the remarkable variation in rainfall over adjacent areas, and the uniform temperature regime which varies slightly throughout the year. In some local areas, winds deviate from the general pattern because of topography. The islands lie on the extremities of both the Western North Pacific typhoon area and the Eastern North Pacific hurricane area, and a tropical cyclone from either region is rare, although August would be the most likely month if one were to occur. The western islands in the Hawaiian chain, such as Kauai, tend to experience more hurricanes than the eastern islands. Considerable more rain falls from November through April over the islands as a whole than from May through October. Historical meteorological data for the Hawaiian Islands is presented in Table 11-2.

⁹⁵ U.S. Department of Commerce. National Oceanic and Atmospheric Administration (NOAA). *United States Coast Pilot. Volume 7. Pacific Coast: California, Oregon, Washington, and Hawaii.* 31st Edition. Page 407.

⁹⁶ U.S. Department of Commerce. National Oceanic and Atmospheric Administration (NOAA). *United States Coast Pilot. Volume 7. Pacific Coast: California, Oregon, Washington, and Hawaii.* 31st Edition. Page 404.

FIGURE 11-6: HANA BAY - NAUTICAL CHART



As discussed earlier in Chapter 8, the Volpe Center conducted a detailed wave climate analysis using a combination of measured wave data sources and modeled hindcast data sources. Data sources used for this region included measured data from NOAA buoys and Scripps Institution of Oceanography (SIO) buoys (see Table 11-3). In total, more than 51,000 data records were utilized.

Figure 11-7 presents the location of the particular buoys and stations from which data was obtained. Based on the proposed operating schedule for the Honolulu to Kahului and Kahului to Hana route segments, a distribution of annual vessel operating hours by sea state was developed. The results of this analysis, presented in Figure 11-8, reveal that significant wave heights in excess of sea state 4 (4.1 to 8.2 feet) would be experienced 21.6% of vessel operating hours. The relatively difficult wave climate of the Hawaiian islands is well suited to the application of SLICE vessels, providing SLICE ample opportunity to improve ride quality and passenger comfort for a substantial number of vessel operating hours annually when compared with other vessel designs with seakeeping ability that is inferior to SLICE.

11.6 Navigational Considerations

Honolulu Harbor is protected from all winds, and is the principal deepwater port of the State of Hawaii. In Honolulu, harbor regulations are established by the Harbors Division of the Hawaii Department of Transportation. Prior to entering the harbor, all vessels must establish radio contact with Aloha Tower traffic control. The speed limit in Honolulu Harbor is 5 knots for all vessels and two and 10 knots for motorboats and other small craft. Mean range of tide at Honolulu is 1.3 feet.

Kahului Harbor, on the south side of Kahului Bay, is protected by breakwaters which extend outward from the west and east shores. On the southeast side of the harbor is the commercial deepwater port of Kahului. From deep water on the north, the channel into the harbor leads between the breakwaters then turns southeast to the piers at Kahului. Controlling depth of the channel and of a harbor basin is 35 feet. The west part of the inner

harbor is relatively shallow, with controlling depths of about 3 to 6 feet. Also, there are reefs northwest and northeast of the breakwaters extending 0.7 to 1.2 miles offshore.

TABLE 11-2: METEOROLOGICAL TABLES FOR THE HAWAIIAN ISLANDS

METEOROLOGICAL TABLE FOR COASTAL AREA OFF HAWAIIAN (WINDWARD) ISLANDS
Boundaries: Between 18°N TO 22°N FROM 154°W TO ISLAND

Weather Elements	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Wind > 33 Knots (1)	1.4	0.8	1.3	0.4	0.0	0.1	0.2	0.2	0.1	0.2	1
Wave Height > 9 ft (1)	4.0	4.0	5.6	3.9	2.5	1.3	1.9	1.8	0.5	1.8	4
Visibility < 2 nmi (1)	1.2	0.6	0.3	0.5	0.2	0.3	0.2	1.0	0.6	0.4	0
Precipitation (1)	5.7	5.5	5.6	5.8	3.1	6.4	4.0	5.4	3.1	2.7	5
Temperature > 69 F (1)	89.9	84.7	87.5	85.8	93.2	94.2	99.7	99.9	99.8	99.6	99
Mean Temperature (F)	74.1	73.5	73.5	74.1	75.6	76.7	77.7	78.5	78.7	78.3	76
Temperature < 33 F (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Mean RH (%)	79	79	78	78	77	77	78	79	77	77	
Overcast or Obscured (1)	12.5	13.0	14.7	13.2	7.6	7.1	6.9	7.0	5.7	8.4	11
Mean Cloud Cover (8ths)	4.1	4.2	4.5	4.5	4.1	4.3	4.2	4.1	3.9	4.0	4
Mean SLP (mbs)	1015	1016	1017	1017	1017	1017	1017	1016	1015	1015	10
Ext. Max. SLP (mbs)	1030	1033	1038	1030	1028	1030	1030	1030	1031	1030	10
Ext. Min. SLP (mbs)	998	996	997	1001	1002	1002	1002	1002	1001	999	10
Prevailing Wind Direction	E	E	E	E	E	E	E	E	E	E	
Thunder and Lightning (1)	0.7	0.4	0.4	0.3	0.1	0.1	0.1	0.3	0.2	0.3	0

METEOROLOGICAL TABLE FOR COASTAL AREA OFF HAWAIIAN (LEEWARD) ISLANDS
Boundaries: Between 18°N TO 22°N FROM ISLAND TO 160°W

Weather Elements	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV
Wind > 33 Knots (1)	0.5	0.4	0.8	0.4	0.1	0.1	0.1	0.2	0.1	0.2	0
Wave Height > 9 ft (1)	2.3	2.5	2.9	2.0	0.9	0.7	1.2	0.9	0.9	1.5	0
Visibility < 2 nmi (1)	0.7	0.7	0.3	0.5	0.3	0.3	0.2	0.2	0.2	0.3	0
Precipitation (1)	4.0	4.6	4.0	3.7	3.2	2.2	2.1	2.2	2.1	2.8	0
Temperature > 69 F (1)	94.7	93.6	93.1	97.0	99.1	99.8	99.8	99.9	99.9	99.8	99
Mean Temperature (F)	75.1	74.7	74.7	75.7	77.1	78.5	79.2	79.7	80.0	79.3	7
Temperature < 33 F (1)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
Mean RH (%)	77	77	77	78	77	77	77	77	77	77	
Overcast or Obscured (1)	9.0	10.4	11.9	11.6	7.0	5.4	4.1	4.2	4.8	7.4	0
Mean Cloud Cover (8ths)	3.7	3.8	4.1	4.2	4.0	4.0	3.8	3.6	3.6	3.9	0
Mean SLP (mbs)	1015	1015	1016	1017	1017	1016	1016	1016	1015	1015	10
Ext. Max. SLP (mbs)	1032	1030	1037	1031	1031	1031	1032	1032	1031	1032	10
Ext. Min. SLP (mbs)	993	998	1000	1000	1001	1002	1003	1001	1000	999	0
Prevailing Wind Direction	E	E	E	E	E	E	E	E	E	E	
Thunder and Lightning (1)	0.4	0.5	0.5	0.3	0.2	0.1	0.2	0.1	0.2	0.4	0

(1) Percent frequency

These data are based upon observations made by ships in passage. Such ships tend to avoid bad weather when possible, thus biasing the data toward good weather samples.

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) United States Coast Pilot, Volume 7, Pacific Coast: California, Oregon, Washington, and Hawaii, 31st Edition, Page T-17.

TABLE 11-3: HAWAII CASE STUDY - WAVE DATA SOURCES

Data Source	Buoy or Station	Time Period Observed	Number of Records
NOAA	51026	1/93 - 12/94 & 1/95 - 11/96	36,893
SIO	Pe075	2/93 - 10/93	1,686
SIO	Si034	10/93 - 11/96	6,707
SIO	Si075	10/93 - 7/94	2,043
SIO	Si077	10/93 - 4/95	4,360
TOTALS			51,689

FIGURE 11-7: HAWAII WAVE DATA STATIONS

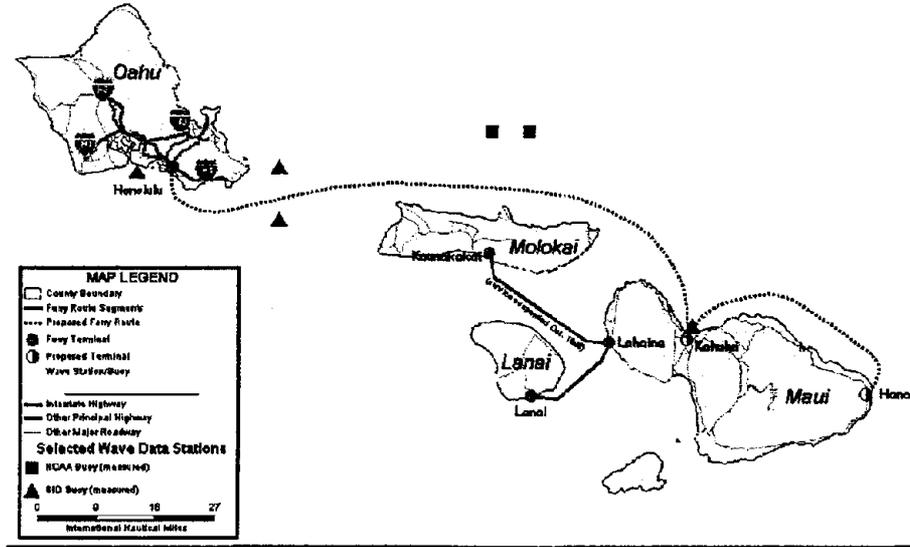
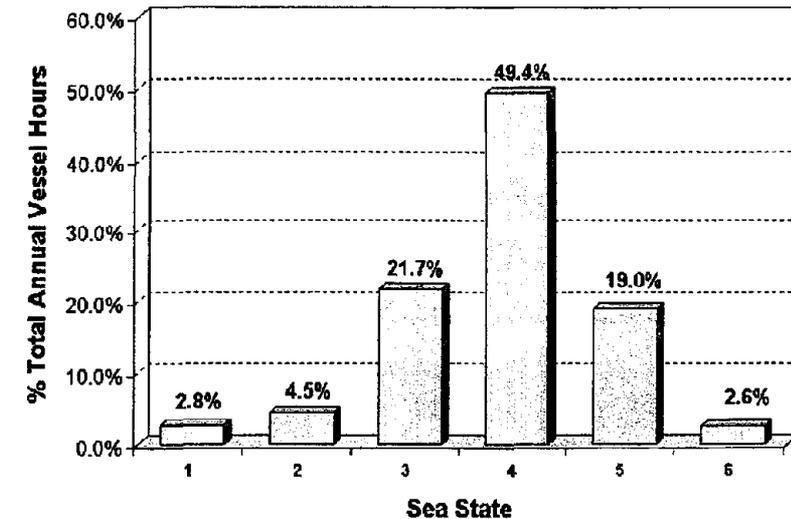


FIGURE 11-8: DISTRIBUTION OF ANNUAL VESSEL OPERATING HOURS BY SEA STATE (HAWAII)



Hana Bay is located at the east end of Maui, and Hana is located on the south side of the bay. A shoal, usually marked by breakers, extends halfway across the bay from the middle of the north shore. The entrance channel to Hana Bay is between Twin Rocks and a 16 foot shoal, and is unmarked. It is a local rule to avoid entering the harbor when the seas are breaking at the entrance.

11.7 Environmental Considerations

The pattern of whale migration generally follows a simple routine of feeding at high latitudes during the summer months, and breeding in warmer latitudes during the winter months. This pattern applies for both northern hemisphere and southern hemisphere whale species, however whales rarely, if ever, cross the equator, primarily because of the excessively warm water temperatures. Humpback whales are prevalent in Hawaiian waters, and appropriate caution would be required when operating SLICE vessels, with their comparatively deep draft, in the vicinity of humpback whales in order to avoid the possibility of striking a whale while underway.

11.8 Market Forecasts and Financial Analysis

11.8.1 Market Forecasts

Inter-Island Transportation System

Any proposed inter-island ferry system will have to compete with existing modes of transportation on any shared routes. The automobile, however, is not one of them.

Hawaii's inter-island transportation system is notable for the lack of any road or bridge connections between the islands. All transportation moves by either sea or air. Unlike demand studies of many locations on the Mainland U.S., a Hawaii demand study does not have to factor in the automobile or bus as a transportation option. Instead, the major competitor to any inter-island ferry system in terms of carrying passengers and light freight is the existing inter-island airline system. An inter-island ferry service can create new market demand by opening up scenic, new routes not currently being served by the airlines. But long term success and growth will also require it to compete head-to-head on many existing routes and capture market share from inter-island airlines. How many riders it can divert in head-to-head competition will depend on how competitive it is with the airplane primarily in terms of price, trip time and frequency of service.

An existing inter-island barge system also provides competition to any ferry system planning to carry heavy freight, commodities or automobiles.

Inter-Island Air Passengers

Hawaii's inter-island air carriers transported over 9,345,000 passengers between the islands in 1993, with Hawaii's two major inter-island air carriers, Aloha and Hawaiian, accounting for about 90 percent of the total.

The infrastructure serving Hawaii's inter-island air system is extensive and modern. Major international, all-weather airports capable of handling multi-engine jet traffic are found on all five major islands - on Oahu at Honolulu; on Maui at Kahului; on the Big Island at Hilo (East Hawaii) and Kona (West Hawaii); and on Kauai at Lihue. Smaller, secondary commercial airports handling smaller jets or turboprop planes are located on Molokai (Molokai and Kalaupapa airports), Lanai, the Big Island (Waimea), Maui (Kapalua and Hana) and Kauai (Princeville). All of these airports offer scheduled inter-island air service.

The biggest tourist market without a major airport is West Maui (Lahaina and Kaanapali) which is serviced only by turboprop planes landing at the small Kapalua airport. Most visitors to Lahaina and Kaanapali must land at Maui's main airport in Kahului and suffer an hour-long car ride to their destination after landing.

In July 1993, the State of Hawaii opened a brand new \$130 million inter-island airline terminal at Honolulu International Airport. The seven-floor structure boasts over 600,000 square feet of terminal space and four-floor parking garage with 1,700 parking stalls. Other recent airport improvements include a new \$7.5 million airport terminal at Lanai; and a \$30 million extension of the main runway at Kona airport from 6,500 feet to 11,000 feet (only 1,000 feet shorter than Honolulu International Airport). In addition, planning is already underway to extend the runway at Kahului airport on Maui from 7,000 to 9,600 feet.

Two airlines dominate the Hawaii inter-island air carrier market with a third inter-island airline in the startup stage. Historically, Hawaii has been served by only two airlines - Hawaiian (founded in 1929) and Aloha (founded in 1946). A third inter-island airline, Mid Pacific Airlines started up in 1981 and captured 20 percent of the inter-island market before ultimately folding a few years later. In 1990, another inter-island airline, Discovery Airways, began service but ceased operations some four months later and filed Chapter 7 in 1991. In October 1993, a new inter-island airline, Mahalo Air, commenced limited service between Honolulu and Kauai. It shut down in May 1993 but returned in November 1994 and plans to use a fleet of six 48-seat turboprops.

Inter-island air travelers are divided into two major segments: tourists and residents. The customers representing these two market segments are quite different and require different marketing approaches.

The Hawaii market is price-sensitive, with big tour wholesalers, local organizations and business groups all seeking volume discounts. Local residents also routinely receive discounted rates on their tickets. Aloha and Hawaiian are often forced to match each other's fares, or at least stay within close proximity to avoid losing market share to each other. The presence of a third inter-island airline has also historically triggered fare wars and reduced ticket prices. Because of the short flying distances between islands, rates are basically the same within the State, regardless of distance.

Current basic rack rate airfares for tourists are \$74 one way and \$148 round trip for most inter-island flight legs. Basic resident rates are \$55-\$65 one way and \$84-\$112 round trip. Seasonal leisure and holiday travel produce cyclical volatility, and during off-peak months (usually including January, May, September and October) airlines must increase the availability and size of discounts.

Aloha Airlines

Aloha carried 5,034,000 passengers in 1992, making it the dominant player in the market. In 1993, it captured 59.2 percent of total inter-island passenger revenue miles as compared to 40.8 percent for Hawaiian Airlines. Privately owned, it is also the most financially healthy of the two major inter-island airlines and one of only a handful of U.S. airlines nationwide which reported a profit (\$2.9 million) in 1993. Revenues in 1993 were \$214 million, of which \$175 million came from passenger operations and \$26.4 million from carrying freight.

Aloha operates a fleet of sixteen Boeing 737-200/300/400 jet planes servicing the larger airports in the State. Aloha carried 4.7 million passengers in 1993. Aloha also owns a subsidiary, IslandAir, which operates eight de Havilland Twin Otter turboprop planes servicing smaller secondary airports in Hawaii. IslandAir carried approximately 400,000 passengers in 1993. According to public document filings, passenger loads on Aloha have averaged 57-62 percent over the last five years.

Aloha estimates that 60% of its passengers are tourists; 40 percent are local residents.

The resident segment of this passenger mix is composed of three major groups:

- "Frequent flyers", primarily business travelers. Aloha estimates that approximately 16,000 individuals fly 20 or more times a year. They demand on-time service, frequency and convenience in flight schedules, and quality service.
- "Infrequent flyers" including local residents visiting relatives, friends and neighbors on other islands, or traveling on vacation. Ticket price is a major consideration for this group.
- "Wholesale traffic" booked by Hawaii tour wholesalers offering group, organizational or discounted Neighbor Island "weekender" packages with perhaps a car or hotel room included in the package.

The tourist segment of Aloha's passenger mix is comprises:

- "Wholesale traffic" composed of tickets sold by tour wholesalers. The nine biggest wholesalers each generate 50,000 passengers a year while another 26 tour wholesalers each generate 10,000 passengers a year.
- Independent travelers who book their own ticket, use their local travel agent to book, or book through a Mainland air carrier via code-sharing on a computer reservation system.

Aloha's fare categories include:

- Published retail rates which account for about 35-40 percent of sales and include a) full rack rate (paid by few people); b) off-peak fares; and c) bargain "kama'aina" fares for local residents.
- Contracted wholesale fares, representing about 31 percent of sales revenue.
- Coupon books with multiple tickets good for one year, representing about 30 percent of sales.

Hawaiian Airlines

Hawaiian Airlines carried 3,386,000 inter-island passengers in 1993. Although it is the second largest carrier in the market, it is weathering some severe financial turbulence. In September 1993, the company filed for reorganization in Bankruptcy Court under Chapter 11 but has since re-emerged and is continuing operations. Inter-island passenger revenues in 1993 were \$119 million while inter-island cargo revenues were \$7 million. (Hawaiian Airlines also operates routes outside the State. The inter-island market in 1993 represented only 43.4 percent of the company's total passenger revenues).

At the end of 1993, Hawaiian operated a fleet of nine McDonnell Douglas DC-9 50 series passenger jets on its inter-island runs, supplemented by four de Havilland DASH 7 turboprops for use to smaller airports. Hawaiian reported an average passenger load factor of 57 percent in 1993, with load factors as high as 66 percent during the high-volume summer months.

According to public filings, Hawaiian indicates its belief that one third of inter-island air passengers are residents, with the balance of two-thirds being tourists.

Market Considerations

Gross Market Estimates

More than 30 studies have been conducted in the last forty years on the inter-island ferry question. Most were done in the period 1955-1975 and have limited value in terms of establishing current potential demand for an inter-island ferry service. Three, however, deserve closer scrutiny. They include:

- The actual operating experience of SeaFlite between 1976-1979 provides us with the most recent proven demand figures for an actual inter-island ferry operation. The Oahu-Maui leg was SeaFlite's most popular and captured an estimated 8.1% of total air passenger traffic between the two islands. Applying the same capture ratio of total 1990 inter-island travelers, ferry passenger volume between Oahu and Maui is estimated to be about 228,000, based on 1990 intrastate air transportation statistics from the State Department of Transportation, Airports Division.
- The 1983 Loui/Singer & Associates ridership study is the most recent professional demand study conducted on a statewide ferry system, and includes ridership projections for Westbound, Eastbound and local resident segments of the population based on 1982 air traffic statistics. The Rogers and Shoemaker methodology, used in the Loui/Singer study, assumes the rate of adoption of new innovations is distributed in bell curve fashion. Using the 1990 DOT statistics to update the Loui/Singer projections, the passenger volume projected for the Honolulu - Kahului SLICE Ferry route is 81,576 for year one, 207,652 and 237,316 for year three.
- The 1984 UMTA study entitled *An Assessment of the Potential for High Speed Waterborne Passenger Services in Selected United States Sites* includes a detailed, professional diversion analysis of the Oahu-Maui route, and adjusts its ridership projections based on travel time and ticket price variables. The UMTA study found that one-way daily ridership would average between 240 and 280 passengers given a \$45 fare and two round trips per day. Air fare at the time of the study was approximately \$50, not factoring in discounts. Utilizing the UMTA model, we find that we might expect 237,000 annual ferry passengers on the Oahu - Maui leg.

Comparing the three methods of projecting SLICE Ferry ridership, we can see that the range is rather narrow, with a low of 228,000 passengers per year and a high of 238,000 per year traveling between Honolulu and Maui. The financial projections assume that an average 150 passengers per leg would take SLICE Ferry between Honolulu and Kahului, which amounts to a total of 188,000 passengers per year or 18% less than the low end of the range.

For the second route, running between Kahului and Hana, it has conservatively been assumed that less than 94,000 passengers would take the cruise. As it is estimated that more than 400,000 people visit Hana every year by automobile, the ridership estimate for the Kahului - Hana route represents less than 25% of the total. Because the drive to Hana is long and somewhat treacherous, the 25% capture ratio would likely be achieved.

Undoubtedly, other marketing factors would affect the actual market share obtained, therefore marketing strategy is discussed below.

The Reliability Question

Perhaps the most significant marketing challenge for the new enterprise would be to overcome the negative impressions and attitudes that may exist in the marketplace toward a similar operation that failed. Creating interest and marketing a new product or concept is difficult but less complicated than trying to overcome impressions and attitudes that may have contributed to the demise of the original product.

Interviews and discussions with travel agents, tour wholesalers, passengers, and persons associated with the SeaFlite operation indicate that the greatest marketing problem was the reliability of the boat. This not seen as a particularly difficult problem for the SLICE Ferry simply because the vessel is a newer and more technologically advanced version of the Navatek I SWATH vessel which has been operating in Hawaiian waters since 1990. However, it will be important that the necessary testing be performed on the prototype vessel to ensure that the eventual SLICE Ferry meets the reliability demands of a scheduled ferry service.

Market Segments and Positioning - Residents

As is the case with the inter-island airlines and the SeaFlite operation, the market for ferry ridership falls into two segments: out-of-state visitors and local residents. While no recent surveys of residents have been performed since the 1983 Loui/Singer study, many of the conclusions of that study are valid today.

Loui/Singer's resident survey comprised 408 mail questionnaire responses from local residents representing a 69% participation rate. The conclusions were that "an opportunity exists for the development of a cruise service for local consumers at reasonable prices," that residents would be more likely to ride the SLICE Ferry both ways as a pleasure service, and additionally, one-third of local ferry riders would take their autos along. The primary concerns of the residents included price, safety, convenient and on-time schedules and comfort. The most appealing features of such a service included a relaxed atmosphere, scenic view and the possibility of auto passage.

The survey further determined that 41% and 38% of survey respondents indicated they would be "very likely" and "somewhat likely," respectively, to use the ferry service. Sixty-five percent of survey respondents traveled to at least one of the major outer islands in the prior 12 months with Maui as the most popular destination and 80% of those travelers did so for pleasure with a family or social group.

Market Segments and Positioning - Visitors

Recent interviews with Japanese and North American travel industry executives indicate what particulars would be necessary to successfully market the SLICE Ferry to all potential markets. Initial reaction to Phase A was very positive with 75% of the North American and 90% of the Japanese respondents indicating their opinion that the concept has potential for success in Hawaii. Only one of the 15 respondents felt the ferry should be marketed as "transportation only". The remaining executives felt the SLICE Ferry should be marketed as a "cruise experience" between destinations.

Nearly all of the Japanese travel industry executives believe that most of their clients would opt for one-way travel only. About half of their North American counterparts agreed, probably reflecting the fact that Japanese tend to visit the islands for much shorter periods of time than westbound visitors.

The following is a preferred "composite" of the SLICE Ferry based on the interviews with the travel industry executives:

Capacity:	200 - 400 passengers
Seating:	Open-space
Atmosphere:	Luxury cruise (not cattle boat or bus atmosphere)
Duration:	2.5 hours or less between 2 points
Amenities:	Food service, ample storage, activities and tour narration
Retail Fare:	\$50 - \$80 one-way

Other comments and conclusions from the interviews included recommendations that a 3-tiered price structure be created: Kama'aina, Visitor and Groups, which would be further broken down by deluxe and economy class fares. The concept of a ferry pass program for multiple destinations was also highly regarded.

Marketing Strategy

The retail/wholesale travel industry marketing channels are well established globally, and the Hawaiian tourism infrastructure is highly developed. The SLICE Ferry is an enticing experience to offer and there are many ways to reach both the tourist and resident customer. From a marketing standpoint, there is little question that sufficient revenues can be developed to achieve profitability.

A key strategy in developing revenues rapidly will be the ability to work through existing, established sales and marketing organizations. Tour wholesalers, incentive group organizations, tour desks, ground handlers and even the inter-island airlines can all contribute to the success of SLICE Ferry. This effort would be facilitated because Pacific Marine, through its subsidiary, Royal Hawaiian Cruises, is already closely tied into those channels.

The major problem in establishing a profitable SLICE Ferry will be overcoming the failures of previous inter-island ferry operations. It would likely take an estimated six months of reliable SLICE Ferry operations before the major tour wholesalers can confidently promote the product.

In general, the leisure traveler is more likely to use the SLICE Ferry than the business traveler due to the length of time required to reach the destination and advertising and public relations programs will reflect that assumption. Additionally, public relations and advertising programs will be started far in advance to generate awareness and excitement about the coming attraction.

Pricing

The SLICE Ferry would be marketed as a "high-end cruise experience". The vessel would feature the latest in vessel technology as well as all the comforts of first class travel. Open-space seating allowing freedom of movement, windows allowing panoramic views of the coastline, an observation deck - all contribute to relaxed and luxurious passage and the possibility of premium ticket prices. However, one-way fare pricing would be competitive with airline rates making the SLICE Ferry a high value product given all that is offered on each cruise.

Resident Awareness

It should be relatively easy to re-establish awareness within the local community because of the tremendous effort put forth in the past. A great deal of media interest will likely be created in the new product and close attention will be paid to the reliability of the operation. Again the key will be reliability. Public relations, visual awareness, direct sales efforts by employees would likely create a substantial impact which might release more money for mainland marketing activities. Introductory ads in local newspapers followed by television spots will enhance the visibility of the SLICE Ferry.

Visitor Target Markets

North American and European visitors tend to stay an average of 10 days in Hawaii and so are prime targets for SLICE Ferry. Besides U.S. mainland visitors, Canadian, German and British visitors generally visit for five days or more. From the east, Japanese, Taiwanese, Korean and Australian visitors are likely customers for SLICE Ferry.

To reach these visitor markets, a full scale advertising campaign would be launched in conjunction with public relations activities to generate awareness and create excitement of the product in key markets. The four-color advertising along with vessel schematics, schedules and list of on-board amenities would be placed in consumer

and travel trade publications, supplemented with personal selling through the existing Royal Hawaiian Cruises sales staff. Toll-free telephone numbers would naturally be made available for out-of-state inquiries and bookings.

Co-Opting the Competition

Activities with the airlines serving Hawaii should be actively pursued. These fly/sail programs could be especially productive as most ferry passengers are likely to request one-way only fares. Additionally, by creating a potentially lucrative new attraction and generating additional sales for the airlines, relations with the inter-island air carriers could be viewed as a source of mutual strength rather than competition. It is in the interest of the new venture to pursue a good marketing relationship with the inter-island carriers, however, the effort to create viable tour programs using sea and air will have to come from SLICE Ferry. Other marketing opportunities exist with the car rental firms, ground transportation companies and the hotels.

11.8.2 Financial Analysis

Summary Financial Results and Projections

The task of starting an inter-island ferry service is facilitated by the existence of Pacific Marine staff experienced in related and/or support functions. For example, Royal Hawaiian Cruises already operates and markets ocean day cruises in Honolulu, Lahaina, Kona and Kauai. Honolulu Shipyard is a ship repair company that will be largely involved in the construction of the SLICE prototype and in the ongoing repair and maintenance of the SLICE ferry.

The SLICE Ferry is expected to begin operating in mid-1997. Due to extensive pre-marketing efforts, profits before taxes and interest expense are projected to be \$1.5 million for the first year of operation. On an annual basis thereafter, profits before taxes and interest expense of \$2.2 million are expected. Summary financial operating projections are shown in the Table 11-4.

The financial projections include the assumption that each route segment will carry an average 150 passengers, or a total of 164,000 passengers in the first year, and increasing to a steady state of approximately 188,000 every year thereafter. This compares favorably to the broad market analysis previously performed as well as to SeaFlite's actual 1977 experience during which they carried 150,000 passengers between Oahu and Maui during the first 9 months of that year. In the break-even scenario, only 100 passengers on average would need to be carried on each route segment.

Detailed Financial Results and Projections

The annual operating projections and underlying assumptions for SLICE Ferry appear on the following pages. These projections are in large part based on the actual operating experience of the Navatek vessels currently operating in Pacific Marine's fleet of tour boats as well as empirical data gathered from the SeaFlite and other ferry operations.

The market analysis demonstrates that there likely exists considerably more demand for an inter-island ferry than available capacity on the Phase A SLICE ferry, and so a "ramp up" or slow start up period is not anticipated. Additionally, as Pacific Marine has found with the start up of the Navatek vessels, a slow start can be avoided through the use of extensive pre-marketing and advertising campaigns.

TABLE 11-4: SUMMARY PATRONAGE AND FINANCIAL PROJECTIONS

	Year 1	After Year 1	Breakeven
Passenger Projections			
Honolulu-Kahului-Honolulu	86,031	93,852	61,983
Kahului-Hana-Kahului	78,210	93,852	61,983
Total Passengers	164,241	187,704	123,966
Financial Projections			
Revenues	\$7,477,000	\$8,541,000	\$5,640,000
Costs of Sales	\$1,811,000	\$2,031,000	\$1,342,000
Gross Profit	\$5,666,000	\$6,509,000	\$4,299,000
Indirect Costs	\$1,675,000	\$1,800,000	\$1,783,000
Adjusted Gross Profit	\$3,991,000	\$4,709,000	\$2,516,000
Operating Expenses	\$1,717,000	\$1,731,000	\$1,895,000
Income Before Financing Costs	\$2,273,000	\$2,978,000	\$621,000
Vessel Lease Expense	\$476,000	\$476,000	\$476,000
Equipment Lease Expense	\$90,000	\$90,000	\$90,000
Interest Expense	\$55,000	\$46,000	\$55,000
Pretax Income	\$1,451,000	\$2,164,000	\$0

Revenues

Net fares after commissions are assumed to average \$40 per passenger. Fifty percent of passengers are expected to opt for round trip fares, as there is a 20% discount incentive to do so. Additional revenues are generated from ancillary sales such as gift shop, snack bar and extra luggage charges.

Passenger volume was assumed to average 150 passengers per route leg, or 164,241 passengers in the first year of operation and 187,704 annually thereafter (see Table 11-4).

It should be noted that the volume assumption of 86,000 passengers in Year 1 for the Honolulu-Kahului route are considerably lower than both market demand projections and actual SeaFlite experience have indicated as likely.

The volume assumed for the Kahului - Hana route represents less than 25% of the estimated 400,000+ travelers that venture into Hana annually. Considering the long and treacherous drive into Hana, the ferry ride offered as part of a "drive/ sail" tour, should easily capture that portion of the market. If we estimate that the 400,000 travelers require entry and exit from Hana, the 94,000 tickets sold on SLICE Ferry represent only 12% of the 800,000 Hana visitor route legs.

Ancillary sales were expected as follows:

	\$ Per Passenger
Gift Shop Sales	\$3.00
Snack Bar Sales	\$5.00
Luggage Check In	\$2.00

Cost of Sales

The predominant variable cost in the SLICE Ferry operation is labor. The passenger to crew/attendant ratio is shown below along with the assumed wage rates. Fringes and other payroll costs amounting to 37% of direct wages is assumed.

	<u>Passengers per Employee</u>	<u>Wage Rate</u>
Crew Member	37.5	\$16.00
Attendant	20.0	\$8.00

Other cost of sale items include:

	<u>Per Passenger</u>	<u>As a % of Sales</u>
Materials and supplies	\$ 0.50	---
Gift Shop cost of sales	---	50%
Snack bar cost of sales	---	50%
General excise tax	---	4%
Harbor fees	---	2%

Indirect Expenses

Indirect expenses are primarily related to the operation of the SLICE Ferry vessel. Repair and maintenance are contracted out on an operating hour basis, assumed to run \$300 per operating hour. Vessel fuel costs are based on consumption of 300 gallons per hour at a rate of \$1.00 per gallon. Total annual cruise hours are 2,503 after the start-up period.

An accrual for "offload" costs are included in the projections in the event that passengers will have to be accommodated on some other means of transportation due to unexpected vessel downtime. Although all indications are that the vessel would reliably transverse the selected routes, the operating difficulties of SeaFlite have been a constant reminder that an offload accrual is a prudent course of action.

Operating Expenses

Payroll and Related. A total of seven employees would permanently staff the two terminal facilities. The general manager would be located in Honolulu along with an office manager and two reservationists. The Kahului terminal would be run by an assistant manager supplemented by two staff persons. All luggage handling would be performed by the ship's crew and attendants paid on an hourly basis (included in cost of sales). As all marketing and sales are handled by sister company, Island Navigation Marketing & Sales, no sales staff is included in the projections.

Outside Services. Annual accounting fees of \$5,000 and legal fees of \$5,000 are included in the projections. During the first two months of operations, legal fees are expected to amount to \$10,000. Prior to actual operations, legal fees related to securing the necessary licenses and permits are expected to total \$75,000 to \$200,000, depending upon whether Phase A of the SLICE Ferry will be exempt from PUC control. For the purposes of this business plan, it has been assumed that SLICE Ferry, Phase A will achieve exempt status, and the requirements of the PUC for reporting and monitoring will be minimal.

Marketing and Advertising. Six percent of total projected revenues are assumed to be paid to Island Navigation Marketing & Sales. This inter-company charge is assumed to cover actual expenses with no additional markup included.

High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

Marine Insurance. Pacific Marine allocates insurance expense to each of its subsidiaries based on cost of coverage provided. All insurance secured is handled by Pacific Marine's Risk Management department which is able to negotiate favorable rates and coverage due to the size of the consolidated entity. The projections assume rates and premiums similar to that of the Navatek 1, a 400 passenger SWATH vessel operating in Honolulu.

Rent Expense. Total rent expense of \$12,000 per month includes office, terminal, and storage space for both Honolulu and Kahului.

Financing Costs/ Capital Required

Hard Costs. The schedule below is a preliminary list of all hard assets expected to be acquired prior to actual operations. The financial projections include vessel lease payments of about \$40,000 per month, and is based on an acquisition cost of \$3,000,000 amortized over a ten year period at a rate of 10% per annum. Additionally, it has been assumed that approximately \$300,000 of equipment would be leased over an average 4 year period at a rate of about 9% per annum. The remainder of the equipment and improvements to be acquired, at a cost of approximately \$500,000, may be financed with debt, grants, and/or equity from investors. The financial projections assume debt financing termed over five years at about 9% per annum.

Soft Costs. Prior to the start of actual SLICE Ferry operations, overhead expenses and other start-up costs amounting to \$1 million are expected. Like a portion of the hard costs listed above, these expenses would likely be funded through a combination of grants, debt and equity capital. However, it has been assumed that all \$1 million of start up expenses would be funded through equity capital provided by Pacific Marine, \$900,000 of which would be amortized over a five year period. The breakdown of these soft costs is presented in the following schedule.

SLICE Start-Up Expenses	
Legal and consulting fees for permits, etc.	\$75,000
Vessel "dry-runs" and related expenses	\$100,000
Fixed and other overhead expenses	\$325,000
Local and international marketing launch	\$400,000
Working capital during initial operating period	\$100,000
TOTAL	\$1,000,000

Equipment Acquisitions	
Vessel Acquisition	
(1) SLICE Vessel (250 passengers)	\$3,000,000
Oahu Terminal Facilities	
Fenders	\$40,000
Ramps	\$32,000
Power Connections	\$10,000
Other Leasehold Improvements	\$278,000
Autos (2)	\$60,000
Forklift	\$30,000
Small crane	\$40,000
Computers, other office equipment	\$50,000
Kahului Terminal Facilities	
Fenders	\$40,000
Ramps	\$32,000
Power Connections	\$10,000
Other Leasehold Improvements	\$38,000
Autos (1)	\$20,000
Small crane	\$40,000
Computers, other office equipment	\$18,000
Containers / Luggage Lockers	\$72,000
TOTAL	\$3,810,000

TABLE 11-5: DETAILED PATRONAGE AND FINANCIAL PROJECTIONS

INTER-ISLAND SUCE FERRY SYSTEM
CONSOLIDATED ANNUAL OPERATING PROJECTIONS

One-way Passengers per Year
Honolu-Kahului-Honolulu Ferry
Kahului-Hana-Kahului Ferry

REVENUES:

Passenger fares
Less RT discounts
Gift shop sales
Snack bar sales
Luggage check-in revenue

COST OF SALES:

Payroll & Related:
Salaries and wages
Fringe and payroll taxes
Total Payroll & Related
Materials and supplies
Gift shop COS
Snack bar COS
General excise tax
Harbor fees

INDIRECT EXPENSE:

Vessel repairs and preventive maintenance
Offload costs
Vessel fuel
Total Indirect Expense
Adjusted Gross Profit

OPERATING EXPENSES:

Payroll & Related:
Salaried Employees
Benefits and Payroll Taxes
Total Payroll & Related
Outside Services:
Accounting
Legal services
Bank fees
Professional consulting
Total Outside Services
Other Operating Expenses:
Rent expense
Marine insurance
Non-marine insurance
Office supplies
Parking
S/E Non-marine
Fuel expense (land vehicles)
Telephone & communications
Utilities
Depreciation & amortization
Marketing and Advertising
Entertainment & promotion
Travel
Uniforms
Dues & publications
Licenses & permits
Contributions
Accident Expense
Meetings & Schoolings
Total Operating Expenses
Income before Tax and Financing Expense
Vessel Lease expense
Equipment Lease expense
Interest expense
Pre-tax Income

	Year 1		Year 2		Baseline*	
	164,241		187,704		123,965	
	95,031		93,852		61,993	
	78,210		93,852		61,993	
		Per Pass		Per Pass		Per Pass
Passenger fares	6,589,840	\$40.00	7,508,160	\$40.00	4,358,616	\$40.00
Less RT discounts	658,964	4.00	782,816	4.00	465,862	4.00
Gift shop sales	462,723	3.00	563,112	3.00	371,896	3.00
Snack bar sales	821,205	5.00	938,530	5.00	619,827	5.00
Luggage check-in revenue	250,272	1.52	281,556	1.50	185,548	1.50
Total Revenues	7,479,876	\$46.62	8,540,532	\$45.50	5,640,426	\$45.50
COST OF SALES:						
Payroll & Related:						
Salaries and wages	500,896	3.21	574,234	3.08	379,242	3.06
Fringe and payroll taxes	194,848	1.19	212,467	1.12	140,319	1.13
Total Payroll & Related	721,894	\$4.38	786,701	\$4.19	519,561	\$4.19
Materials and supplies	82,121	0.50	93,852	0.50	61,993	0.50
Gift shop COS	246,962	1.50	281,556	1.50	185,848	1.50
Snack bar COS	410,603	2.50	468,260	2.50	308,914	2.50
General excise tax	231,777	1.41	264,888	1.41	174,940	1.41
Harbor fees	118,254	0.72	136,147	0.72	89,265	0.72
Total Cost of Sales	1,810,848	\$11.03	2,031,405	\$10.82	1,341,800	\$10.82
Gross Profit	5,669,027	\$34.50	6,509,126	\$34.68	4,298,626	\$34.68
INDIRECT EXPENSE:						
Vessel repairs and preventive maintenance	673,380	4.10	750,960	4.00	730,960	6.08
Offload costs	328,482	2.00	375,406	2.00	358,651	2.89
Vessel fuel	673,380	4.10	673,380	3.58	673,380	5.43
Total Indirect Expense	1,675,242	\$10.20	1,799,748	\$9.58	1,762,991	\$14.38
Adjusted Gross Profit	3,993,785	\$24.30	4,709,378	\$25.09	2,535,635	\$20.29
OPERATING EXPENSES:						
Payroll & Related:						
Salaried Employees	222,000	\$1.55	222,000	\$1.18	222,000	\$1.79
Benefits and Payroll Taxes	82,140	0.50	82,140	0.44	82,140	0.66
Total Payroll & Related	304,140	\$1.85	304,140	\$1.62	304,140	\$2.45
Outside Services:						
Accounting	4,800	0.03	4,800	0.03	4,800	0.04
Legal services	14,000	0.09	14,000	0.07	14,000	0.11
Bank fees	98,545	0.60	112,822	0.60	74,979	0.60
Professional consulting	50,000	0.30	50,000	0.27	50,000	0.40
Total Outside Services	167,345	\$1.02	181,422	\$0.97	143,779	\$1.15
Other Operating Expenses:						
Rent expense	144,000	0.88	144,000	0.77	144,000	1.16
Marine insurance	216,000	1.32	216,000	1.15	216,000	1.74
Non-marine insurance	48,000	0.29	48,000	0.26	48,000	0.39
Office supplies	40,800	0.25	40,800	0.22	40,800	0.33
Parking	5,780	0.04	6,780	0.03	5,780	0.05
S/E Non-marine	6,000	0.04	6,000	0.03	6,000	0.05
Fuel expense (land vehicles)	14,400	0.09	14,400	0.08	14,400	0.12
Telephone & communications	48,000	0.29	48,000	0.26	48,000	0.39
Utilities	14,400	0.09	14,400	0.08	14,400	0.12
Depreciation & amortization	280,000	1.70	280,000	1.49	280,000	2.26
Marketing and Advertising	448,519	2.73	448,519	2.38	448,519	3.62
Entertainment & promotion	30,000	0.18	30,000	0.16	30,000	0.24
Travel	26,400	0.16	26,400	0.14	26,400	0.21
Uniforms	30,000	0.18	30,000	0.16	30,000	0.24
Dues & publications	3,600	0.02	3,600	0.02	3,600	0.03
Licenses & permits	44,400	0.27	44,400	0.24	44,400	0.36
Contributions	14,400	0.09	14,400	0.08	14,400	0.12
Accident Expense	20,400	0.12	20,400	0.11	20,400	0.16
Meetings & Schoolings	12,600	0.08	12,600	0.07	12,600	0.10
Total Operating Expenses	1,819,257	\$11.69	1,833,335	\$10.30	1,895,092	\$15.29
Income before Tax and Financing Expense	2,071,429	\$12.81	2,776,043	\$14.79	1,640,543	\$13.01
Vessel Lease expense	475,743	\$2.80	475,743	\$2.53	475,743	\$3.84
Equipment Lease expense	90,000	\$0.55	90,000	\$0.48	90,000	\$0.73
Interest expense	55,000	\$0.33	48,000	\$0.25	55,000	\$0.44
Pre-tax Income	1,450,686	\$8.85	2,164,303	\$11.53	0	\$0.00

* Average 160 passengers per leg
** Average 100 passengers per leg

11.9 Conclusions

The relatively difficult wave climate of the Hawaiian Islands is well suited to the application of SLICE vessels, providing SLICE ample opportunity to improve ride quality and passenger comfort for a substantial number of vessel operating hours annually relative to other vessel designs. Projected net income before interest expense and taxes for Phase A of the inter-island SLICE ferry, as described earlier, are conservatively estimated to be \$1.7 million during the first year of operation and \$2.4 million annually thereafter. It should be noted, however, that the \$3.0 million purchase price for the SLICE 250 appears to be optimistically low, with a price more than twice this amount more likely.

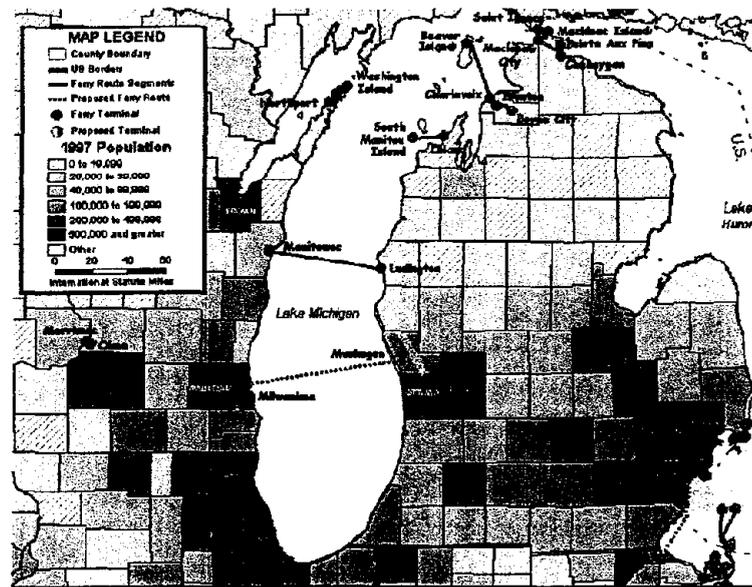
Chapter 12: Case Study #4 – Lake Michigan (Milwaukee – Muskegon)

The ferry route reviewed in this case study is a proposed new high speed service between Milwaukee, Wisconsin, and Muskegon, Michigan, a distance of 75 nautical miles across Lake Michigan. Lake Michigan has an extensive history of cross-lake ferry services, extending back more than 100 years to the late 19th century. Although virtually all of the ferry services that historically operated across Lake Michigan were abandoned by the late 1970s, there have been various proposals to revive some former routes with either conventional or high speed ferry service. The most recent plan for new ferry service, and the focus of this case study, involves the proposed use of one or more high speed RoPax catamaran vessels, operating between Milwaukee and Muskegon, with seasonal service planned to begin in the spring of the year 2001.

12.1 Introduction and Regional Overview

The area reviewed for this case study consists of the region surrounding Lake Michigan, including the eastern portion of the state of Wisconsin, and the western portion of the lower peninsula of Michigan (see Figure 12-1). This region is collectively referred to here as the Lake Michigan region. Important cities and metropolitan areas in the region include Milwaukee, Madison, Green Bay, Sheboygan and Manitowoc in Wisconsin, and Grand Rapids, Muskegon, Lansing and Kalamazoo in Michigan. In the southeast of the lower peninsula of Michigan is the Detroit metropolitan area, and the Chicago metropolitan area in Illinois is located south of Milwaukee, near the southern most part of Lake Michigan.

FIGURE 12-1: LAKE MICHIGAN REGION POPULATION DISTRIBUTION (1997) AND EXISTING & PROPOSED FERRY ROUTES



High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

Lake Michigan is part of the Great Lakes system, which also includes Lakes Ontario, Erie, Huron, and Superior, their connecting waters, and the St. Lawrence River. In total, this system has a shoreline of approximately 11,000 miles, and covers an area of 95,000 square statute miles. Oceangoing deep draft vessels can access the Great Lakes system via the St. Lawrence Seaway, which has a limiting depth of 26 feet.⁹⁷ The route distance from the mouth of the Gulf of St. Lawrence to Chicago is about 2,000 nautical miles. Barge traffic and smaller vessels can also access the Great Lakes system via two shallow draft routes, one from the Gulf of Mexico via the Mississippi River and the Illinois Waterway to Lake Michigan at Chicago, and the other from New York City via the Hudson River and the New York State Barge Canal System to Lake Ontario at Oswego.

Lake Michigan is the third largest of the Great Lakes, and is the only one located entirely within the United States. The only natural outlet of the lake is at the northern end through the Straits of Mackinac. The northern part of the lake is relatively sparsely populated, and has many islands as well as numerous bays, the largest of which are Green Bay and Grand Traverse Bay. The shores of the southern part of the lake are more regular, with more artificial harbors having been constructed in this region, and are much more heavily populated.

Table 12-1 presents a general overview of the population in the Lake Michigan region. In 1997, the state of Michigan had an estimated resident population of approximately 9,654,000, with Wayne, Oakland and Macomb counties in the Detroit metropolitan area accounting for over 40% of the entire resident population of the state.⁹⁸ The state of Wisconsin had an estimated 1997 resident population of approximately 5,192,000.⁹⁹ The state of Illinois had estimated 1997 resident population of approximately 11,896,000, with 6,578,000 (55%) in Lake, Dupage and Cook counties in the Chicago metropolitan area alone.¹⁰⁰ Throughout the region in 1997, approximately 12.7 million persons lived within about 50 miles of the Lake Michigan shoreline.

TABLE 12-1: LAKE MICHIGAN REGION POPULATION AND PROJECTIONS

Year	Michigan				Wisconsin			Regional Total
	County			State Total	County		State Total	
	Kent	Ottawa	Muskegon		Waukesha	Milwaukee		
1990	500,631	187,768	158,983	9,295,297	304,715	959,275	4,891,769	14,187,066
1997	539,583	216,358	165,914	9,654,851	345,901	927,720	5,192,057	14,846,908
2002	568,072	237,172	171,020	9,923,467	375,870	906,372	5,413,050	15,336,517
2007	596,572	258,047	176,103	10,192,474	405,995	885,140	5,634,404	15,826,878

Sources:

(1) U.S. Department of Commerce, Bureau of the Census.

(2) U.S. Census Block Groups with Estimates and Projections. Caliper Corporation, and Applied Geographic Solutions.

Major industries in Michigan include manufacturing, tourism and agriculture. More automobiles are produced in Michigan than in any other state, and in total manufacturing industries comprised more than 25% of total employment in Michigan in 1996.¹⁰¹ Although perhaps not typically thought of as an important tourist destination, Michigan also ranks 16th of U.S. states in expenditures by U.S. tourists.¹⁰² Major tourist attractions include Detroit, the Straits of Mackinac area, Isle Royale, the Soo Locks, the state capital at Lansing.¹⁰³ Service sector em-

⁹⁷ U.S. Department of Commerce. National Oceanic and Atmospheric Administration (NOAA). United States Coast Pilot. Volume 6. Great Lakes. 29th edition. Page 106.

⁹⁸ U.S. Department of Commerce, Bureau of the Census.

⁹⁹ U.S. Department of Commerce, Bureau of the Census.

¹⁰⁰ U.S. Department of Commerce, Bureau of the Census.

¹⁰¹ U.S. Department of Commerce. 1996 County Business Patterns for Michigan.

¹⁰² Florida Tourism Industry Marketing Association (Visit Florida). 1997 Florida Visitor Study. Page 75.

¹⁰³ Library of Michigan. Michigan in Brief.

employees in total represent about 32% of the total labor force in Michigan, with the retail trade sector accounting for an additional 22% of employment in the state.

In Wisconsin, manufacturing industries also represent more than 25% of the total labor force, with the service sector accounting for another 30% and retail trade a further 20%.¹⁰⁴ Tourism related expenditures in Wisconsin for 1998 were approximately \$7.6 billion, ranking it about 25th in the U.S..¹⁰⁵ There are about 12.5 to 15 million overnight visits annually to Wisconsin from out of state, with an additional 7.5 to 10 million day trips annually as well from out state.¹⁰⁶ The majority of out of state visitors to Wisconsin originate in the major markets of Chicago and northern Illinois, the Minneapolis/St. Paul area of Minnesota, and to a lesser extent Iowa.¹⁰⁷ Important tourist destinations in Wisconsin are located in Milwaukee, Madison, Door County and the Green Bay area, Wisconsin Dells in central Wisconsin, the Mississippi River area and the Northwoods and Lakes area.

12.2 Ferry Market Overview and Operational Profiles

As noted earlier, Lake Michigan has an extensive history of cross-lake ferry services. Passenger steamship service across Lake Michigan began in 1875, with service offered by the Flint and Pere Marquette Railway. The year 1955 was the height of success for Lake Michigan car ferry service, with a total of 205,000 passengers and more than 204,000 railroad cars transported, and 6,986 vessel crossings of Lake Michigan performed.¹⁰⁸ By 1960, a total of eight car ferry routes serving Lake Michigan remained:

- Milwaukee - Muskegon (Grand Trunk Railroad)
- Milwaukee - Ludington (Chesapeake and Ohio Railway System)
- Manitowoc - Ludington (Chesapeake and Ohio Railway System)
- Kewaunee - Ludington (Chesapeake and Ohio Railway System)
- Frankfort - Manitowoc (Ann Arbor Railroad)
- Frankfort - Kewaunee (Ann Arbor Railroad)
- Frankfort - Menominee (Ann Arbor Railroad)
- Frankfort - Manistique (Ann Arbor Railroad)

Improved all-rail options around Chicago, and changing economics rendered many of the railroad car ferry routes obsolete during the 1960s, and by 1973 only four routes remained:

- Frankfort - Kewaunee (Ann Arbor Railroad)
- Manitowoc - Ludington (Chesapeake and Ohio Railway System (C&O))
- Kewaunee - Ludington (Chesapeake and Ohio Railway System (C&O))
- Milwaukee - Muskegon (Grand Trunk Railroad)

Of these routes, passenger and vehicle ferry service was provided by the C&O and the Ann Arbor Railroad on their routes, with railroad freight car service only offered on the Grand Trunk Railroad route. C&O operated three vessels on its two routes, carrying passengers and automobiles as well as railroad freight cars. During the 1970s, the quality and availability of C&O passenger and vehicle service diminished, with passenger totals falling from 197,000 in 1971 to 126,000 in 1979.¹⁰⁹ The Grand Trunk Railroad freight car ferry service from Mil-

¹⁰⁴ U.S. Department of Commerce. *1996 County Business Patterns for Wisconsin*.

¹⁰⁵ Wisconsin Department of Tourism. *1998 Economic Impact of Traveler Expenditures on Wisconsin*.

¹⁰⁶ Phone contact. David Scheler, Wisconsin Division of Tourism, Tours and Research. July 30, 1999.

¹⁰⁷ Phone contact. David Scheler, Wisconsin Division of Tourism, Tours and Research. July 30, 1999.

¹⁰⁸ KAIT, Kari and Thomas Hawley. "Charting the Course of Car Ferry History." *Crossings: The Magazine of the Lake Michigan Carferry Service*. 1999. Pages 5-7.

¹⁰⁹ Wisconsin Department of Transportation. *Passenger Ferry Service: An overview and study proposal for passenger ferry service in Wisconsin*. June 1994.

waukee to Muskegon ended in 1978. After 1971, the Ann Arbor Railroad ferry service operated on an unscheduled basis only, which led to reductions in passenger demand from 30,000 in 1971 to only 6,000 in 1979.¹¹⁰ The Ann Arbor Railroad services continued to operate with a public subsidy after 1977, but ultimately service ended in April 1982. The newly-created Michigan-Wisconsin Transportation Company (MWT) purchased the vessels of the C&O in 1983, and continued operations until they ceased in 1990. The MWT operated service year round without any subsidy between Kewaunee and Ludington, with additional service operated at times between Milwaukee and Ludington during the summer months. Passenger demand was promising at first, with approximately 100,000 passengers carried in the 1983/84 operating season.¹¹¹ However, By 1990 the MWT went bankrupt, and there were no Lake Michigan cross-lake ferry services remaining.

In addition to the conventional RoPax vehicle and railroad car ferry services described above, one high speed ferry demonstration service has been operated in Lake Michigan. In 1961, North American Hydrofoils, Inc., contracted with Marine Systems Corporation (MSC), a Miami hydrofoil design group, for a vessel design to be used for a commuter ferry service between Atlantic Highlands, New Jersey, and Wall Street, Manhattan. During the summer of 1964, this vessel was operated in Lake Michigan on demonstrations, short excursions, and charter services across Lake Michigan.¹¹² Shore facilities, routes, and schedules were never established, however, and the operation ended after this single summer season.

12.2.1 Current Routes

As noted above, after the MWT ceased operations between Kewaunee and Ludington in November of 1990, there were no Lake Michigan cross-lake ferry services remaining. In the spring of 1991, a private company, Lake Michigan Carferry, Inc. (LMC) was formed by Michigan resident Charles Conrad, and in July of that year, LMC purchased the former C&O and MWT vessels *SS Badger*, *SS Spartan* and the *City of Midland*. Plans were to resume cross-lake ferry service from Ludington, with a focus on passenger and vehicle service only, and no railroad car ferry service to be offered. Although this sale was later nullified when MWT declared bankruptcy in November 1991, LMC was ultimately awarded the vessels by the court in February 1992. The *SS Badger* was subsequently refurbished, and three months later on May 15, 1992, LMC resumed RoPax ferry service and placed the *SS Badger* into service between Ludington and Manitowoc. The *SS Badger* has a passenger capacity of 620 persons, a vehicle capacity of 180 AEU, and an operated speed of 15 knots. This vessel is described in more detail in a subsequent section of this chapter.

Since 1992, LMC has continued to operate seasonal RoPax service on this route between May and October of each year. During the 1992 operating season, LMC offered a single round trip daily from May 15 to October 12, with a second daily round trip added during the peak summer months of July and August. With this operating schedule, the *SS Badger* carried 115,000 passengers and 34,000 vehicles between Manitowoc and Ludington.¹¹³ It is the company policy of Lake Michigan Carferry not to disclose patronage data, nor are they required to do so as a condition of receiving any federal, state or local operating or non-operating subsidies, since they receive none. Therefore, more recent patronage data are not available. LMC operates the service seasonally, every day of the week, between mid May to mid October. In the off-season, the vessel is winterized and laid up.

On the 54 nautical mile route between Manitowoc, Wisconsin, and Ludington, Michigan, total one-way trip time is 4 hours. In Manitowoc, the ferry terminal is located at 900 South Lakeview Drive, on the south side of Manitowoc Harbor, at the mouth of the Manitowoc River. Coal is also provided for the *SS Badger* in Manitowoc,

¹¹⁰ Wisconsin Department of Transportation. *Passenger Ferry Service: An overview and study proposal for passenger ferry service in Wisconsin*. June 1994.

¹¹¹ Wisconsin Department of Transportation. *Passenger Ferry Service: An overview and study proposal for passenger ferry service in Wisconsin*. June 1994.

¹¹² Existing and Former High Speed Waterborne Passenger Transportation Operations in the United States. U.S. Department of Transportation, Urban Mass Transit Administration. August 1984. Report # UMTA-IT-32-0001-84-3. Pages II.5 - II.7.

¹¹³ Phone contact. Thomas Hawley. Lake Michigan Carferry, Inc. May 25, 1999.

loaded from dump trucks through hatches in the vehicle deck. In Ludington, the ferry terminal is located at 701 Maritime Drive, on north side of Ludington Harbor in Pere Marquette Lake.

Adult fares for the 1999 season on this route were \$61.00 round trip, with discounts for seniors and children (seniors are \$56.00 round trip, children 5 to 15 years old are \$29.00 round trip, and children under 5 travel free). A state room, with two beds, a sink and toilet, is an additional \$54 round trip. Fares for automobiles, vans and pickups (not including their passengers) are \$92 round trip, and for motorcycles \$52 round trip. Bicycles are accommodated for \$10 round trip. Trailers, recreational vehicles, and motorhomes are charged a round trip fare of between \$7 to \$11 per foot of length, depending on their width. One-way fares for motorcoaches are \$140 (not including passengers), and tractor trailers are charged \$225 one-way (not including passengers).

Service is offered daily, and in 1999, a single round trip was offered daily from May 14 to June 17 and August 30 to October 17, with the vessel departing Ludington at 8:30AM eastern time and arriving at Manitowoc 12:30 PM eastern time, and departing Manitowoc at 3:00PM eastern time and arriving back in Ludington at 7:00 PM eastern time.¹¹⁴ Two round trips were offered daily from June 18 to August 29, with the vessel departing Ludington at 7:30 AM eastern time and arriving in Manitowoc at 11:30 AM eastern time, departing Manitowoc at 2:00 PM eastern time and arriving back in Ludington at 6:00 PM eastern time, departing Ludington at 7:45 PM and arriving in Manitowoc at 11:45 PM, and departing Manitowoc at 1:30 AM eastern time and returning to Ludington at 5:30 AM eastern time. Passengers are asked to arrive 60 minutes prior to departure, and reservations are held until 30 minutes prior to departure, and vehicles are loaded and unloaded by LMC personnel. Since 1992, this is the general schedule that has been offered each year.

12.2.2 Proposed Routes

Since the earlier 1980's, a number of proposals have been made to restore ferry service on routes other than the existing Manitowoc to Ludington route operated by LMC. A 1980 study completed for the Board of Harbor Commissioners in Milwaukee reviewed possible service by hovercraft on a route connecting Milwaukee to Muskegon. At fare levels of \$26 per vehicle and \$14 per passenger (in 1980 dollars), estimated patronage in the year 2000 for this service was 468,000 passenger boardings and 268,000 vehicle boardings.¹¹⁵

The U.S. Department of Transportation also reviewed the potential for new or restored cross-lake ferry services in a 1984 study. Two routes were analyzed, including a passenger and vehicle ferry between Milwaukee and Muskegon, and a passenger-only ferry service between Chicago and Muskegon.¹¹⁶ The study assumed the use of large high speed hovercraft vessels (the British Hovercraft Corporation SR.N4 Mk3) with a capacity of 344 persons and 46 automobiles. Service was assumed to be operated five round trips daily between June and August, and two round trips daily the remainder of the year, and the study found the financial feasibility of this route was marginal.

In the past, LMC considered the refurbishing of the *SS Spartan*, and restoring service on a route between Milwaukee and Muskegon. In the spring of 1999, LMC indicated that what it felt to be the relatively low docking fees being offered to the currently proposed operator, Hydrolink LLC, by the ports of Milwaukee and Muskegon amounted to a joint subsidy of the proposed ferry operation by those cities, and that if such a proposal had been made earlier to LMC, service could have been restored using the *SS Spartan*.¹¹⁷ The Port of Milwaukee, however, countered that the LMC proposal required the two cities to assume approximately \$9 million in expense

¹¹⁴ Ludington, Michigan is located in the eastern time zone, and Manitowoc, Wisconsin is located in the central time zone. For convenience, all departure and arrival times for both cities are expressed here in eastern time.

¹¹⁵ Transportation and Economic Research Associates, Inc. *Phase I Report on Feasibility Study of a Cross-Lake Passenger Auto Air Cushion Ferry Service*. Prepared for the Board of Harbor Commissioners, City of Milwaukee. August 1980.

¹¹⁶ *Study of High Speed Waterborne Transportation Services Worldwide*. U.S. Department of Transportation, Office of the Secretary of Transportation. 1984. Pages IV.16 - IV.20.

¹¹⁷ Muskegon Chronicle. April 23, 1999.

for converting the *SS Spartan* to diesel propulsion from coal powered steam propulsion. LMC prides itself on the fact that it does not received any federal, state or local subsidies, and continues to feel that the Hydrolink proposal, with its possible use of Maritime Administration Title XI loan guarantees and other possible direct or indirect financial support from federal, state or local governments, is being provided an unfair competitive advantage over LMC.¹¹⁸

Currently, Hydrolink LLC, an Eau Claire, Wisconsin based organization incorporated in December 1998, is planning to acquire two Incat 72 meter RoPax wave piercing catamarans for use between Milwaukee and Muskegon. It is this proposal that is the focus of the current case study and the remainder of this chapter.

The Hydrolink service is planned to operate seasonally from approximately April 1 to mid-November, beginning with the 2001 season. Two of the 72 meter WPC vessels would be utilized, each operating 3 round trips per day, for a total of 6 round trips daily for the route. These vessels would each be designed to accommodate 325 passengers and 75 AEU, or a combination of up to 2 motorcoaches and 65 automobiles. Service speed is 40 knots, however the vessel would be subject to speed restrictions in both Milwaukee Harbor and Muskegon Harbor, as noted under the discussion of navigational issues later in this chapter. Although the breakwater-to-breakwater travel time would be 1 hour and 45 minutes using the 72 meter WPCs, the total one-way trip time due to these speed restrictions would therefore be just under three hours.

According to the market study conducted for Hydrolink by the firm Anderson & Roethle of Milwaukee, fares are currently planned to be \$115 one-way for two passengers and a vehicle, or \$150 one-way for four passengers and a vehicle. This equates to a one-way adult passenger fare of approximately \$33.00 (not including passenger facility charges), and a one-way automobile fare of \$49.00 (not including passengers). Motorcoach fares are estimated at \$150 one-way (not including passengers). These fares are approximately 7.3% higher than those currently offered by LMC on their Ludington to Manitowoc route, perhaps reflecting in part the more frequent service and reduced trip time to be offered by Hydrolink in comparison to the existing LMC service.

Although there are no firm plans yet regarding how to employ the vessels during the off-season, there are two major options. The first option would be operate from April 1 through mid December, and then simply lay the vessel up for three months locally. This is the least desirable option financially, since two multi-million dollar vessels would then be unproductive for 25% of the year. The second option is operate from April 1 through mid November, and then reposition the vessels from mid November to April 1 in a warmer seasonal climate such as Florida or the Gulf of Mexico, and serve peak season demand in those areas during the Lake Michigan off-season. The only feasible route out of Lake Michigan to the Atlantic Ocean would be via the Saint Lawrence Seaway, with a repositioning trip from Lake Michigan to Florida taking approximately one week to complete.

Assuming seasonal service provided between early April and mid December, and an operating schedule of 6 one-way trips per vessel daily, a total of 3,024 one-way trips would be performed annually, providing a total route capacity of up to 982,800 seats and 226,800 AEU annually. Assuming for the moment an average capacity utilization rate of 60%, this would equate to approximately 589,000 passenger boardings and 136,000 vehicles boardings annually.

¹¹⁸ Lake Michigan Carferry, Inc. WWW at URL <http://www.ssbadger.com/lmc-hydro1.htm>.

12.3 Existing and Proposed Vessels

Although the *SS Badger* currently operates on a different route than that currently proposed by Hydrolink, Lake Michigan Carferry currently considers the proposed Hydrolink service as a potential competitor to its existing cross-lake ferry service between Ludington and Manitowoc. Therefore, the *SS Badger* is briefly described (vessel particulars appear in Table 12-2) to provide additional background information.

TABLE 12-2: SS BADGER VESSEL PARTICULARS

Particulars	SS Badger ⁽¹⁾
Vessel Builder	Christy Corporation
Vessel Type	RoPax
Hull Construction	Steel
Year Entered Service	1953
Original Purchase Price ⁽²⁾	\$5,000,000
Principal Dimensions (feet)	
Length Overall	410.5
Beam Overall	59.5
Full Load Draft	18.5
Freeboard	5.5
Capacities	
Passenger Capacity	620
Vehicle Capacity (AEU) ⁽³⁾	180
Fuel Capacity (tons of coal)	589
Vessel Manning	
Total Crew Complement ⁽⁴⁾	50 to 80
Weights	
Full Load Displacement (long tons)	7,901
Gross Tonnage ⁽⁵⁾	4,244
Net Tonnage ⁽⁶⁾	2,033
Propulsion	
Main Engines	(2) Skinner Uniflow 4 cyl. steam engines
Total Installed Horsepower	7,000
Service Speed (knots)	15.0
Fuel Consumption (short tons of coal)	
Average Daily Tons of Coal	55

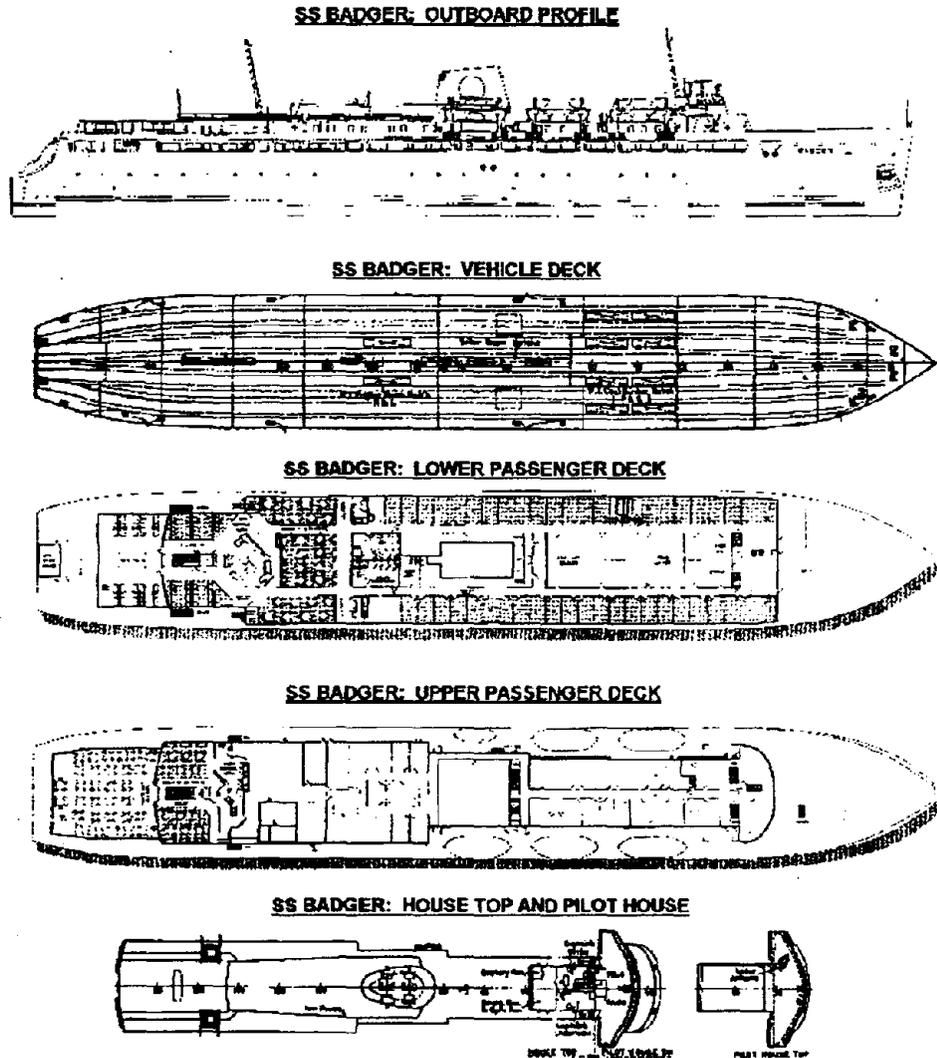
Sources:

- (1) Vessel particulars data obtained primarily from Lake Michigan Carferry, Inc.
- (2) Current (then-year) dollars.
- (3) Automobile equivalent unit (AEU), typically a minimum of a 17' x 8.5' space on the vehicle deck.
- (4) Total permanent crew is 50, with an additional 30 crew required during peak summer months.
- (5) Gross tonnage or "gross register tonnage" refers to the total measured cubic volume (100 cubic feet per ton of 2,240 lbs.), based on varying formulas.
- (6) Net tonnage refers to the gross tonnage, minus spaces generally not used for cargo, according to varying formulas.

The *SS Badger* was launched in 1952 at an original purchase price of \$5 million. It originally served the Chesapeake and Ohio Railway (later renamed the Chessie System after merging with the B&O Railroad) on three routes between Ludington, Michigan, and Milwaukee, Manitowoc and Kewaunee in Wisconsin. A steam powered, coal fired vessel, the *SS Badger* had a capacity of over 30 freight railroad cars, or 140 automobiles, plus

accommodations for 620 passengers. In January 1996, the vehicle capacity of the *SS Badger* was increased by approximately 30%, providing vehicle deck space up to 180 AEU. The vehicle deck, with an overhead clearance of 19 feet, can accommodate motorcoaches and tractor trailers as well as automobiles. Vehicles are loaded from the stern, and all vehicles are loaded and unloaded by LMC personnel. Passenger facilities include a gift shop, bar, movie lounge, arcade, and cafeteria. General arrangements for the *SS Badger* appear in Figure 12-2.

FIGURE 12-2: SS BADGER GENERAL ARRANGEMENTS



Source: Lake Michigan Carferry, Inc.

Based on information obtained from the Port of Milwaukee and Hydrolink, the 72 meter Incat RoPax high speed catamaran is selected here as the baseline vessel type for the proposed Milwaukee to Muskegon route. The AMD K50 and SLICE 600 RoPax craft are selected as the comparative high speed vessel types. Vessel particulars for the Incat 72 meter catamaran, AMD K50 catamaran, and SLICE 600 appear in Table 12-3.

TABLE 12-3: LAKE MICHIGAN CASE STUDY - VESSEL PARTICULARS

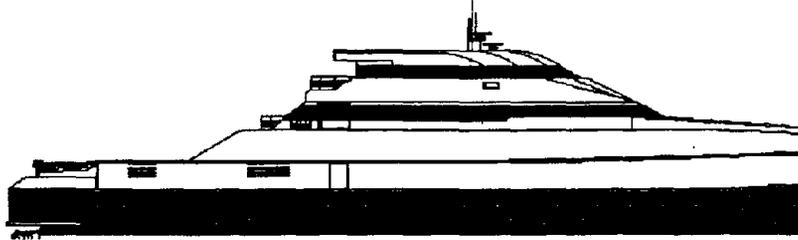
Particulars	Baseline Vessels		SLICE Variant
	Incat 72m ⁽¹⁾	AMD K50 ⁽²⁾	SLICE 600 ⁽³⁾
Vessel Designer	Incat	Advanced Multihull Designs	Lockheed Marine Systems
Vessel Type	RoPax	RoPax	RoPax
Hull Construction	Aluminum	Aluminum	Steel
Purchase Price (1997 US\$)	\$27,500,000	\$30,000,000	\$37,000,000
Annual Maintenance Cost ⁽⁴⁾	\$962,500	\$1,050,000	\$1,295,000
Principal Dimensions (feet)			
Length Overall	238.3	262.7	213.2
Beam Overall	56.4	62.3	105.0
Full Load Draft	7.2	7.1	28.5
Main Passenger Deck Freeboard	data not available	21.0	31.0
Vehicle Deck Freeboard	data not available	11.0	21.5
Capacities			
Passenger Capacity	325	400	600
Vehicle Capacity (AEU) ⁽⁵⁾	75	89	90
Fuel Capacity (gallons)	8,981	12,680	39,087
Vessel Manning			
Deck Crew Officers	2	2	2
General Deck Crew	5	4	5
Engineering Officers	2	1	2
Engine Crew	3	2	3
Onboard Passenger Service	7	7	8
Total Crew Complement	19	16	20
Weights (long tons)			
Payload	120.0	138.9	177.9
Total Deadweight	151.0	174.0	355.0
Displacement	531.0	612.0	1,500.0
Propulsion			
Main Engines	(4) MTU 16 V 595 marine diesel engines	(4) Ruston 16 RK270 marine diesel engines	(2) RLM1600 gas turbines or equivalent
Total Installed Horsepower	21,036	29,476	36,000
Service Speed (knots)	40	45	30
Range at Service Speed (nm)	350	390	620
Fuel Consumption (gallons per hour at indicated speed)			
GPH at service speed	1,014	1,439	1,891
GPH at 30.0 knots	539	590	1,891
GPH at 15.0 knots	269	344	1,757
GPH at 7.0 knots	180	246	484
GPH at 3.5 knots	158	222	450
GPH at idle	152	216	284

Sources:

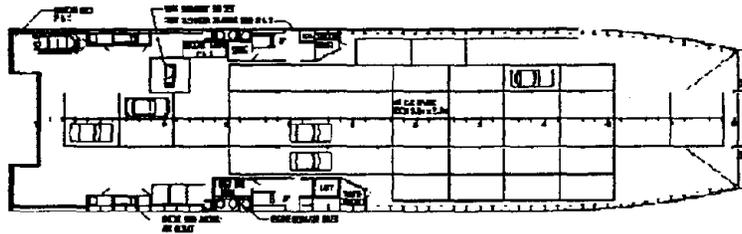
- (1) Gladding-Hearn Shipbuilding, the Duclos Corporation. Also, Volpe Center estimates for some data elements, as per discussion in Chapter 8.
- (2) Advanced Multihull Designs. Also, *Fast Ferry International*, October 1998, pp. 21-24. Also, *Jane's High-Speed Marine Transportation*, 1998-1999. Also, Volpe Center estimates for some data elements, as per discussion in Chapter 8.
- (3) Lockheed Marine Systems. SLICE 600 Passenger Vehicle Ferry. Technical Data Package. April 1995.
- (4) For a nominal vessel operating hours of 3,000 annually.
- (5) Automobile equivalent unit (AEU), typically a minimum of a 17' x 8.5' space on the vehicle deck.

FIGURE 12-3: INCAT 72 METER WPC GENERAL ARRANGEMENTS

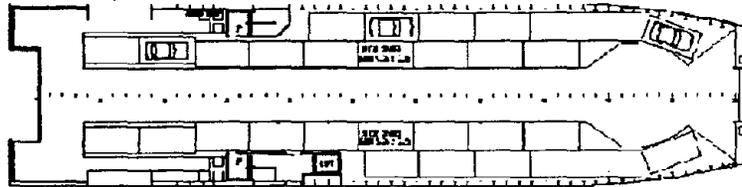
INCAT 72 METER ROPAX FERRY: OUTBOARD PROFILE



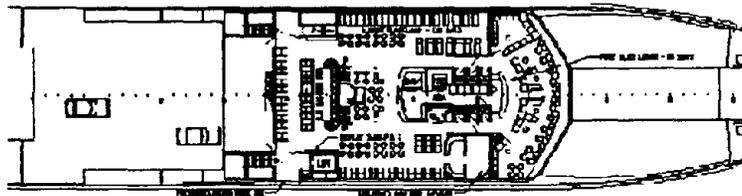
INCAT 72 METER ROPAX FERRY: MAIN VEHICLE DECK



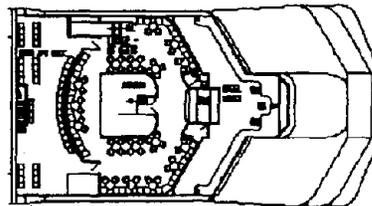
INCAT 72 METER ROPAX FERRY: MEZZANINE VEHICLE DECK



INCAT 72 METER ROPAX FERRY: MAIN PASSENGER DECK



INCAT 72 METER ROPAX FERRY: UPPER PASSENGER DECK AND WHEEL

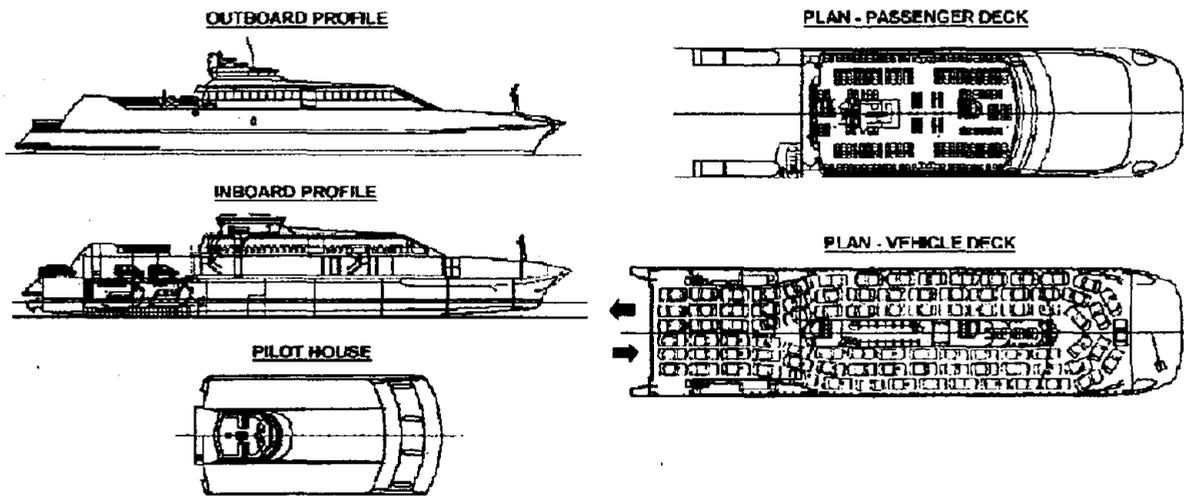


Source: Gladding-Hearn Shipbuilding, the Ductus Corporation.
WWW at URL http://gladding-hearn.com/trucks/72M_carpassferry.html

The Incat 72 meter catamaran is an aluminum hulled 72 meter high speed wave piercing catamaran, with a typical capacity of 325 passengers and 75 AEU, or a combination of up to 2 motorcoaches and 65 automobiles. Powered by four marine diesel engines, the Incat 72 meter WPC has a service speed of 40 knots. Typical general arrangements for the Incat 72 meter WPC are presented in Figure 12-3. Vehicle carrying capacity is provided by a main vehicle deck that accommodates approximately 47 AEU, and two mezzanine vehicle decks that accommodate 14 AEU each. Passengers are accommodated on two decks, with 230 passengers on the main passenger deck, and 95 passengers on an upper passenger deck and lounge area. Each deck has a bar and snack area, with restrooms located on the main passenger deck. It is assumed here that a gift shop is also located on the main passenger deck. Although no 72 meter vessels of this type have yet been built, this design is a further development of the larger line of Incat 74 meter to 96 meter wave piercing catamarans. Hydrolink is currently in negotiations with Gladding-Hearn Shipbuilding of Massachusetts, regarding the purchase of one or more of these vessels.

The AMD K50 is an aluminum hulled 80 meter high speed conventional catamaran, with a capacity of 400 passengers and 89 automobiles, or a combination of up to 4 motorcoaches and 46 automobiles. Although generally referred to as the AMD K50, Incat is also jointly involved in the design of the K50, with AMD responsible for the design of the main structure and propulsion system, while Incat is responsible for the design of the superstructure and engineering. The first AMD K50 to be built was delivered to the Dae A Gosh Ferry Company in South Korea in 1995 by Incat Tasmania. An additional three K50 vessels are to be built under license in China by Afai Ships. The first of these three, designated Afai08, was launched in mid 1998. Powered by four marine

FIGURE 12-4: AMD K50 GENERAL ARRANGEMENTS



Source: Advanced Multihull Designs (AMD). WWW at URL <http://www.amd.com.au/designs/n108/n108.html>

diesel engines, the AMD K50 has a service speed of 45 knots. Passengers are accommodated on a single passenger deck, divided into two lounge areas with a bar and snack facilities. A gift shop and other passenger amenities are located in the center of the vehicle deck. As can be seen in the general arrangements presented in Figure 12-4, the vehicle deck is arranged to provide for simultaneous loading and unloading of vehicles.

The SLICE 600 is a conceptual design of a steel hulled 65 meter SLICE RoPax ferry. The vessel would accommodate approximately 600 passengers and 90 automobiles, or a combination of 4 motorcoaches and 75

automobiles, with access to the vehicle deck from stern. Passengers are accommodated on two decks, with approximately 422 in economy class seating in two separate compartments on the gallery deck, with each compartment having its own restroom and snack bar. An additional 178 passengers are accommodated on the upper deck in first class or lounge type seating. Two gas turbine engines are to deliver an operating speed of 30 knots. General arrangements for the SLICE 600 are presented earlier in Chapter 4.

12.4 Related Infrastructure and Facilities

No passenger or vehicle ferry services currently exist between Milwaukee and Muskegon, and as such, there are currently no suitable facilities in either port of call to accommodate the volume of passengers or vehicles that would need to be serviced under the Hydrolink proposal. Hydrolink is currently in negotiation with both cities for possible options for the provision of suitable facilities, which are discussed later in this section.

12.4.1 Milwaukee

Milwaukee has one of the most important harbors serving Lake Michigan. Located at the mouth of the Milwaukee River, the harbor comprises an outer harbor formed by breakwaters paralleling the shore (see Figure 12-5), and an inner harbor in the Milwaukee River, Menomonee River, and Kinnickinnic River. The main entrance to the harbor is through a dredged channel which leads from deep water in Lake Michigan, between the breakwaters and across the harbor to the mouth of the river (see Figure 12-6). At the opening of the breakwaters, the channel has a controlling depth of 32 feet, and in April 1998, had a controlling depth of 26 feet thereafter to the mouth of the river. Depths in the part of the harbor to the north of this channel generally range between 16 and 24 feet, with an approach channel to the Municipal Pier dredged to 18 feet. South Slip No. 1 at the Municipal Pier has been dredged to 26 feet, and South Slip Nos. 2 and 3 have been dredged to 27 feet. The part of the harbor to the south of the main harbor channel are generally somewhat deeper, generally ranging between 27 and 32 feet. All types of marine supplies and provisions are available in Milwaukee Harbor.

In Milwaukee, two possible ferry terminal locations have been proposed for further consideration.¹¹⁹ The first potential location is at the municipal pier south of the Milwaukee Art Museum, in the northern part of the harbor. The second potential location is in the commercial port area in the vicinity of the U.S. Coast Guard base, in the southern part of the harbor. Both locations have suitable access from major roadways. To maximize the visibility of the ferry service to the public, Hydrolink and the Port of Milwaukee would like to locate it at the Municipal Pier. Although a final decision has not yet been made, it appears that the latter location near the U.S. Coast Guard base would be a more suitable location, however, due in part to the greater available of space for vehicle parking and vehicle loading. This location is assumed for the purpose of this case study. As currently proposed, facilities in both Milwaukee and Muskegon would be publicly owned by either the city or the port, with Hydrolink paying a passenger facility charge for use of the facilities. As noted below, current plans in Muskegon call for a modest charge of \$0.50 for each passenger disembarking, with a minimum annual payment of \$50,000. Buildings would be leased for an additional \$15,000 annually. A similar fee structure is assumed for use of the Milwaukee facilities as well. Also, as noted earlier, such low docking fees have been called into question by Lake Michigan Carferry, which feels these low fees amount to a subsidy to Hydrolink by both Milwaukee and Muskegon.

¹¹⁹ Hawkins, Lee, Jr. "Port official says ferry possible in 2002." *Milwaukee Journal Sentinel*. April 17, 1999.

FIGURE 12-5: MILWAUKEE HARBOR - NAUTICAL CHART

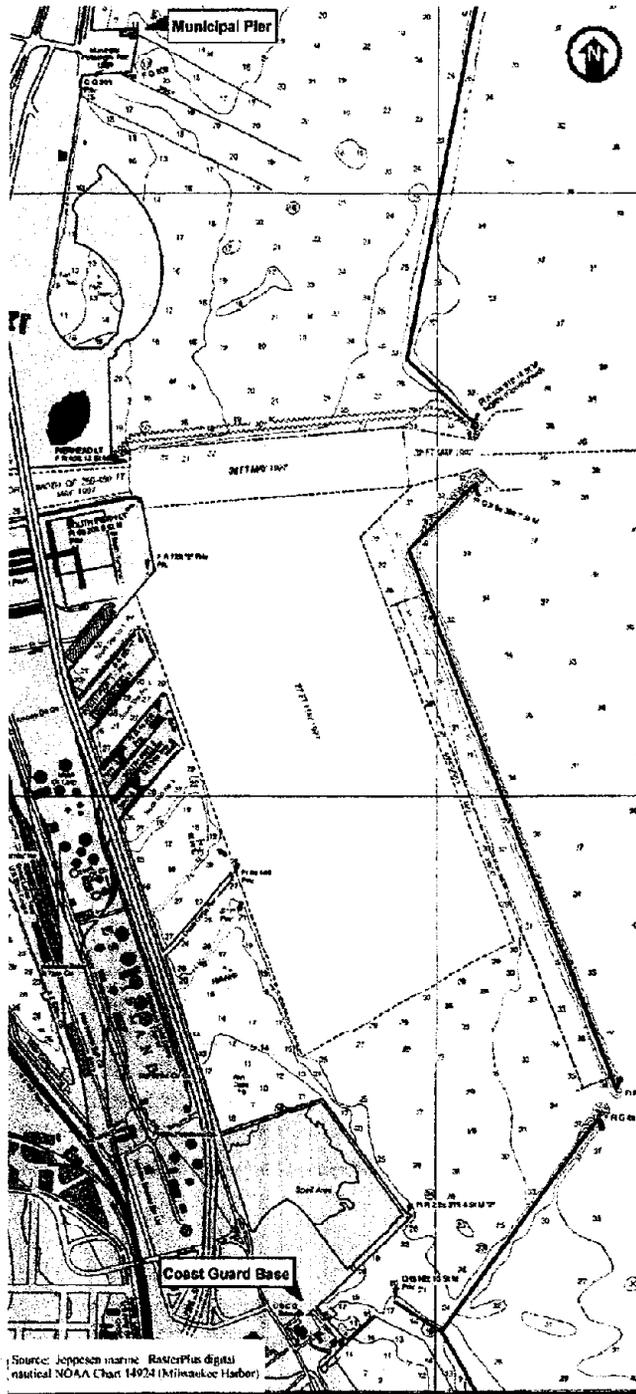
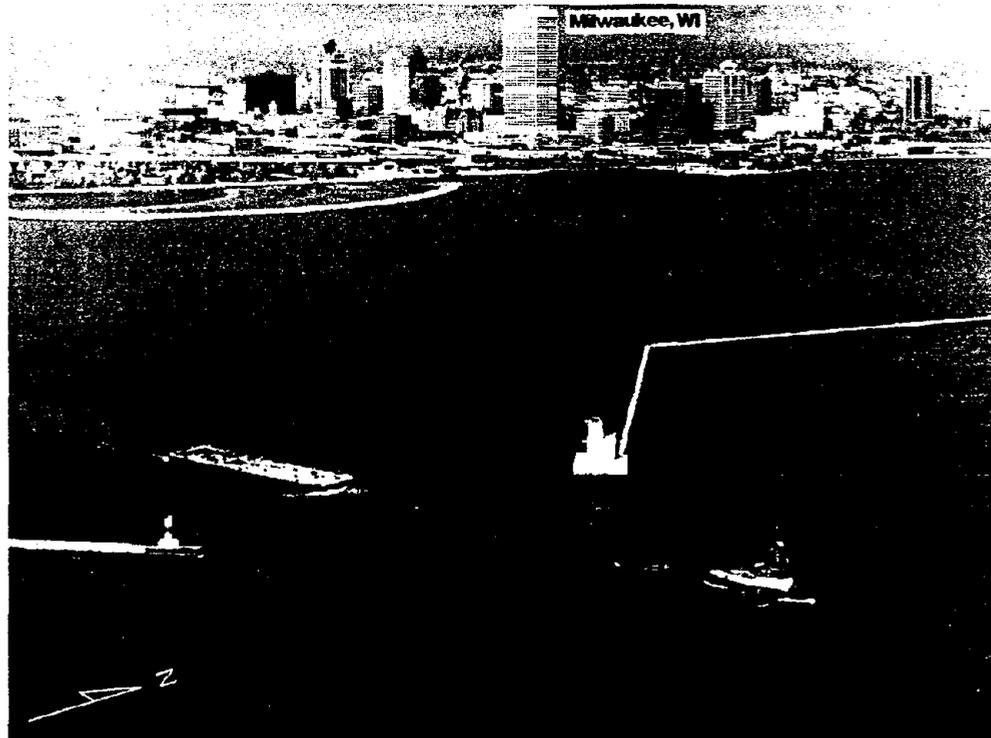


FIGURE 12-6: MILWAUKEE HARBOR AERIAL PHOTO



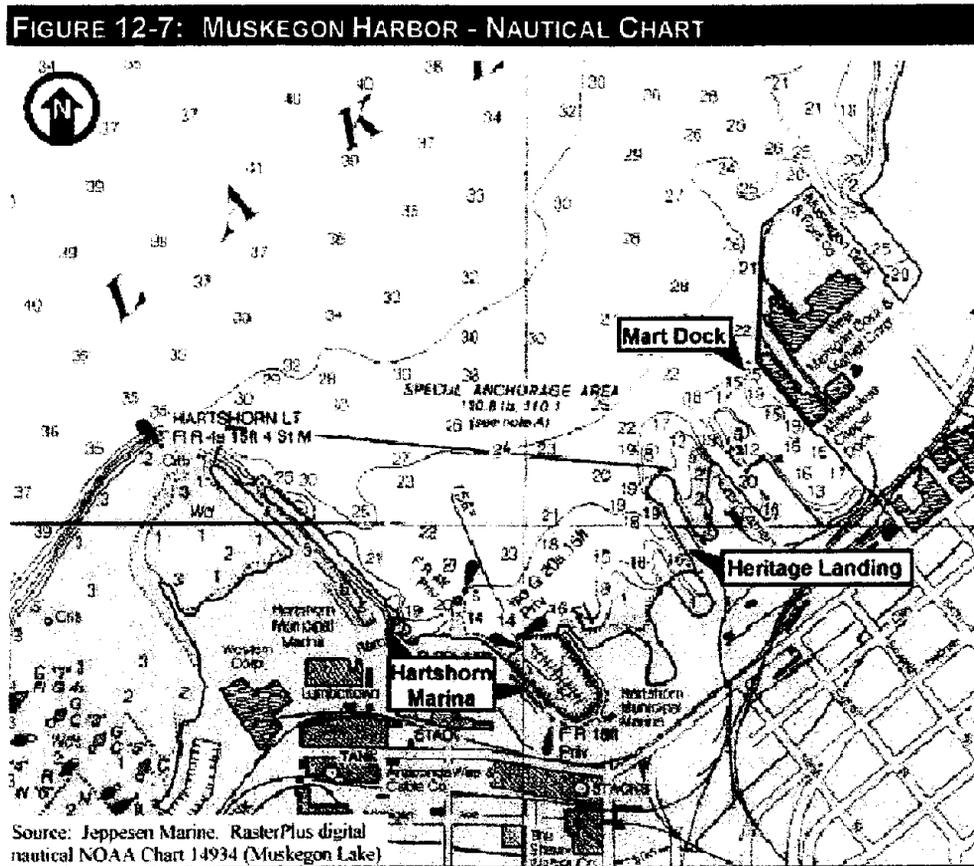
In general, controlling depths in Milwaukee Harbor leading to the proposed ferry terminal location in the vicinity of the U.S. Coast Base, and depths alongside at the proposed location, are marginal in comparison to the 28.5 foot draft of the SLICE 600, despite the fact that this part of the Milwaukee harbor south of the main channel is deeper than the northern part of the harbor in the vicinity of the Municipal Pier.¹²⁰ From the main harbor entrance where controlling depths are 32 feet, a channel runs south parallel to the breakwater, and has depths of between 27 to 35 feet. As the vessel nears the location of the Coast Guard station, depths decrease to as little as 17 feet. Although not subject to tidal fluctuation of any significant amount, water levels in Lake Michigan due fluctuate seasonally, with the lowest stages prevailing during the winter and the highest levels during the summer. During the summer months, water levels can be up to 2 feet above the charted low water datums referenced above and on the nautical charts, which would work to the advantage of the deep draft of the SLICE 600.

Presumably, the ferry terminal facilities that are to be developed in both Milwaukee and Muskegon will be designed for a deck height of approximately 6 to 8 feet, which would be suitable to interface with the 72 meter Incat WPC baseline vessel. Although suitable for either the 72 meter WPC or the AMD K50, this deck height would be incompatible with the vehicle deck freeboard height of 21.5 feet for the SLICE 600, and would likely result in significant and unacceptable operational constraints for the SLICE 600.

¹²⁰ As noted in Chapter 8, the Technical Data Packages for the SLICE 400 and SLICE 600 were not received from Lockheed Marine Systems prior to the case study market selection process, so some of the case study markets selected for further analysis do not necessarily have sufficient controlling depth to accommodate the SLICE 600.

12.4.2 Muskegon

Muskegon Harbor consists of Muskegon Lake, and dredged entrance channel which connects it with Lake Michigan. Muskegon Lake is about 4 miles long and varies in width from between 0.6 miles to 2.0 miles wide. The main harbor facilities are located on the south shore of the harbor at the city of Muskegon, with additional facilities also located at the east end of Muskegon Lake (see Figure 12-7). The lake has central depths of 25 to 79 feet, with deep water access to the city of Muskegon limited to a wide channel on the southern part of the Lake. A dredged entrance channel leads from deep water in Lake Michigan between converging breakwaters to an outer basin, thence between piers and revetments to Muskegon Lake (see Figure 12-8). In August 1996, the controlling depths were 21 feet in the south half of the approach and 23 feet in the north half to the ends of the breakwaters, thence 27 feet in the outer basin, thence 25 feet (27 feet at midchannel) between the piers and revetments to Muskegon Lake. From there, depths generally range from 31 feet to 79 feet to the harbor facilities on the south shore of Lake Muskegon.



In Muskegon, three possible ferry terminal locations have been proposed for further consideration: (1) Mart Dock (owned by Detroit-based West Michigan Dock & Market Corp.), (2) Hartshorn Marina (owned by the city of Muskegon), and (3) Heritage Landing (a park and festival grounds on the shore of Lake Muskegon, owned by Muskegon County). All locations have suitable access from major roadways. Of the three locations, Hartshorn Marine would be the easiest for the city to develop into a passenger and vehicle ferry terminal because the city owns it. At Mart Dock, depths alongside are between 21 feet and 30 feet at the northwest dock, with deck

vements to Muskegon Lake. From there, depths generally range from 31 feet to 79 feet to the harbor facilities on the south shore of Lake Muskegon.

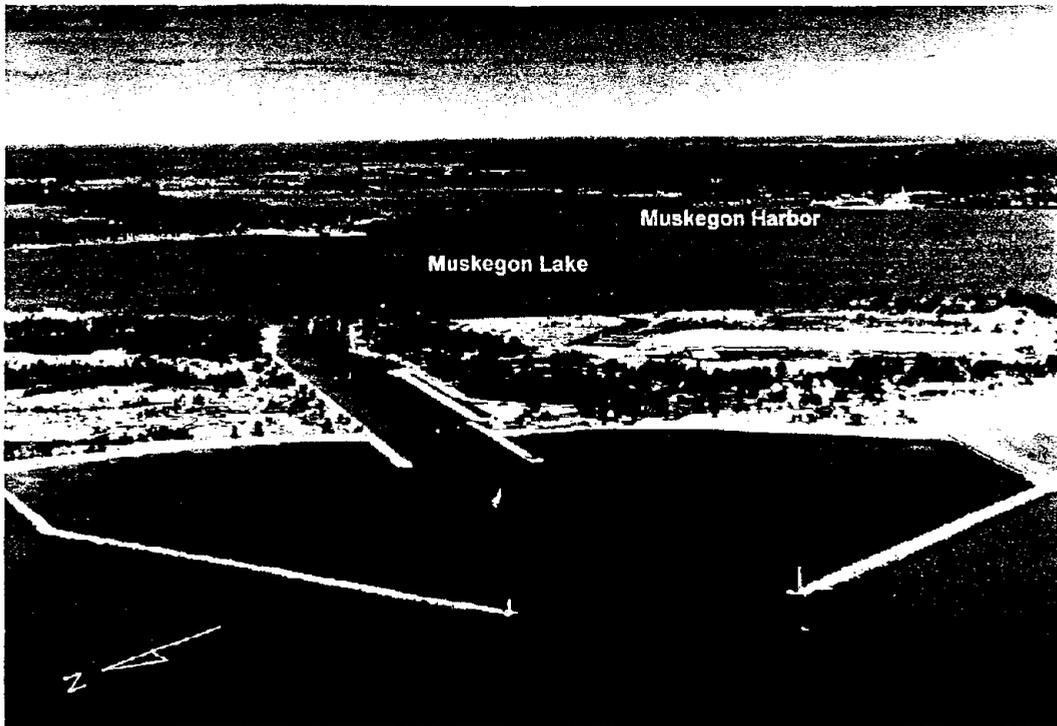
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Current plans call for the city of Muskegon to develop suitable ferry terminal facilities at one of the three locations. A commitment letter drafted in April 1999 from the city of Muskegon to Hydrolink calls for Hydrolink to pay a passenger facility charge or docking fee of a \$0.50 per passenger disembarking, with a minimum \$50,000 annual payment of \$50,000. Buildings would be leased for an additional \$15,000 annually. The proposed lease would be guaranteed for five years beginning January 1, 2001, with an option for Hydrolink to extend the lease for two additional five year periods through 2015.¹²¹ On April 13, 1999, the Muskegon city commission voted to approve up to \$1.4 million for shoreline improvements for the proposed high speed ferry service. These improvements would include property acquisition, a 2,500 square feet of building space for offices and ticketing, a 1,000 square foot maintenance building, vehicle and pedestrian ramps, 260 parking spaces, and other site improvements such as sidewalks, lighting, benches and other amenities.¹²²

¹²¹ "Three sites in race for Lake Michigan ferry dock." *Milwaukee Journal Sentinel*, April 12, 1999.

¹²² Bryon Mazade, City Manager, City of Muskegon. July 2, 1999.

FIGURE 12-8: MUSKEGON HARBOR AERIAL PHOTO



heights of between 5 and 6 feet. Depths alongside at Hartshorn Marina and at Heritage Landing are generally not as deep, ranging from 16 to 19 feet at Heritage Landing, and from only a few feet up to about 25 feet at a few locations in the vicinity of Hartshorn Marine. As in Milwaukee, although not subject to tidal fluctuation of any significant amount, water levels in Lake Michigan do fluctuate seasonally, and during the summer months, water levels can be up to 2 feet above the charted low water datums referenced above and on the nautical charts, which would work to the advantage of the deep draft of the SLICE 600.

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As in Milwaukee, the ferry terminal facilities that are to be developed will presumably be designed for a deck height of approximately 6 to 8 feet, which would be suitable to interface with the 72 meter Incat WPC baseline

¹²¹ "Three sites in race for Lake Michigan ferry dock." *Milwaukee Journal Sentinel*, April 12, 1999.

¹²² Bryon Mazadc, City Manager, City of Muskegon. July 2, 1999.

vessel. Although suitable for either the 72 meter WPC or the AMD K50, this deck height would be incompatible with the vehicle deck freeboard height of 21.5 feet for the SLICE 600, and would likely result in significant and unacceptable operational constraints for the SLICE 600.

12.5 Weather and Wave Climate

The climate in the case study region varies seasonally, with temperatures ranging from average lows of about 27°F in January, up to an average high during the month of July of about 80°F. The prevailing wind direction is generally from the northwest. Average annual precipitation is about 32 inches in both Milwaukee and Muskegon. In spring, when there is often a clash between cold and warm air, thunderstorms can be violent; although rare, the area lies at the extreme northeast edge of the tornado belt. Fog is most likely in the spring and early summer over open water and from late fall through spring along the shore. Historical meteorological data for the coastal areas of Lake Michigan are presented in Table 12-4.

TABLE 12-4: METEOROLOGICAL TABLE FOR LAKE MICHIGAN

METEOROLOGICAL TABLE FOR COASTAL AREA											
LAKE MICHIGAN											
Boundaries: From 41.5°N to 46.0°N From 85.0°W to 88.0°W											
Weather Elements	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	1
Wind > 33 Knots (1)	5.6	4.5	2.6	1.7	0.8	0.3	0.3	0.5	1.6	3.8	1
Wave Height > 9 ft (1)	2.8	2.1	1.0	0.9	0.6	0.2	0.2	0.4	1.2	2.5	1
Visibility < 2 nmi (1)	11.4	7.0	8.2	7.4	11.0	11.4	5.7	4.2	2.8	2.0	1
Precipitation (1)	16.2	9.0	7.8	8.7	5.2	4.1	3.7	5.0	6.1	7.8	1
Temperature > 69 F (1)	0.0	0.3	0.2	0.0	0.4	4.2	21.5	30.3	8.0	0.3	1
Mean Temperature (F)	22.9	25.2	33.6	40.0	46.6	55.8	65.5	67.4	60.9	50.0	3
Temperature < 33 F (1)	78.7	74.3	38.8	8.5	1.0	0.2	0.1	0.1	0.0	1.0	2
Mean RH (%)	52	79	80	80	77	81	86	83	82	70	1
Overcast or Obscured (1)	48.4	41.0	34.5	34.2	26.1	23.3	19.3	22.6	24.4	29.8	4
Mean Cloud Cover (8ths)	6.0	5.6	5.0	4.9	4.4	4.3	4.1	4.3	4.5	4.9	1
Mean SLP (mbs)	1018	1018	1017	1014	1016	1015	1015	1017	1017	1015	1
Ext. Max. SLP (mbs)	1041	1040	1050	1056	1053	1047	1046	1046	1050	1053	1
Ext. Min. SLP (mbs)	980	983	979	975	975	973	983	986	980	976	1
Prevailing Wind Direction	W	NW	N	N	S	S	S	S	S	S	1
Thunder and Lightning (1)	0.1	0.1	0.4	1.1	1.2	2.0	2.5	2.6	1.8	0.8	1

(1) Percentage Frequency

These data are based upon observations made by ships in passage. Such ships tend to avoid bad weather when possible, thus biasing the data toward good weather.

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), United States Coast Pilot, Volume 6, Great Lakes, 29th edition, Page T-19.

As discussed in Chapter 8, the Volpe Center conducted a detailed wave climate analysis using a combination of measured wave data sources and modeled hindcast data sources. Data sources used for this region included measured data from NOAA buoys and hindcast data from the U.S. Army Corps of Engineers, Wave Information Study (WIS) (Table 12-5). In total, more than 157,000 data records were utilized. Figure 12-9 presents the location of the particular buoys and stations from which data were obtained. Based on the operating schedule proposed by Hydrolink, using the 72 meter WPC, a distribution of annual vessel operating hours by sea state was developed. This schedule assumes operating seasonally between early April and mid November with 12 one-way vessel trips daily on weekdays and 8 one-way vessel trips on weekends. The results of this analysis, presented in Figure 12-10, reveal that significant wave heights in excess of sea state 4 (4.1 to 8.2 feet) would be experienced less than 1% of vessel operating hours. These findings are generally consistent with the wave

height data presented in the U.S. Coast Pilot, which indicates that during the summer, wave heights exceed 10 feet less than 1% of the time, and that sea conditions are worst in October and November, with wave heights of 5 to 10 feet (about sea state 4) encountered about 35% of the time.¹²³ Notably, Lake Michigan Carferry states that it has never cancelled a trip due to bad weather for its seasonal service between Manitowoc and Ludington.¹²⁴

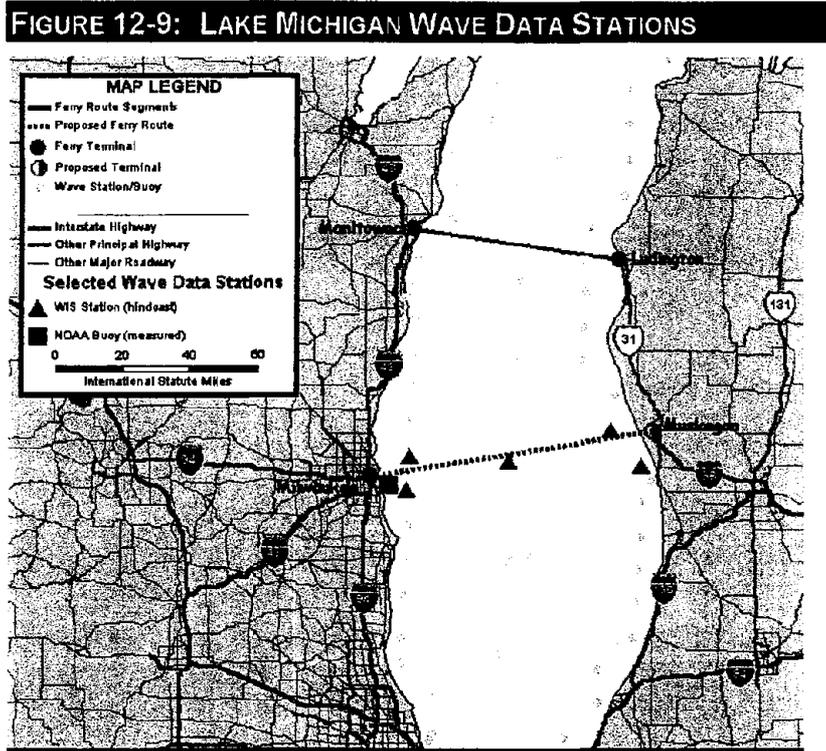
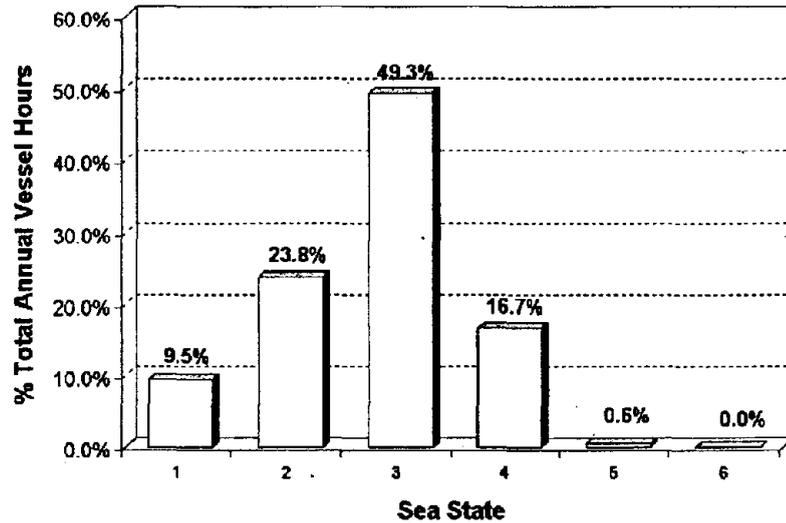


TABLE 12-5: LAKE MICHIGAN CASE STUDY - WAVE DATA SOURCES

Data Source	Buoy or Station	Time Period Observed	Number of Records
NOAA	45010	6/93 - 11/94 & 4/95 - 11/95	11,867
WIS	M0009	1/88 - 12/97	29,224
WIS	M0010	1/88 - 12/97	29,224
WIS	M0051	1/88 - 12/97	29,224
WIS	M0052	1/88 - 12/97	29,224
WIS	M0065	1/88 - 12/97	29,224
TOTALS			157,987

¹²³ U.S. Department of Commerce. National Oceanic and Atmospheric Administration (NOAA). United States Coast Pilot. Volume 6. Great Lakes. 29th edition. Page 239.

FIGURE 12-10: DISTRIBUTION OF ANNUAL VESSEL OPERATING HOURS BY SEA STATE (MILWAUKEE - MUSKEGON ROUTE)



Lake Michigan experiences varying degrees of ice coverage during a typical winter. Ice cover usually begins in Green Bay and extends eastward along the northern coastal areas into the Straits of Mackinac during the second half of December and early January. Ice formation and accumulation proceeds southward with coastal ice found throughout the southern perimeter of the lake by late January, with normal ice thickness ranging from between 10 to 20 centimeters in the south to 40 to 60 centimeters in the north. Shores exposed to the wind often have ice fields extended one to two miles offshore, and in the southern part of the lake, ice can extend 10 to 15 miles offshore. During a typical winter, ice cover extends over approximately 40% of the lake. During a severe winter, this can increase to 85% to 90%, and during a mild winter may only be 10% to 15%. Maximum ice coverage typically occurs by mid March on average, with coverage beginning to break up a week or two later. Under normal conditions, only 10% to 15% of the Lake is covered by ice by mid April, most of it in the northern part of the Lake and Green Bay.

12.6 Navigational Considerations

The route includes harbors at each end enclosed by jetties and the waters of Lake Michigan and Milwaukee Bay between. The Ports of Milwaukee and Muskegon have speed limits of 4 mph (3.5 knots) and 8 mph (7 knots), respectively.¹²⁴ Both SLICE and the comparative high speed vessels would be subject to these reduced speeds for about one nautical mile in Milwaukee and four nautical miles in Muskegon. Lake Muskegon has many shoals and obstructions, the result of which is a 1,600 foot wide navigational channel along its southern portion. There is no traffic separation scheme or traffic control system. In Milwaukee, the entire breakwater system protecting the outer harbor can be obscured by wave action during rough weather, and care must be taken when entering the harbor through the main channel. The Coast Guard Marine Safety Office Milwaukee reports no

¹²⁴ Lake Michigan Carferry, Inc. WWW at URL <http://www.ssbadger.com/sailinfo.html>.

¹²⁵ Telephone contact. LT Sickler and P.O Yusef, U.S. Coast Guard, MSO Milwaukee, August 11, 1999.

Given this operating profile, total one-way trip time from terminal to terminal using the 72 meter Incat WPC is estimated at 2 hours and 55 minutes, comprised of 31 minutes in Milwaukee Harbor, 101 minutes on Lake Michigan, and 43 minutes in Muskegon Harbor. With the SLICE 600, total trip time is 3 hours and 30 minutes, comprised of 31 minutes in Milwaukee Harbor, 135 minutes on Lake Michigan, and 43 minutes in Muskegon Harbor. Finally, with the AMD K50, total trip time is 2 hours and 45 minutes, comprised of 31 minutes in Milwaukee Harbor, 90 minutes on Lake Michigan, and 43 minutes in Muskegon Harbor.

As noted earlier, controlling depths in Milwaukee Harbor are marginal in comparison to the 28.5 foot draft of the SLICE 600. From the main harbor entrance where controlling depths are 32 feet, a channel runs south parallel to the breakwater, and has depths of between 27 to 35 feet. In the vicinity of the proposed ferry terminal location near the Coast Guard station, depths decrease to as little as 17 feet. Although not subject to tidal fluctuation of any significant amount, seasonal water levels in Lake Michigan can be up to 2 feet above the charted low water datums referenced above and on the nautical charts, which would work to the advantage of the deep draft of the SLICE 600.

In Muskegon, in August 1996 the controlling depths in the entrance to Muskegon Lake from deep water in Lake Michigan were 21 feet in the south half of the approach and 23 feet in the north half to the ends of the breakwaters, thence 27 feet in the outer basin, thence 25 feet (27 feet at midchannel) between the piers and revetments to Muskegon Lake. From there, depths generally range from 31 feet to 79 feet to the harbor facilities on the south shore of Lake Muskegon. Although adequate for the 72 meter Incat WPC and the AMD K50, these controlling depths are either unsuitable or marginal with respect to the 28.5 foot draft of the SLICE 600, with the area of greatest limitation being the approach to the main channel, the outer basin, and the channel itself.

12.7 Environmental Considerations

The only known wake and wash restriction is at the Bear Lake Entrance Channel on the north side of Lake Muskegon. The Bear Lake Channel is approximately ½ mile north of the Lake Muskegon navigational channel and wake wash from the SLICE operating at eight knots will not be an issue. The Fox Associates study shows that SLICE's wash energy at eight knots is virtually zero and certainly well below the stringent Washington State Ferry standard. There are no known species of whales or other large marine mammals frequenting these waters, nor are there any known areas of critical environmental concern along the location of the proposed route.

12.8 Market Forecasts and Financial Analysis

As noted earlier in this chapter, Hydrolink LLC is planning to acquire two Incat 72 meter RoPax wave piercing catamarans for use between Milwaukee and Muskegon. The service is planned to operate seasonally from approximately April 1 to mid December, beginning with the 2001 season. The craft would each operate 3 round trips per day, for a total of 6 round trips daily for the route. They each accommodate 325 passengers and 75 AEU, or a combination of up to 2 motorcoaches and 65 automobiles. Service speed is 40 knots, however the vessel would be subject to speed restrictions in both Milwaukee Harbor and Muskegon Harbor, as noted under the discussion of navigational issues later in this chapter. Although the breakwater-to-breakwater travel time would be 1 hour and 45 minutes using the 72 meter WPCs, the total one-way trip time due to these speed restrictions would therefore be just under three hours.

12.8.1 Baseline Ferry Patronage

As noted earlier, the Hydrolink market study suggests fares of \$115 one-way for two passengers and a vehicle, or \$150 one-way for four passengers and a vehicle. This equates to a one-way adult passenger fare of approximately \$33.00 (not including passenger facility charges), and a one-way automobile fare of \$49.00 (not including passengers). Motorcoach fares are estimated at \$150 one-way (not including passengers). These fares are

approximately 7.3% higher than those currently offered by LMC on their Ludington to Manitowoc route, perhaps reflecting in part the more frequent service and reduced trip time to be offered by Hydrolink in comparison to the existing LMC service.

Although there are no firm plans yet regarding how to employ the vessels during the off-season, there are two major options. The first option would be operate from April 1 through mid December, and then simply lay the vessel up for three months locally. This is the least desirable option financially, since two multi-million dollar vessels would then be unproductive for 25% of the year. The second option is operate from April 1 through mid November, and then reposition the vessels from mid November to April 1 in a warmer seasonal climate such as Florida or the Gulf of Mexico, and serve peak season demand in those areas during the Lake Michigan off-season. The only feasible route out of Lake Michigan to the Atlantic Ocean would be via the Saint Lawrence Seaway, with a repositioning trip from Lake Michigan to Florida taking approximately one week to complete.

Both of these two possible vessel repositioning scenarios are considered in the market and financial analysis. Under the scenario in which no vessel repositioning occurs, the operating season is assumed to run from April 1 through mid December, and the total annual vessel debt repayment expense is allocated to these operations on the Milwaukee to Muskegon route. Under the second scenario in which the vessel is assumed to be repositioned to another market in the off-season, the operating season is assumed to run from April 1 to mid November, and only eight months of the total annual vessel debt repayment expenses is allocated to the operations between Milwaukee and Muskegon, with the remaining four months allocated to the off-season operator. Separate tables presenting the financial analysis results are presented later in this chapter for both of these vessel repositioning scenarios.

Regarding passenger and vehicle patronage, note that, on many conventional RoPax ferry services, the observed ratio of vehicle boardings to passenger boardings ranges from between 0.28 to about 0.40, with an average of approximately 0.34.¹²⁶ However, the three RoPax vessels reviewed here (Incat 72 meter WPC, AMD K50, and SLICE 600) have a ratio of AEU vehicle capacity to passenger capacity ranging between 0.15 and 0.23. It is assumed for this case study that for each vessel type analyzed, vehicle boardings will be equal to 100% of the ratio of AEU vehicle capacity to passenger capacity. For example, for the Incat 72 meter WPC, the ratio of AEU vehicle capacity to passenger capacity is 75/325, or 0.23. Therefore, for example, if 200 passengers board the Incat 72 meter WPC on a given trip, 46 vehicles are also assumed to board on that trip.

Based on the market and financial analysis that follows, and utilizing the market analysis financial analysis methods described in Chapter 8, baseline annual equilibrium (year 3 and beyond) passenger boardings would total 757,100, and baseline equilibrium vehicle boardings would total 174,133 under the baseline case using the Incat 72 meter WPC and assuming that the vessel is not repositioned to another market during the off-season (see the baseline vessel portion of Table 12-6). Assuming the vessel is repositioned to another market during the off-season, then the baseline annual equilibrium (year 3 and beyond) passenger boardings would total 647,000 annually, and baseline equilibrium vehicle boardings would total 148,810 under the baseline case using the Incat 72 meter WPC (see the baseline vessel portion of Table 12-7). In order to evaluate these baseline patronage estimates in the context of the overall travel market between Milwaukee and Muskegon, a review of the existing travel between these two areas is performed below. Modes of travel that currently service this market include auto, air, rail, bus and other ferry services.

Baseline Travel Market - Auto

From Muskegon, U.S. Route 31 extends south to Interstate 196, which runs along the eastern shore of southern Lake Michigan. Interstate 196 then connects with Interstate 94, which continues around the southern part of the Lake Michigan shoreline, through Chicago and north to Milwaukee. Total driving distance from Milwaukee to

¹²⁶ Based on observed total passenger boardings and vehicle boardings for BC Ferries, Washington State Ferries, Cape May - Lewes ferry, Alaska Marine Highway System, Lake Michigan Carferry, and Bay Ferries service between Saint John and Digby.

Muskegon is 270 statute miles, and driving time one-way from Milwaukee to Muskegon is about 5 hours and 15 minutes under normal traffic conditions.

Assuming an out of pocket cost of \$0.32 per vehicle mile, and an average vehicle occupancy of 2 persons, the 270 statute mile trip between Milwaukee and Muskegon by automobile would cost approximately \$43 one-way per person. According to the market study conducted for Hydrolink by the firm Anderson & Roethle of Milwaukee, it is estimated that there are approximately 7 million annual one-way persons trips by automobile around the perimeter of Lake Michigan. It is assumed here that this figure includes all trips around Lake Michigan, including those to and from areas that are outside of the Milwaukee and Muskegon/Grand Rapids metropolitan areas. Therefore, to be more conservative, it is assumed that only 30% of these 7 million person trips, or 2.1 million persons trips, are made between the Milwaukee and Muskegon/Grand Rapids metropolitan areas.

Baseline Travel Market - Air Travel

There are three commercial service airports that service the Muskegon and Milwaukee metropolitan areas. These are (1) General Mitchell International Airport in Milwaukee, (2) Muskegon County Airport, and (3) Kent County International Airport (Grand Rapids).

General Mitchell International is located on Milwaukee's south side, approximately one mile from Interstate 94. Total passenger enplanements in 1996 for General Mitchell International were 2,682,179, composed of 2.5 million major air carrier enplanements, with the remainder being almost entirely commuter air carrier enplanements. Muskegon County Airport is located near the junction of U.S. Route 31 and Interstate 96 in southern Muskegon County. Total passenger enplanements in 1996 for Muskegon County Airport were 32,941, composed almost entirely of commuter air carrier enplanements. Kent County International Airport is located several miles to the southeast of downtown Grand Rapids, off of Interstate 96. Total passenger enplanements in 1996 for Kent County International were 851,050, composed of 778,000 major air carrier enplanements, with the remainder being almost entirely commuter air carrier enplanements.

Airlines that offer flights from Milwaukee to Muskegon include only Midwest Express, which operates the Beechcraft B100 turboprop (9 seats). There are three round trips daily, with a one-way travel time from gate-to-gate of 30 minutes. Information from airline reservation systems for the month of October 1999 indicates that current round trip coach air fares are \$390. Indirect service between Milwaukee and Muskegon is also offered by United Airlines via Chicago O'Hare, and Northwest via Detroit Metro. Recent round trip coach air fares on these indirect flights range from \$369 to \$575, with aircraft types including various turboprops and narrow body jets.

Airlines that offer direct flights from Milwaukee to Kent County International in Grand Rapids include only Midwest Express, which operates the Beechcraft B100 turboprop (9 seats) and the Fairchild Aerospace 328JET regional jet (32 seats), which was introduced to service on this route in October 1999. There are about eight round trips daily. One-way travel time from gate-to-gate is 40 minutes with the Beechcraft B100, and only 5 minutes shorter with the 328JET. Information from airline reservation systems for the month of October 1999 indicates that round trip coach air fares range from between \$354 and \$438. Indirect service between Milwaukee and Grand Rapids is also offered by United Airlines via Chicago O'Hare, US Airways via Indianapolis, American Trans Air via Chicago Midway, Northwest Airlines via Detroit Metro, and Continental Airlines via Detroit Metro and Cleveland, with recent round trip coach fares on these indirect flights ranging from a low of \$349 on United, up to \$1,093 on Continental. Total travel times on these indirect flights range from just over 2 hours on United to 3 hours and 30 minutes on Continental, with aircraft types including various turboprops and narrow body jets.

Air travel data for calendar year 1995, developed from a combination of Form 41, Form 298-C and 10% Sample data obtained from the U.S. Department of Transportation, Office of Airline Information, reveal that there were only about 150 origin-destination passengers that flew direct between General Mitchell International Airport in

Milwaukee and Muskegon County Airport in 1995. An additional 9,500 transfer passengers also flew between these two airports, with 4,250 passengers flying from Muskegon to Milwaukee, where they connected with flights beyond Milwaukee, and 4,150 passengers arriving at Milwaukee from another airport, where they then connected with flights on to Muskegon.

Between General Mitchell International Airport in Milwaukee and Kent County International Airport in Grand Rapids, that there were approximately 8,250 origin-destination passengers that flew direct in each direction in 1995, for a total of 16,500 direct origin-destination air trips between these two airports. An additional 41,600 transfer passengers also flew between these two airports, with 18,350 passengers flying from Grand Rapids to Milwaukee, where they connected with flights beyond Milwaukee, and 19,100 passengers arriving at Milwaukee from another airport, where they then connected with flights on to Grand Rapids.

Baseline Travel Market - Rail

Amtrak provides indirect rail passenger service between Milwaukee and Grand Rapids, which is about 35 statute miles southeast of Muskegon along Interstate 96. This service is provided indirectly via Chicago, requiring passengers to change trains in Chicago. The "Hiawatha Service" operates on the 86 statute mile route between Milwaukee and Chicago, with stops at Sturtevant and Glenview. The spring/summer 1999 Amtrak schedule indicates that this train operates six round trips daily, except for Sundays when five round trips are performed. Departures from Milwaukee are at 6:20 AM, 8:00 AM, 10:35 AM, 12:35 PM, 3:00 PM, and 5:40 PM. Departures from Chicago are at 8:25 AM, 10:30 AM, 12:33 PM, 3:15 PM, 5:08 PM, and 8:05 PM. One-way travel time is one hour and 30 minutes. At Chicago, one is then required to transfer to the "Pere Marquette" train, which operates on the 176 statute mile route between Chicago and Grand Rapids, with stops at Benton Harbor and Holland. The spring/summer 1999 Amtrak schedule indicates that this train operates one round trip daily, departing Chicago at 5:35 PM central time and arriving in Grand Rapids at 9:30 PM central time, for a 4 hour travel time on this leg of the journey. From Grand Rapids, the train departs at 7:45 AM eastern time and arrives in Chicago at 11:40 AM eastern time.

To travel from Milwaukee to Grand Rapids, one would depart Milwaukee on the Hiawatha at 3:00PM, arriving in Chicago at 4:32 PM, and then transfer to the Pere Marquette, which departs Chicago at 5:35 PM and arrives in Grand Rapids at 9:30 PM central time. Including transfers, this is a total trip time of 6 hours and 30 minutes. To travel from Grand Rapids to Milwaukee, one would depart Grand Rapids at 6:45 AM central time on the Pere Marquette, arriving in Chicago at 10:40 AM central time, and then transfer to the Hiawatha, with the next train for Milwaukee departing Chicago at 12:33 PM and arriving in Milwaukee at 2:07 PM. Including transfers, this is a total trip time of almost 7 hours.

The lowest fare available in the fall of 1999 for an unreserved coach seat on the Milwaukee to Chicago route was \$19 one-way, and the lowest fare available in the fall of 1999 for an unreserved coach seat on the Chicago to Grand Rapids route was \$33 one-way, for a total cost of \$52 one-way. Because the trip involves a change of train, ridership figures for those whose true origins and destinations are in Milwaukee and Grand Rapids are difficult to obtain. However, fiscal year 1998 ridership on the Hiawatha Service, as reported by Amtrak, was 298,334, and on the Pere Marquette was 46,804.¹²⁷ Therefore, the absolute maximum number of rail passengers traveling between Milwaukee and Grand Rapids would be 46,804. However, because Chicago is an Amtrak hub serving other major destinations as well, such as Minneapolis/St. Paul, Kansas City, St. Louis and Indianapolis, it is likely that a sizeable portion of this total consists of passengers whose final destination is Chicago, or passengers who are connecting at Chicago to travel on to destinations other than Milwaukee. Therefore, it is estimated that true origin and destination rail ridership between Milwaukee and Grand Rapids is approximately 20% of this total, or about 4,750 passengers annually in each direction.

Baseline Travel Market - Bus

¹²⁷ Amtrak. WWW at URL <http://www.amtrak.com/news/pr/atk98126b.html>.

Russel's Official National Motorcoach Guide for the U.S. and Canada for August 1999 was referenced to identify intercity bus companies offering service between Milwaukee and Muskegon. Greyhound is the only carrier providing motorcoach service between Milwaukee and Muskegon. The service requires lengthy stopovers in Chicago and Grand Rapids of 2 to 3 hours on average, with total travel times including stopovers ranging from between 6 hours to more than 12 hours, and with some departures occurring at inconvenient times in the early morning pre-dawn hours. Total route distance is approximately 288 statute miles. Service operates daily, with two departures daily from Milwaukee at 3:30 AM and 2:00 PM, and three departures daily from Muskegon at 7:00 AM, 10:10 PM, and 3:15 AM. Current adult round trip fares range from between \$89 to \$108.

This operating schedule indicates a total of approximately 1,825 one-way vehicle trips are made annually. Given that a typical intercity motorcoach has a seating capacity between 46 and 55 seats, with a fleet average of about 49 seats, this equates to a total of approximately 44,700 one-way bus passenger trips annually, assuming an average load factor of 50%, which is typical of scheduled intercity motorcoach service nationwide.

Baseline Travel Market - Other Ferry Service

As noted earlier, Lake Michigan Carferry operates seasonal RoPax service between Manitowoc, Wisconsin and Ludington, Michigan between May and October. Service is offered daily, and in 1999, a single round trip was offered daily from May 14 to June 17 and August 30 to October 17, and two round trips were offered daily from June 18 to August 29. Since 1992, this is the general schedule that has been offered each year. The SS Badger carried 115,000 passengers and 34,000 vehicles between Manitowoc and Ludington during its first season in 1992, operating on a similar schedule.¹²⁸ It is the company policy of Lake Michigan Carferry not to disclose patronage data, nor are they required to do so as a condition of receiving any federal, state or local operating or non-operating subsidies, since they receive none. Therefore, more recent patronage data are not available, however anecdotal evidence suggest current ridership exceeds these historical figures, and a figure of 138,000 annual passenger boardings is used here as a current estimate.

On the 54 nautical mile route between Manitowoc, Wisconsin, and Ludington, Michigan, total one-way trip time is 4 hours. Adult fares for the 1999 season on this route were \$61.00 round trip, with discounts for seniors and children. Round trip fares are \$92 for automobiles, vans and pickups (not including their passengers), \$280 for motorcoaches (not including passengers), and \$450 for tractor trailers (not including passengers).

In 1984, the Michigan Department of Transportation conducted a survey of ferry passengers on Lake Michigan. Key findings were that 58% of ferry passengers were residents of Wisconsin or Michigan, about evenly split between the two states, and that 67% of passengers were recreational travelers, with only 6% on business related trips.¹²⁹

Baseline Travel Market - All Modes

Based on the above analysis of baseline travel by mode, it is estimated that total travel by all modes between Milwaukee and Muskegon/Grand Rapids metropolitan area is approximately 2.3 million one-way trips annually, comprised of 2.1 million one-way persons trips by auto, 16,650 one-way trips by air, 4,750 trips by rail, 44,700 trips by bus, and 138,000 trips by other ferry services. In addition to diversion from these existing modes of travel, it is possible that the introduction of high speed ferry service could result in some level of induced travel demand, which is typically defined as trips that are new to the overall travel market, and that are not currently being made on other existing modes, and that would not otherwise be made absent the introduction of the new transportation service. Assuming here a modest level of induced travel resulting from the introduction of high speed ferry service equal to 5% of the overall travel market, the estimated baseline equilibrium passenger board-

¹²⁸ Phone contact. Thomas Hawley. Lake Michigan Carferry, Inc. May 25, 1999.

¹²⁹ Wisconsin Department of Transportation. *Passenger Ferry Service: An overview and study proposal for passenger ferry service in Wisconsin.* June 1994.

ings of 757,100 in the baseline case using the 72 meter WPC and assuming no vessel repositioning in the off-season would represent approximately 31% of the total travel market.

Other than the Hydrolink market study, which was not made available by Hydrolink for review, the only other high speed ferry market study performed for Lake Michigan is the 1980 study completed for the Board of Harbor Commissioners in Milwaukee, which as noted earlier reviewed possible service by hovercraft on the route between Milwaukee and Muskegon. At the time the study was completed in 1980, estimated patronage in the year 2000 for this service was 468,000 passenger boardings and 268,000 vehicle boardings.¹³⁰

Without the application of the more advanced travel forecasting methods discussed earlier in Chapter 8, a reasonable and empirically defensible independent estimate of the baseline patronage that might materialize on this proposed ferry route, with full consideration given to the level of service attributes on other competing modes in this market, cannot be made. However, given the travel times, fares and frequency of service offered by the proposed Hydrolink service relative to these level of service attributes on other modes serving this market such as auto, air, rail, and bus, it does not seem unreasonable that the Hydrolink service would capture a sizeable share of the existing market.

12.8.2 Financial Analysis

The economic performance of the various vessel types and operating scenarios is first estimated at a break-even level of patronage for the proposed operating schedule. The break-even level is defined here as the level of passenger and vehicle patronage required to achieve an internal rate of return of 15% with the baseline fare. This is then followed by a baseline fare scenario, in which the baseline fare is utilized in conjunction with the estimated patronage for each vessel type. Finally, a profit maximizing fare scenario is conducted in which fare levels are varied to achieve the maximum internal rate of return, or minimum annual net cash deficit, possible.

Break Even Scenario

As noted above, the estimate of the baseline annual equilibrium passenger and vehicle patronage is based upon the level of patronage that would be required to return a 15% internal rate of return given the proposed baseline vessel, and the proposed baseline operating schedule and fares. This is referred to here as a "break-even" financial analysis. Again, applying this methodology to the baseline case using the Incat 72 meter WPC, annual equilibrium (year 3 and beyond) passenger boardings are estimated at 757,100 and annual equilibrium vehicle boardings at 174,133, assuming no off-season vessel repositioning (see Table 12-6). Therefore, to achieve this minimum level of profitability using the Incat 72 meter WPC, an average passenger capacity utilization rate, or load factor, of 77% would be required. Even under the break-even analysis assuming vessel repositioning, presented in Table 12-7, the required passenger load factor for the Incat 72 meter WPC is 74.1%.

This break-even methodology was next extended to the other comparative vessel types analyzed for this case study, with the results also presented in Table 12-6 and Table 12-7. This type of analysis is illuminating because it identifies how much patronage an operator would be required to attract to attain a minimum level of profitability, for a given type of vessel and given operating scenario. If all else held equal, an operator is required to attract a significantly greater number of passengers, or achieve an unrealistically high annual load factor, with a particular vessel to attain the same level of minimum profitability possible with an alternative base-

¹³⁰ Transportation and Economic Research Associates, Inc. *Phase I Report on Feasibility Study of a Cross-Lake Passenger Auto Air Cushion Ferry Service*. Prepared for the Board of Harbor Commissioners, City of Milwaukee. August 1980.

line vessel, then this indicates that the baseline vessel would likely be viewed as superior by the potential operator.

The off-season vessel repositioning scenario, presented in Table 12-7, results in financial performance that is only marginally superior to the no vessel repositioning scenario presented in Table 12-6. Therefore, the focus of the following discussion of the break-even financial analysis will be on the findings in Table 12-6 only.

The AMD K50 is able to achieve an internal rate of return of 15% with a passenger load factor of 66.3%, and a vehicle load factor of 72.2%, with annual passenger boardings of 802,500 and annual vehicle boardings of 176,550, both only slightly higher than the number of boardings required for the Incat 72 meter WPC. Significant differences in operating expenses and revenues between the AMD K50 and the baseline Incat 72 meter WPC include salaries, wages and benefits for deck and engine crew, which are 29% less for the AMD K50, largely because of the somewhat smaller total crew complement of the AMD K50, and because somewhat fewer operating hours with the AMD K50 because of the faster operating speed and a one-way trip time that is 6.3% less than for the baseline Incat 72 meter WPC. Vessel fuel and lubricant expense for the AMD K50 is 29% greater than in the baseline case, because of the higher fuel consumption rate per hour at operating speed for the AMD K50, which is offset only slightly by the fewer total operating hours annually for the AMD K50.

For the SLICE 600, only a single vessel operating three round trips daily is assumed, largely because the SLICE 600 has a passenger capacity nearly twice that of the baseline Incat 72 meter WPC. This schedule would require operations a minimum of 21 hours per day, however, as compared to about 18 hours a day for the Incat 72 meter WPC and the AMD K50. In both cases, additional time would be required for vessel loading and unloading and turnaround activities, suggesting that in all cases, perhaps two round trips per day per vessel would be somewhat more realistic. To achieve the break-even 15% internal rate of return, the SLICE 600 requires 725,700 annual passenger boardings, and 108,855 vehicle boardings, which correspond to load factors of 80% and 82.4%, respectively. These patronage levels represent only a 4% decrease in passenger boardings, but a 37% decline in vehicle boardings relative to the Incat 72 meter WPC. Major differences in SLICE 600 operating expenses relative to the Incat 72 meter WPC include vessel debt repayment expense, which for the SLICE 600 is 32% less than for the Incat 72 meter WPC, due to the fact that only one SLICE 600 vessel is utilized, but two Incat 72 meter WPC vessels are used. Expenses for salaries, wages and benefits for both deck and engine crew are 40% less for the SLICE 600, for vessel maintenance are 26% less, and for marine hull insurance are 32% less, all a reflection of the use of a single vessel rather than two vessels. However, fuel and lubricant expense is actually greater by 26% for the SLICE 600, despite the use of only one vessel, because of the higher fuel consumption rates at operating speed of the SLICE 600, and its slower operating speed which increases total operating hours per vessel.

Baseline Fare Scenario

For the next set of market and financial analyses, presented in Table 12-8 and Table 12-9, the baseline Incat 72 meter WPC annual ridership of 757,100 passengers and 174,133 vehicles serves as the basis from which patronage estimates for the other comparative vessel types are made, according to the observed demand elasticities for RoPax ferry travel with respect to total travel time, fare and frequency of service, and based on sea state and seakeeping analyses, as discussed in Chapter 8. As was the case with the break-even analyses, the baseline fare scenario that assumes that there is off-season vessel repositioning, presented in Table 12-9, results in financial performance that is only marginally superior to the scenario presented in Table 12-8 that assumes that there is no vessel repositioning. Therefore, the focus of the following discussion of the baseline fare scenario financial analysis will be on the findings in Table 12-8 only.

Table 12-8 presents the "baseline fare scenario," in which the Incat 72 meter WPC baseline patronage is varied as a function of the comparative vessel travel times, and the relative seakeeping performance of each vessel under the wave climate conditions for this case study region, but fares are kept the same for all vessel types at the baseline fare levels. The relative financial performance of the comparative vessels are generally the same for the direct operating cost categories such as crew and fuel, as described earlier under the break-even scenarios.

Under this scenario, for the AMD K50 it is estimated that there would be approximately 35,692 additional passenger boardings than in the baseline case with the Incat 72 meter WPC because of the decrease in total one-way travel time relative to the Incat 72 meter WPC of 6.3%, or about 11 minutes. Based on the seakeeping analysis presented in Chapter 5, both the Incat 72 meter WPC and the AMD K50 are assumed to have generally similar seakeeping performance, and therefore there is no change in estimated ridership due to relative seakeeping performance for the AMD K50. The resulting annual patronage of 792,792 passengers and 174,414 vehicles yields an internal rate of return under this scenario for the AMD K50 of 14.03%, approximately the same as the 15% baseline internal rate of return achieved with the Incat 72 meter WPC.

Because of the speed restrictions in Milwaukee Harbor and Muskegon Harbor, which all of the vessel types considered here would be subject to, the SLICE 600 has an overall travel time only 19.4% greater than the Incat 72 meter WPC, despite the fact that the SLICE 600 has a 25% slower operating speed than the Incat 72 meter WPC. For the SLICE 600, it is estimated that there would be approximately 110,320 fewer passenger boardings than in the baseline case with the Incat 72 meter WPC because of the 19.4% increase in one-way travel time relative to the Incat 72 meter WPC, a total travel time increase of about 30 minutes.

Based on the seakeeping analysis presented in Chapter 5 and the methodology presented in Chapter 8 regarding the impact of seakeeping performance on patronage, it is estimated that about 3,388 additional passengers would board the SLICE 600 relative to the baseline case with the Incat 72 meter WPC. The resulting annual patronage of 551,745 passengers and 82,762 vehicles yields no meaningful figure for the internal rate of return, because there are no positive net cash flows generated in any of the years analyzed under this scenario. The annual net cash flow for years 3 through 15 for the SLICE 600 is minus \$1.7 million.

Profit Maximizing Fare Scenario

In Table 12-10 and Table 12-11, an extension of the baseline fare scenario referred to as the "profit maximizing fare scenario" is presented. Under this scenario, fares for the comparative vessel types were varied to determine if a fare level other than the baseline fare could yield an internal rate of return higher than that under the baseline fare scenario. Therefore, in addition to changes in the baseline patronage resulting from different travel times and seakeeping performance, changes in patronage resulting from different fare levels are also considered in combination with these other level of service parameters. As before, the assumption of off-season vessel repositioning, as presented Table 12-11, results in financial performance that is only marginally superior to the scenario assuming no vessel repositioning as presented Table 12-10. Therefore, the focus of the following discussion of the profit maximizing fare scenario financial analysis will be on the findings in Table 12-10 only.

TABLE 12-6: MILWAUKEE - MUSKEGON "BREAK-EVEN" FINANCIAL ANALYSIS (NO VESSEL REPOSITIONING)

Results from Discounted Cash Flow Analysis (Amounts and Percent Difference from Baseline)			
Vessel Type	Baseline	Scenarios	
	Incat 72m	AMD K50	SLICE 600
Internal Rate of Return (IRR) ⁽¹⁾	15.00%	15.00%	15.00%
Equity Investment - Vessel Purchase	-\$5,500,000	-\$6,000,000	-\$7,400,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	-\$4,451,561	-\$4,674,355	-\$3,947,565
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$11,756,784	-\$12,272,188	-\$9,480,607
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL OPERATING PROFILE⁽²⁾			
Vessel Type	Incat 72m	AMD K50	SLICE 600
Passenger Capacity Per Vessel	325	400 (23.1%)	600 (84.6%)
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	75	89 (18.7%)	90 (20.0%)
Number of Vessels	2	2 (0.0%)	1 (-50.0%)
One-Way Vessel Travel Time	2 hrs, 55 min	2 hrs, 44 min (-6.3%)	3 hrs, 29 min (19.4%)
Total Annual One-Way Vessel Trips Performed	3,024	3,024 (0.0%)	1,512 (-50.0%)
Annual Operating Hours per Vessel	4,410	4,133 (-6.3%)	5,267 (19.4%)
Adult One-Way Passenger Fare (Including pfc's) ⁽³⁾	\$34.00	\$34.00 (0.0%)	\$34.00 (0.0%)
Total Annual One-Way Passenger Boardings	757,100	802,500 (6.0%)	725,700 (-4.1%)
Passenger Capacity Utilization Rate	77.0%	66.3% (-13.9%)	80.0% (3.8%)
Automobile One-Way Fare	\$49.00	\$49.00 (0.0%)	\$49.00 (0.0%)
Total Annual One-Way Vehicle Boardings	174,133	176,550 (1.4%)	108,855 (-37.5%)
Vehicle Capacity (AEU) Utilization Rate	79.8%	72.2% (-9.6%)	82.4% (3.2%)
ANNUAL VESSEL DEBT REPAYMENT			
Vessel Debt Repayment (combined principal and interest)	\$5,673,915	\$6,189,725 (9.1%)	\$3,816,997 (-32.7%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)			
Direct Operating Costs			
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$4,876,442	\$3,457,246 (-29.1%)	\$2,911,933 (-40.3%)
Vessel Fuel and Lubricants	\$6,143,968	\$7,869,104 (27.9%)	\$7,717,053 (25.6%)
Vessel Maintenance Costs	\$2,286,900	\$2,417,184 (5.7%)	\$1,686,401 (-26.3%)
Marine Hull Insurance	\$1,375,000	\$1,500,000 (9.1%)	\$925,000 (-32.7%)
Direct Operating Costs Subtotal	\$14,682,310	\$15,233,534 (3.8%)	\$13,240,387 (-9.8%)
Indirect Operating Costs			
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$1,484,135	\$1,390,846 (-6.3%)	\$1,012,846 (-31.8%)
Marketing and Advertising	\$1,618,749	\$1,699,766 (5.0%)	\$1,435,478 (-11.3%)
Reservations & Sales	\$1,138,172	\$1,192,376 (4.8%)	\$989,349 (-13.1%)
Docking Fees / Passenger Facility Charges / Shore Operations	\$787,100	\$832,500 (5.8%)	\$755,700 (-4.0%)
Protection and Indemnity (P&I) Insurance	\$227,130	\$240,750 (6.0%)	\$217,710 (-4.1%)
General Administration	\$6,251,075	\$6,625,625 (6.0%)	\$5,992,025 (-4.1%)
Outside Professional Services	\$752,062	\$796,739 (5.9%)	\$721,135 (-4.1%)
Onboard Food & Beverage Sales - Cost of Sales	\$2,460,575	\$2,608,125 (6.0%)	\$2,358,525 (-4.1%)
Gift Shop - Cost of Sales	\$1,022,085	\$1,083,375 (6.0%)	\$979,695 (-4.1%)
Onboard Gaming - Cost of Sales	\$946,375	\$1,003,125 (6.0%)	\$907,125 (-4.1%)
Indirect Operating Costs Subtotal	\$16,687,458	\$17,473,227 (4.7%)	\$15,369,587 (-7.9%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL REVENUES			
Passenger Fares	\$23,810,795	\$25,238,625 (6.0%)	\$22,823,265 (-4.1%)
Vehicle Fares	\$8,708,391	\$8,829,266 (1.4%)	\$5,443,839 (-37.5%)
Ancillary Sales - Onboard Food & Beverage Sales	\$3,785,500	\$4,012,500 (6.0%)	\$3,628,500 (-4.1%)
Ancillary Sales - Gift Shop Sales	\$2,271,300	\$2,407,500 (6.0%)	\$2,177,100 (-4.1%)
Ancillary Sales - Onboard Gaming	\$1,892,750	\$2,006,250 (6.0%)	\$1,814,250 (-4.1%)
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0 (n/a)	\$0 (n/a)
Total Revenues	\$40,468,736	\$42,494,141 (5.0%)	\$35,886,954 (-11.3%)
EQUILIBRIUM YEARS 3 THROUGH 15 NET CASH FLOW BEFORE TAXES			
Equilibrium Year 3 Net Cash Flow Before Taxes	\$3,425,054	\$3,597,654 (5.0%)	\$3,459,982 (1.0%)

Notes:

"no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning

(1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.

(2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years.

Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years 3 through 15 are presented in the above summary of the discounted cash flow analysis.

(3) Passenger facility charges (pfc).

**TABLE 12-7: MILWAUKEE - MUSKEGON "BREAK-EVEN" FINANCIAL ANALYSIS
(WITH OFF-SEASON VESSEL REPOSITIONING)**

Results from Discounted Cash Flow Analysis (Amounts and Percent Difference from Baseline)

Vessel Type	Scenarios		
	Baseline	AMD K50	SLICE 600
Internal Rate of Return (IRR) ⁽¹⁾	15.00%	15.00%	15.00%
Equity Investment - Vessel Purchase	-\$5,500,000	-\$5,000,000	-\$7,400,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	-\$3,804,200	-\$3,987,618	-\$3,415,566
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$9,821,928	-\$10,222,526	-\$7,976,116
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL OPERATING PROFILE⁽²⁾			
Vessel Type	Incat 72m	AMD K50	SLICE 600
Passenger Capacity Per Vessel	325	400 (23.1%)	600 (84.6%)
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	75	89 (18.7%)	90 (20.0%)
Number of Vessels	2	2 (0.0%)	1 (-50.0%)
One-Way Vessel Travel Time	2 hrs, 55 min.	2 hrs, 44 min. (-6.3%)	3 hrs, 29 min. (19.4%)
Total Annual One-Way Vessel Trips Performed	2,688	2,688 (0.0%)	1,344 (-50.0%)
Annual Operating Hours per Vessel	3,920	3,674 (-6.3%)	4,682 (19.4%)
Adult One-Way Passenger Fare (including pfc's) ⁽³⁾	\$34.00	\$34.00 (0.0%)	\$34.00 (0.0%)
Total Annual One-Way Passenger Boardings	647,000	684,600 (5.8%)	527,900 (-3.0%)
Passenger Capacity Utilization Rate	74.1%	63.7% (-14.0%)	77.9% (5.1%)
Automobile One-Way Fare	\$49.00	\$49.00 (0.0%)	\$49.00 (0.0%)
Total Annual One-Way Vehicle Boardings	148,810	150,612 (1.2%)	94,185 (-36.7%)
Vehicle Capacity (AEU) Utilization Rate	76.8%	69.3% (-9.8%)	80.2% (4.5%)
ANNUAL VESSEL DEBT REPAYMENT			
Vessel Debt Repayment (combined principal and interest)	\$3,782,610	\$4,126,484 (9.1%)	\$2,544,665 (-32.7%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)			
Direct Operating Costs			
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$4,334,615	\$3,073,108 (-29.1%)	\$2,588,385 (-40.3%)
Vessel Fuel and Lubricants	\$5,461,304	\$6,985,870 (27.9%)	\$6,859,603 (25.6%)
Vessel Maintenance Costs	\$2,161,133	\$2,288,608 (5.9%)	\$1,585,356 (-26.5%)
Marine Hull Insurance	\$1,375,000	\$1,500,000 (9.1%)	\$925,000 (-32.7%)
Direct Operating Costs Subtotal	\$13,332,053	\$13,847,586 (3.9%)	\$11,958,344 (-10.3%)
Indirect Operating Costs			
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$1,319,231	\$1,236,308 (-6.3%)	\$900,308 (-31.8%)
Marketing and Advertising	\$1,383,346	\$1,450,043 (4.8%)	\$1,242,024 (-10.2%)
Reservations & Sales	\$972,655	\$1,017,197 (4.6%)	\$856,018 (-12.0%)
Docking Fees / Passenger Facility Charges / Shore Operations	\$677,000	\$714,600 (5.6%)	\$657,900 (-2.8%)
Protection and Indemnity (P&I) Insurance	\$194,100	\$205,380 (5.8%)	\$188,370 (-3.0%)
General Administration	\$5,342,750	\$5,652,950 (5.8%)	\$5,185,175 (-2.9%)
Outside Professional Services	\$643,518	\$680,618 (5.8%)	\$624,660 (-2.9%)
Onboard Food & Beverage Sales - Cost of Sales	\$2,102,750	\$2,224,950 (5.8%)	\$2,040,675 (-3.0%)
Gift Shop - Cost of Sales	\$873,450	\$924,210 (5.8%)	\$847,665 (-3.0%)
Onboard Gaming - Cost of Sales	\$808,750	\$855,750 (5.8%)	\$784,875 (-3.0%)
Indirect Operating Costs Subtotal	\$14,317,549	\$14,962,006 (4.5%)	\$13,327,869 (-6.9%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL REVENUES			
Passenger Fares	\$20,348,150	\$21,530,670 (5.8%)	\$19,747,455 (-3.0%)
Vehicle Fares	\$7,441,988	\$7,532,108 (1.2%)	\$4,710,192 (-36.7%)
Ancillary Sales - Onboard Food & Beverage Sales	\$3,235,000	\$3,423,000 (5.8%)	\$3,139,900 (-3.0%)
Ancillary Sales - Gift Shop Sales	\$1,941,000	\$2,053,800 (5.8%)	\$1,883,700 (-3.0%)
Ancillary Sales - Onboard Gaming	\$1,617,500	\$1,711,500 (5.8%)	\$1,569,750 (-3.0%)
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0 (n/a)	\$0 (n/a)
Total Revenues	\$34,583,638	\$36,251,076 (4.8%)	\$31,050,597 (-10.2%)
EQUILIBRIUM YEARS 3 THROUGH 15 NET CASH FLOW BEFORE TAXES			
Equilibrium Year 3 Net Cash Flow Before Taxes	\$3,151,426	\$3,315,000 (5.2%)	\$3,219,919 (2.2%)

Notes:
 "no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning.
 (1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.
 (2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years. Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years 3 through 15 are presented in the above summary of the discounted cash flow analysis.
 (3) Passenger facility charges (pfc).

TABLE 12-8: MILWAUKEE - MUSKEGON BASELINE FARE SCENARIO FINANCIAL ANALYSIS (NO VESSEL REPOSITIONING)

Results from Discounted Cash Flow Analysis (Amounts and Percent Difference from Baseline)

Vessel Type	Scenarios		
	Incat 72m	AMD K50	SLICE 600
Internal Rate of Return (IRR) ⁽¹⁾	15.00%	14.03%	no meaningful figure
Equity Investment - Vessel Purchase	\$5,500,000	\$5,000,000	\$7,400,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	-\$4,451,561	-\$4,617,808	-\$3,001,307
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$11,756,784	-\$12,519,824	-\$15,390,341
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL OPERATING PROFILE⁽²⁾			
Passenger Capacity Per Vessel	325	400 (23.1%)	600 (84.6%)
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	75	89 (18.7%)	90 (20.0%)
Number of Vessels	2	2 (0.0%)	1 (-50.0%)
One-Way Vessel Travel Time	2 hrs, 55 min.	2 hrs, 44 min. (-6.3%)	3 hrs, 29 min. (19.4%)
Total Annual One-Way Vessel Trips Performed	3,024	3,024 (0.0%)	1,512 (-50.0%)
Annual Operating Hours per Vessel	4,410	4,133 (-6.3%)	5,267 (19.4%)
Adult One-Way Passenger Fare (including p/c's) ⁽³⁾	\$34.00	\$34.00 (0.0%)	\$34.00 (0.0%)
Total Annual One-Way Passenger Boardings	757,100	792,792 (4.7%)	551,745 (-27.1%)
Passenger Capacity Utilization Rate	77.0%	65.5% (-14.9%)	60.8% (-21.1%)
Automobile One-Way Fare	\$49.00	\$49.00 (0.0%)	\$49.00 (0.0%)
Total Annual One-Way Vehicle Boardings	174,133	174,414 (0.2%)	82,762 (-52.5%)
Vehicle Capacity (AEU) Utilization Rate	79.8%	71.3% (-10.7%)	62.6% (-21.5%)
ANNUAL VESSEL DEBT REPAYMENT			
Vessel Debt Repayment (combined principal and interest)	\$5,673,915	\$6,189,725 (9.1%)	\$3,816,997 (-32.7%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)			
Direct Operating Costs			
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$4,876,442	\$3,457,246 (-29.1%)	\$2,911,933 (-40.3%)
Vessel Fuel and Lubricants	\$6,143,668	\$7,859,104 (27.9%)	\$7,717,053 (25.6%)
Vessel Maintenance Costs	\$2,286,900	\$2,417,184 (5.7%)	\$1,686,401 (-26.3%)
Marine Hull Insurance	\$1,375,000	\$1,500,000 (9.1%)	\$925,000 (-32.7%)
Direct Operating Costs Subtotal	\$14,682,310	\$15,233,534 (3.8%)	\$13,240,387 (-9.8%)
Indirect Operating Costs			
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$1,484,135	\$1,390,846 (-6.3%)	\$1,012,846 (-31.8%)
Marketing and Advertising	\$1,618,749	\$1,679,203 (3.7%)	\$1,091,384 (-32.6%)
Reservations & Sales	\$1,138,172	\$1,177,952 (3.5%)	\$752,195 (-33.9%)
Docking Fees / Passenger Facility Charges / Shore Operations	\$787,100	\$822,792 (4.5%)	\$581,745 (-26.1%)
Protection and Indemnity (P&I) Insurance	\$227,130	\$237,838 (4.7%)	\$165,523 (-27.1%)
General Administration	\$6,251,075	\$6,545,533 (4.7%)	\$4,556,894 (-27.1%)
Outside Professional Services	\$752,062	\$787,189 (4.7%)	\$549,383 (-26.9%)
Onboard Food & Beverage Sales - Cost of Sales	\$2,460,575	\$2,576,574 (4.7%)	\$1,793,170 (-27.1%)
Gift Shop - Cost of Sales	\$1,022,085	\$1,070,269 (4.7%)	\$744,855 (-27.1%)
Onboard Gaming - Cost of Sales	\$946,375	\$990,990 (4.7%)	\$689,681 (-27.1%)
Indirect Operating Costs Subtotal	\$16,687,458	\$17,279,185 (3.5%)	\$11,937,677 (-28.5%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL REVENUES			
Passenger Fares	\$23,810,795	\$24,933,304 (4.7%)	\$17,352,372 (-27.1%)
Vehicle Fares	\$8,708,391	\$8,722,455 (0.2%)	\$4,138,913 (-52.5%)
Ancillary Sales - Onboard Food & Beverage Sales	\$3,785,500	\$3,963,959 (4.7%)	\$2,758,724 (-27.1%)
Ancillary Sales - Gift Shop Sales	\$2,271,300	\$2,378,376 (4.7%)	\$1,655,234 (-27.1%)
Ancillary Sales - Onboard Gaming	\$1,892,750	\$1,981,980 (4.7%)	\$1,379,362 (-27.1%)
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0 (n/a)	\$0 (n/a)
Total Revenues	\$40,468,736	\$41,980,073 (3.7%)	\$27,284,605 (-32.6%)
EQUILIBRIUM YEARS 3 THROUGH 15 NET CASH FLOW BEFORE TAXES			
Equilibrium Year 3 Net Cash Flow Before Taxes	\$3,425,054	\$3,277,629 (-4.3%)	-\$1,710,457 (-149.9%)

Notes:

"no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning.

(1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.

(2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years.

Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years

3 through 15 are presented in the above summary of the discounted cash flow analysis.

(3) Passenger facility charges (pfc).

TABLE 12-9: MILWAUKEE - MUSKEGON BASELINE FARE SCENARIO FINANCIAL ANALYSIS (WITH VESSEL REPOSITIONING)

Results from Discounted Cash Flow Analysis (Amounts and Percent Difference from Baseline)

Vessel Type	Baseline	Scenarios	
	Incat 72m	AMD K50	SLICE 600
Internal Rate of Return (IRR) ⁽¹⁾	15.00%	14.15%	no meaningful figure
Equity Investment - Vessel Purchase	-\$5,500,000	-\$6,000,000	-\$7,400,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	-\$3,804,200	-\$3,946,271	-\$2,564,847
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$9,821,928	-\$10,316,093	-\$13,084,645
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL OPERATING PROFILE			
Vessel Type	Incat 72m	AMD K50	SLICE 600
Passenger Capacity Per Vessel	325	400 (23.1%)	600 (84.6%)
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	75	89 (18.7%)	90 (20.0%)
Number of Vessels	2	2 (0.0%)	1 (-50.0%)
One-Way Vessel Travel Time	2 hrs, 55 min.	2 hrs, 44 min. (-6.3%)	3 hrs, 29 min. (19.4%)
Total Annual One-Way Vessel Trips Performed	2,688	2,688 (0.0%)	1,344 (-50.0%)
Annual Operating Hours per Vessel	3,920	3,674 (-6.3%)	4,682 (19.4%)
Adult One-Way Passenger Fare (including pfc's) ⁽³⁾	\$34.00	\$34.00 (0.0%)	\$34.00 (0.0%)
Total Annual One-Way Passenger Boardings	647,000	677,501 (4.7%)	471,508 (-27.1%)
Passenger Capacity Utilization Rate	74.1%	63.0% (-14.9%)	58.5% (-21.1%)
Automobile One-Way Fare	\$49.00	\$49.00 (0.0%)	\$49.00 (0.0%)
Total Annual One-Way Vehicle Boardings	143,810	149,050 (0.2%)	70,726 (-52.5%)
Vehicle Capacity (AEU) Utilization Rate	76.8%	68.5% (-10.7%)	60.2% (-21.5%)
ANNUAL VESSEL DEBT REPAYMENT			
Vessel Debt Repayment (combined principal and interest)	\$3,782,610	\$4,126,484 (9.1%)	\$2,544,665 (-32.7%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)			
Direct Operating Costs			
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$4,334,615	\$3,073,108 (-29.1%)	\$2,588,385 (-40.3%)
Vessel Fuel and Lubricants	\$5,461,304	\$6,985,870 (27.9%)	\$6,859,603 (25.6%)
Vessel Maintenance Costs	\$2,161,133	\$2,288,608 (9.9%)	\$1,585,356 (-26.6%)
Marine Hull Insurance	\$1,375,000	\$1,500,000 (9.1%)	\$925,000 (-32.7%)
Direct Operating Costs Subtotal	\$13,332,053	\$13,847,586 (3.9%)	\$11,958,344 (-10.3%)
Indirect Operating Costs			
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$1,319,231	\$1,236,308 (-6.3%)	\$900,308 (-31.8%)
Marketing and Advertising	\$1,383,346	\$1,435,008 (3.7%)	\$932,671 (-32.6%)
Reservations & Sales	\$972,655	\$1,006,650 (3.5%)	\$642,808 (-33.9%)
Docking Fees / Passenger Facility Charges / Shore Operations	\$677,000	\$707,501 (4.5%)	\$501,508 (-25.9%)
Protection and Indemnity (P&I) Insurance	\$194,100	\$203,250 (4.7%)	\$141,452 (-27.1%)
General Administration	\$6,342,750	\$5,594,387 (4.7%)	\$3,894,943 (-27.1%)
Outside Professional Services	\$643,518	\$673,617 (4.7%)	\$469,927 (-27.0%)
Onboard Food & Beverage Sales - Cost of Sales	\$2,102,750	\$2,201,880 (4.7%)	\$1,532,402 (-27.1%)
Gift Shop - Cost of Sales	\$373,450	\$914,627 (4.7%)	\$636,536 (-27.1%)
Onboard Gaming - Cost of Sales	\$808,750	\$846,877 (4.7%)	\$589,385 (-27.1%)
Indirect Operating Costs Subtotal	\$14,317,549	\$14,820,104 (3.5%)	\$10,241,941 (-28.5%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL REVENUES			
Passenger Fares	\$20,348,150	\$21,307,420 (4.7%)	\$14,828,932 (-27.1%)
Vehicle Fares	\$7,441,988	\$7,454,006 (0.2%)	\$3,537,019 (-52.5%)
Ancillary Sales - Onboard Food & Beverage Sales	\$3,235,000	\$3,387,507 (4.7%)	\$2,367,541 (-27.1%)
Ancillary Sales - Gift Shop Sales	\$1,941,000	\$2,032,504 (4.7%)	\$1,414,525 (-27.1%)
Ancillary Sales - Onboard Gaming	\$1,617,500	\$1,693,754 (4.7%)	\$1,178,770 (-27.1%)
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0 (n/a)	\$0 (n/a)
Total Revenues	\$34,583,638	\$35,875,191 (3.7%)	\$23,316,787 (-32.6%)
EQUILIBRIUM YEARS 3 THROUGH 15 NET CASH FLOW BEFORE TAXES			
Equilibrium Year 3 Net Cash Flow Before Taxes	\$3,151,426	\$3,081,018 (-2.2%)	-\$1,428,163 (-145.3%)

Notes:

"no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning

(1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.

(2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years.

Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years 3 through 15 are presented in the above summary of the discounted cash flow analysis.

(3) Passenger facility charges (pfc).

TABLE 12-10: MILWAUKEE - MUSKEGON PROFIT MAXIMIZING FARE SCENARIO (NO VESSEL REPOSITIONING)

Results from Discounted Cash Flow Analysis (Amounts and Percent Difference from Baseline)

Vessel Type	Baseline	Scenarios	
	Incat 72m	AMD K50	SLICE 600
Internal Rate of Return (IRR) ⁽¹⁾	15.00%	25.42%	no meaningful figure
Equity Investment - Vessel Purchase	-\$5,500,000	-\$6,000,000	-\$7,400,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	-\$4,451,576	-\$4,644,574	-\$2,913,544
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$11,756,733	-\$11,003,833	-\$14,668,836
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL OPERATING PROFILE⁽²⁾			
Vessel Type	Incat 72m	AMD K50	SLICE 600
Passenger Capacity Per Vessel	325	400 (23.1%)	600 (84.6%)
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	75	89 (18.7%)	90 (20.0%)
Number of Vessels	2	2 (0.0%)	1 (-50.0%)
One-Way Vessel Travel Time	2 hrs, 55 min.	2 hrs, 44 min. (-6.3%)	3 hrs, 29 min. (19.4%)
Total Annual One-Way Vessel Trips Performed	3,024	3,024 (0.0%)	1,512 (-50.0%)
Annual Operating Hours per Vessel	4,410	4,133 (-6.3%)	5,267 (19.4%)
Adult One-Way Passenger Fare (including pfc's) ⁽³⁾	\$34.00	\$49.00 (44.1%)	\$40.00 (17.6%)
Total Annual One-Way Passenger Boardings	757,100	589,043 (-22.2%)	470,245 (-37.9%)
Passenger Capacity Utilization Rate	77.0%	48.7% (-36.8%)	51.8% (-32.7%)
Automobile One-Way Fare	\$49.00	\$70.62 (44.1%)	\$57.65 (17.6%)
Total Annual One-Way Vehicle Boardings	174,133	129,589 (-25.6%)	70,537 (-59.5%)
Vehicle Capacity (AEU) Utilization Rate	79.8%	53.0% (-33.7%)	53.4% (-33.1%)
ANNUAL VESSEL DEBT REPAYMENT			
Vessel Debt Repayment (combined principal and interest)	\$5,673,915	\$6,189,725 (9.1%)	\$3,816,997 (-32.7%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)			
Direct Operating Costs			
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$4,876,442	\$3,457,246 (-29.1%)	\$2,911,933 (-40.3%)
Vessel Fuel and Lubricants	\$6,143,988	\$7,859,104 (27.9%)	\$7,717,053 (25.6%)
Vessel Maintenance Costs	\$2,286,900	\$2,417,184 (5.7%)	\$1,686,401 (-26.3%)
Marine Hull Insurance	\$1,375,000	\$1,500,000 (9.1%)	\$925,000 (-32.7%)
Direct Operating Costs Subtotal	\$14,682,310	\$15,233,534 (3.8%)	\$13,240,387 (-9.8%)
Indirect Operating Costs			
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$1,484,135	\$1,390,846 (-6.3%)	\$1,012,846 (-31.8%)
Marketing and Advertising	\$1,616,755	\$1,668,936 (4.3%)	\$1,059,471 (-34.6%)
Reservations & Sales	\$1,138,176	\$1,261,346 (10.8%)	\$754,222 (-33.7%)
Docking Fees / Passenger Facility Charges / Shore Operations	\$787,100	\$619,043 (-21.4%)	\$500,245 (-36.4%)
Protection and Indemnity (P&I) Insurance	\$227,130	\$176,713 (-22.2%)	\$141,074 (-37.9%)
General Administration	\$6,251,075	\$4,864,604 (-22.2%)	\$3,884,522 (-37.9%)
Outside Professional Services	\$752,062	\$586,266 (-22.0%)	\$468,675 (-37.7%)
Onboard Food & Beverage Sales - Cost of Sales	\$2,460,575	\$1,914,389 (-22.2%)	\$1,528,297 (-37.9%)
Gift Shop - Cost of Sales	\$1,022,085	\$795,208 (-22.2%)	\$634,831 (-37.9%)
Onboard Gaming - Cost of Sales	\$946,375	\$736,304 (-22.2%)	\$587,806 (-37.9%)
Indirect Operating Costs Subtotal	\$16,687,468	\$14,033,656 (-15.9%)	\$10,571,989 (-36.6%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL REVENUES			
Passenger Fares	\$23,810,795	\$26,698,369 (12.1%)	\$17,399,070 (-26.9%)
Vehicle Fares	\$8,708,531	\$9,340,080 (7.3%)	\$4,150,118 (-52.3%)
Ancillary Sales - Onboard Food & Beverage Sales	\$3,785,500	\$2,945,214 (-22.2%)	\$2,351,226 (-37.9%)
Ancillary Sales - Gift Shop Sales	\$2,271,300	\$1,767,128 (-22.2%)	\$1,410,735 (-37.9%)
Ancillary Sales - Onboard Gaming	\$1,892,750	\$1,472,607 (-22.2%)	\$1,175,613 (-37.9%)
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0 (n/a)	\$0 (n/a)
Total Revenues	\$40,468,876	\$42,223,399 (4.3%)	\$26,486,763 (-34.8%)
EQUILIBRIUM YEARS 3 THROUGH 15 NET CASH FLOW BEFORE TAXES			
Equilibrium Year 3 Net Cash Flow Before Taxes	\$3,425,183	\$6,766,484 (97.6%)	-\$1,142,610 (-133.4%)

Notes:
 "no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning.
 (1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.
 (2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years. Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years 3 through 15 are presented in the above summary of the discounted cash flow analysis.
 (3) Passenger facility charges (pfc)

**TABLE 12-11: MILWAUKEE - MUSKEGON PROFIT MAXIMIZING FARE SCENARIO
(WITH OFF-SEASON VESSEL REPOSITIONING)**

Results from Discounted Cash Flow Analysis (Amounts and Percent Difference from Baseline)

Vessel Type	Scenarios		
	Incat 72m	AMD K50	SLICE 600
Internal Rate of Return (IRR) ⁽¹⁾	15.00%	25.52%	no meaningful figure
Equity Investment - Vessel Purchase	-\$5,500,000	-\$6,000,000	\$7,400,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	-\$3,804,213	-\$3,969,145	-\$2,489,847
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$9,821,883	-\$9,122,763	-\$12,467,954
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL OPERATING PROFILE⁽²⁾			
Vessel Type	Incat 72m	AMD K50	SLICE 600
Passenger Capacity Per Vessel	325	400 (23.1%)	600 (84.6%)
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	75	89 (18.7%)	90 (20.0%)
Number of Vessels	2	2 (0.0%)	1 (-50.0%)
One-Way Vessel Travel Time	2 hrs, 55 min.	2 hrs, 44 min. (-6.3%)	3 hrs, 29 min. (19.4%)
Total Annual One-Way Vessel Trips Performed	2,688	2,688 (0.0%)	1,344 (-50.0%)
Annual Operating Hours per Vessel	3,920	3,674 (-6.3%)	4,682 (19.4%)
Adult One-Way Passenger Fare (including pfc's) ⁽³⁾	\$34.00	\$49.00 (44.1%)	\$40.00 (17.6%)
Total Annual One-Way Passenger Boardings	647,000	503,382 (-22.2%)	401,861 (-37.9%)
Passenger Capacity Utilization Rate	74.1%	46.8% (-36.8%)	49.8% (-32.7%)
Automobile One-Way Fare	\$49.00	\$70.62 (44.1%)	\$57.65 (17.6%)
Total Annual One-Way Vehicle Boardings	146,810	110,744 (-25.6%)	60,279 (-59.5%)
Vehicle Capacity (AEU) Utilization Rate	76.8%	50.9% (-33.7%)	51.3% (-33.1%)
ANNUAL VESSEL DEBT REPAYMENT			
Vessel Debt Repayment (combined principal and interest)	\$3,782,610	\$4,126,484 (9.1%)	\$2,544,665 (-32.7%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)			
Direct Operating Costs			
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$4,334,615	\$3,073,108 (-29.1%)	\$2,588,385 (-40.3%)
Vessel Fuel and Lubricants	\$5,461,304	\$6,985,870 (27.9%)	\$6,859,603 (25.6%)
Vessel Maintenance Costs	\$2,161,133	\$2,288,608 (9.9%)	\$1,585,356 (-26.6%)
Marine Hull Insurance	\$1,375,000	\$1,500,000 (9.1%)	\$925,000 (-32.7%)
Direct Operating Costs Subtotal	\$13,332,053	\$13,847,586 (3.9%)	\$11,958,344 (-10.3%)
Indirect Operating Costs			
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$1,319,231	\$1,236,308 (-6.3%)	\$900,308 (-31.8%)
Marketing and Advertising	\$1,383,350	\$1,443,325 (4.3%)	\$905,399 (-34.8%)
Reservations & Sales	\$972,659	\$1,077,917 (10.8%)	\$644,540 (-33.7%)
Docking Fees / Passenger Facility Charges / Shore Operations	\$677,000	\$533,382 (-21.2%)	\$431,861 (-36.2%)
Protection and Indemnity (P&I) Insurance	\$194,100	\$151,015 (-22.2%)	\$120,558 (-37.9%)
General Administration	\$5,342,750	\$4,157,904 (-22.2%)	\$3,320,349 (-37.9%)
Outside Professional Services	\$643,518	\$501,509 (-22.1%)	\$400,837 (-37.7%)
Onboard Food & Beverage Sales - Cost of Sales	\$2,102,750	\$1,635,993 (-22.2%)	\$1,306,047 (-37.9%)
Gift Shop - Cost of Sales	\$873,450	\$679,568 (-22.2%)	\$542,512 (-37.9%)
Onboard Gaming - Cost of Sales	\$808,750	\$629,228 (-22.2%)	\$502,326 (-37.9%)
Indirect Operating Costs Subtotal	\$14,317,558	\$12,046,146 (-15.9%)	\$9,074,736 (-36.6%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL REVENUES			
Passenger Fares	\$20,348,150	\$22,815,803 (12.1%)	\$14,868,840 (-26.9%)
Vehicle Fares	\$7,442,108	\$7,981,815 (7.3%)	\$3,546,594 (-52.3%)
Ancillary Sales - Onboard Food & Beverage Sales	\$3,235,000	\$2,516,912 (-22.2%)	\$2,009,303 (-37.9%)
Ancillary Sales - Gift Shop Sales	\$1,941,000	\$1,510,147 (-22.2%)	\$1,205,582 (-37.9%)
Ancillary Sales - Onboard Gaming	\$1,517,500	\$1,258,456 (-22.2%)	\$1,004,651 (-37.9%)
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0 (n/a)	\$0 (n/a)
Total Revenues	\$34,583,758	\$36,083,132 (4.3%)	\$22,634,970 (-34.6%)
EQUILIBRIUM YEARS 3 THROUGH 15 NET CASH FLOW BEFORE TAXES			
Equilibrium Year 3 Net Cash Flow Before Taxes	\$3,151,536	\$6,062,916 (92.4%)	-\$942,775 (-129.9%)

Notes:

"no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning.

(1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.

(2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years.

Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years

3 through 15 are presented in the above summary of the discounted cash flow analysis.

(3) Passenger facility charges (pfc).

As can be seen in Table 12-10, somewhat higher fare levels result in a greater internal rate of return of 25.42% for the AMD K50. The internal rate of return for the SLICE 600 still yields no meaningful figure, however the annual net cash flow for years 3 through 15 for the SLICE 600 is increases somewhat from a deficit of \$1.7 million to a deficit of \$1.1 million.

12.9 Conclusions

The SLICE 600 is not profitable under any of the scenarios considered, including those in which the vessel would be repositioned in the off-season. Also, the deep draft of the SLICE 600 would likely limit opportunities for repositioning in the off-season, if this approach were to be pursued by the operator of the Milwaukee to Muskegon route. The deep draft of the SLICE 600 would also result in unacceptable or marginally acceptable operating conditions in both Milwaukee Harbor and Muskegon Harbor. The SLICE 600, with its 21.5 foot main vehicle freeboard height, also would not interface adequately with the planned ferry terminal facilities. There would be relatively little additional ridership due to the superior seakeeping ability of SLICE because of the relatively benign sea state conditions encountered in this region. The single SLICE 600, offering three round trips daily, would provide service less frequently than the two smaller baseline Incat 72 meter WPC vessels. No tractor trailers could be accommodated on the SLICE 600, or any of the other comparative high speed vessels including the baseline 72 meter WPC. The operating speed restrictions in both Milwaukee Harbor and Muskegon Harbor work slightly to the advantage of the SLICE 600, since this prevents the baseline and comparative high speed vessels from obtaining any travel time advantage on these portions of the route. Repositioning of the vessel or vessels in either the baseline case or the other scenario cases including SLICE helps somewhat, but the increase in profit resulting from this is relatively small.

Chapter 13: Case Study #5 – Florida Keys (Miami – Key West)

The ferry route reviewed in this case study is a proposed new high speed service that would operate between Miami and Key West, Florida, a route length of 168 nautical miles. A variety of different proposals have been advanced during the last two years for both high speed and conventional ferry services within, to or from the state of Florida. Some of these services, which are described later, have been recently implemented. The most recent proposal for service between Miami and Key West, utilizing a high speed RoPax catamaran, is the focus of this case study.

13.1 Introduction and Regional Overview

The area reviewed in this case study extends south from Broward and Dade counties in the state of Florida, continuing south and west along the Florida Keys in Monroe County to Key West (see Figure 13-1). This region of Florida including Broward, Dade and Monroe counties is collectively referred to here as South Florida. Major cities and metropolitan areas in the region include Miami, Fort Lauderdale, and in the Florida Keys, major communities include Key Largo, Marathon and Key West.

FIGURE 13-1: SOUTH FLORIDA POPULATION DISTRIBUTION (1997) AND EXISTING & PROPOSED FERRY ROUTES

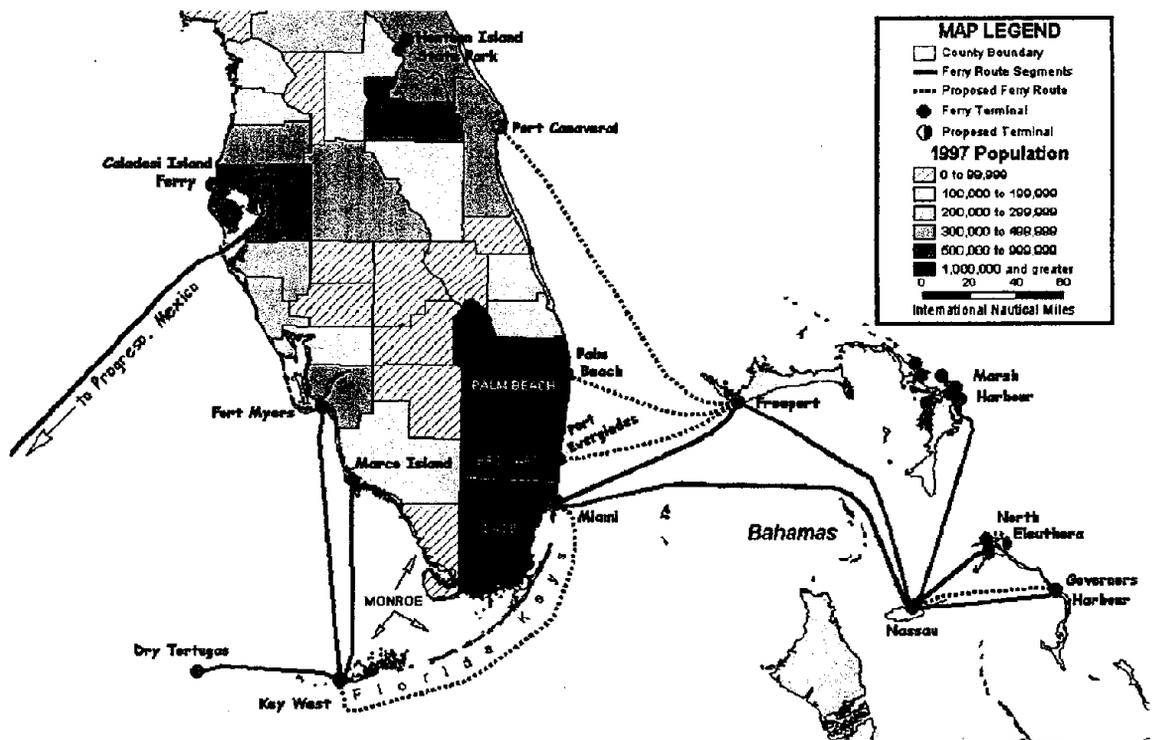
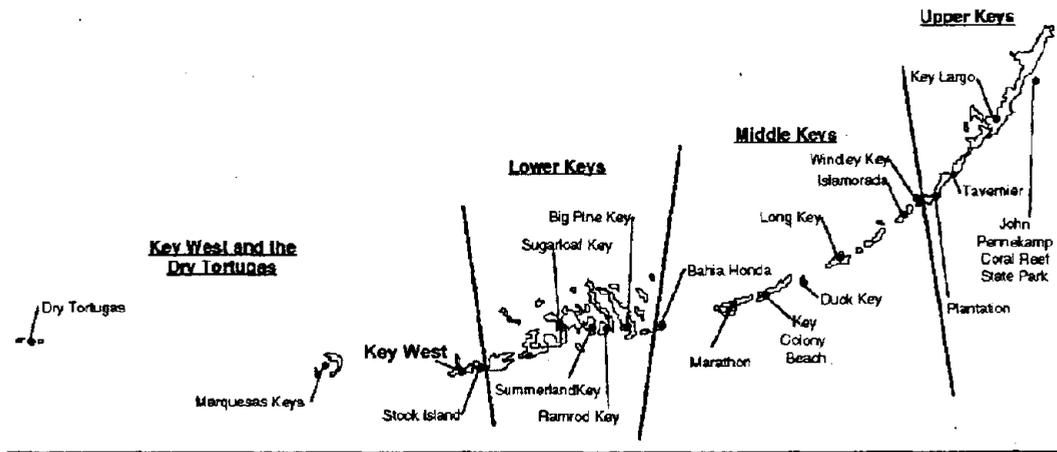


FIGURE 13-2: THE FLORIDA KEYS AND KEY WEST



The Florida Keys area of South Florida consists of a chain of low lying islands, beginning with Virginia Key and extending in a circular sweep to Loggerhead Key, a distance of about 192 miles (see Figure 13-2). For some 100 miles of that distance they skirt the southeast coast of the Florida Peninsula, from which they are separated by shallow bodies of water known as Biscayne Bay, Card Sound, Barnes Sound, Blackwater Sound, and Florida Bay. The Keys are mostly of coral formation, low, and generally covered with dense mangrove growth, though some are wooded with pine, and on a few are groves of coconut trees. The Keys are accessible from the Florida Peninsula via U.S. Route 1, also known as the Overseas Highway, a mostly two lane highway extending a total of 113 miles from Dade County. With 42 bridges spanning the gaps between the islands, U.S. Route 1 was completed in 1938, largely following the route of the former Florida East Coast Railroad, which extended to Key West in 1912, but ceased operations in 1935 following extensive hurricane damage. Most of the Keys that are connected by U.S. Highway 1 to Key West are inhabited. Key West, with an area of approximately 5.5 square miles, had a 1997 resident population of approximately 25,800, or about 29% of the entire 1997 population of the Florida Keys total of 87,000.

Historically, the economy of South Florida has been strongly influenced by tourism and national and international immigration. Like many areas of the United States, the economy continues to become more service oriented with less of an emphasis on manufacturing industries. Overall, service sector employees represent 40% of the total labor force in the region, with manufacturing sector employees representing only 9% and the retail trade sector about 24%.¹³¹ In recent years, the region has experienced an increase in international trade, with the area well positioned for trade with Central and South America and the Caribbean Basin. Agriculture, which had been an important sector of the economy in southern Dade County, was set back by damage received from Hurricane Andrew in 1992, and is under increasing pressure from urban and suburban development.

One of the most important forces shaping the character of South Florida has been population growth. From only 176,000 residents in 1930, the population of the region grew to 1.3 million by 1960, 3.27 million by 1990, and 3.62 million by 1997 (see Table 13-1).¹³² The three counties of South Florida alone currently represent almost 25% of the entire population of the state of Florida, which in 1997 was 14,654,000 persons.¹³³ By 1997, the population of Dade county alone had reached just over two million residents, and by 2005 the regional popula-

¹³¹ U.S. Department of Commerce, Bureau of the Census. *1996 County Business Patterns for Florida*.

¹³² South Florida Regional Planning Council. *Regional Profile and Identity*.

¹³³ U.S. Department of Commerce, Bureau of the Census.

tion of South Florida is forecast to exceed 3.8 million.¹³⁴ Throughout the region, approximately 80% of the population of South Florida lives within 10 miles of the coast. In 1990, the region had approximately 544,000 residents who were 65 years old or over, or about 17% of the total regional population at that time. This compares to only 13% of the population nationally in this age group. In 1990, nearly one of every five South Florida residents was not fluent in English (with Spanish being the predominant foreign language spoken), nearly three times the national average.

TABLE 13-1: SOUTH FLORIDA POPULATION AND PROJECTIONS

Year	County			South Florida Regional Total	State of Florida Total
	Broward	Dade	Monroe		
1980	1,018,000	1,626,000	63,000	2,707,000	9,747,000
1990	1,256,000	1,937,000	78,000	3,271,000	12,938,000
1997	1,448,000	2,089,775	87,000	3,624,775	14,653,945
2000	1,456,000	2,115,000	90,000	3,661,000	15,449,000
2005	1,553,000	2,231,000	96,000	3,880,000	16,742,000

Sources:

(1) U.S. Department of Commerce, Bureau of the Census.

(2) Bureau of Economic and Business Research, Projections of Florida Population by County, 1993-2020.

In Monroe County, virtually the entire population is located in the Florida Keys, with Everglades National Park extending across most of the mainland portion of Monroe County on the Florida Peninsula. The limited availability of land in the Florida Keys has tended to suppress population growth rates in this area relative to the rest of the South Florida region.

In addition to a large and growing resident population in South Florida, tourism is the state of Florida's largest industry, with 47 million domestic and international visitors to the state in 1997, approximately 25% of which visited the South Florida region.¹³⁵ There were more than 3 million person trips to the Florida Keys and Key West between June 1995 and May 1996, with 43% of these person trips being made to Key West, followed by the Upper Keys (27%), the Middle Keys (21%) and the Lower Keys (9%).¹³⁶

13.2 Ferry Market Overview and Operational Profiles

A number of ferry routes of interest operated historically in the case study region, but are no longer in service. During three winter seasons between late 1995 and early 1998, the 27 meter catamaran *Miss Barnegat Light*, built in 1973 by Breaux's Bay, was operated in common carrier passenger service between Fort Myers and Key West, a route 117 nautical miles in length.¹³⁷ This passenger-only vessel has a certificated capacity of 149 persons, but is configured for a practical passenger capacity of 100 persons. In 1996, the vessel was outfitted with new more powerful Detroit Diesel MTU 16V 2000 diesel engines, increasing its service speed by about 5 knots to 26 knots.^{138,139} The typical service schedule included a single round trip daily, with a travel time of approxi-

¹³⁴ Bureau of Economic and Business Research. *Projections of Florida Population by County, 1993-2020*.

¹³⁵ Florida Tourism Industry Marketing Association (Visit Florida). *1997 Florida Visitor Study*. Page ii. Page 39. 32.8% of total visited a seven county region including Dade, Broward, Palm Beach, Monroe, Glades, Hendry, and Martin counties. 25% of total is estimate for the three county South Florida Region only.

¹³⁶ Leeworthy, Vernon R., and Peter C. Wiley. *Linking the Economy and Environment of Florida Keys/Florida Bay. Visitor Profiles: Florida Keys / Key West* November 1996. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. Page 7.

¹³⁷ Telephone contact, Captain John Larson, *Miss Barnegat Light*, August 10, 1999.

¹³⁸ Fast Ferry International Operators Directory. 1997. Page 33.

mately five hours in each direction, and a five hour stopover in Key West. The route was very successful in terms of ridership, with demand consistently strong according to the former operator, and service was discontinued largely for personal rather than business reasons.¹⁴⁰ Total annual patronage on this route is estimated at approximately 18,000.¹⁴¹

In the late 1960's, the Grumman Aircraft Engineering Corporation, working with Garrett Corporation, ordered two "Dolphin Class" passenger hydrofoils from a German shipyard.¹⁴² The one vessel that was completed was configured for 88 passengers, was 22.8 meters in length, with a draft of 13.5 feet with the foils deployed, and a service speed of 50 knots. A second vessel which was never completed was configured for 110 passengers. The first vessel, then named the "Gulf Stream," was chartered by the U.S. company Bahama Hydro Lines, Ltd., and placed into service on the 95 nautical mile long route between Miami and Freeport in February 1969. The operating schedule consisted of two round trips daily, with departures from Miami at 9:00AM and 2:00PM, and departures from Freeport at 11:30AM and 4:30PM, with an actual travel time of about 1 hour and forty minutes one-way, with a built in allowance to provide for additional passenger comfort while crossing the Gulf Stream. In 1969, the fare was \$27.50 round trip or \$17.50 one-way, with discounts for children, and the operation was planned for a breakeven load factor of 30%. The service was planned largely for day trips and overnight trips, and proved to be popular with demand exceeding the breakeven load factor when the vessel ran. However, too many trips had to be cancelled due to poor weather, and adverse Gulf Stream conditions, when northerly winds interact with the current to form sizeable waves. As a result, passenger ride quality and operational availability suffered, so much so that for a time, it became practice for the ferry operator to hire a helicopter so that the ferry captain could observe the route conditions first hand before deciding whether to depart. The service acquired a reputation for poor reliability, and ultimately, the number of cancelled trips, particularly during the peak demand winter months, prevented the service from being a success, and the service was cancelled after only several weeks of operations.

From 1968 to 1970, Wetermoen Hydrofoil A/S of Norway built three PT 150 hydrofoils, one of which was later acquired via a bareboat charter arrangement by Bahamas Hydrofoil Cruises, Inc., and placed into service in April 1978 between Miami and Freeport, Grand Bahama, and Fort Lauderdale and Freeport. The service from Miami discontinued after only one month because of unsuitable terminal facilities and the longer distance to Freeport than the service from Fort Lauderdale. The vessel was configured for 200 passengers, and was 37.86 meters in length, with a draft of 18 feet and a service speed of 36.5 knots.¹⁴³ The operating schedule consisted of one round trip per day on Mondays, Thursdays, Fridays, Saturdays and Sundays, with morning departures from Fort Lauderdale and afternoon departures from Freeport. In 1977 dollars, fares were \$54.95 round trip and \$29.95 one-way for economy class seating below deck, and \$64.95 round trip and \$34.95 one-way for seating on the main deck, with discounts for children. Terminal facilities were leased in both Fort Lauderdale and Freeport. Despite planning based on previous experience with hydrofoil vessels in Florida - Bahamas service, the vessel were not well suited to the Gulf Stream current, where waves up to ten feet high were sometimes experienced. This adversely affected passenger comfort and operational reliability, and as a result, service was suspended in April 1979.

Finally, in addition to the former ferry services reviewed above, in the 1950's there were numerous ferries operating between points in Florida (including Key West) and Cuba.¹⁴⁴ These services have been prohibited, how-

¹³⁹ *Fast Ferry International*. January-February 198. Page 63.

¹⁴⁰ Telephone contact, Captain John Larson, Miss Bamegart Light, August 10, 1999.

¹⁴¹ Assumes an operating season of November through March, with operations six days per week, a single round trip daily, and an average of 75 persons per one-way trip.

¹⁴² Existing and Former High Speed Waterborne Passenger Transportation Operations in the United States. U.S. Department of Transportation, Urban Mass Transit Administration. August, 1984. Report # UMTA-IT-32-0001-84-3. Pp. II.31 - II.33.

¹⁴³ Existing and Former High Speed Waterborne Passenger Transportation Operations in the United States. U.S. Department of Transportation, Urban Mass Transit Administration. August, 1984. Report # UMTA-IT-32-0001-84-3. Pp. II.42 - II.44.

¹⁴⁴ Cottrill, Ken. "Invitation to Cuba." *Traffic World*. December 14, 1998. Page 31.

ever, for nearly forty years by the U.S. trade embargo with Cuba. Recently, proposals for high speed ferry service between non-U.S. countries (such as Mexico) and Cuba have been under consideration by foreign operators and the Cuban government.

13.2.1 Current Routes

Despite the failure or suspension of service on the former routes mentioned above, a number of conventional and high speed ferry routes continue to serve several ports of call in the region, with some of these services introduced only during the last one to two years.

Seasonal service is operated from October to early April on two routes between Palm Grove Marina in Fort Myers and Key West, and between Factory Bay Marina on Marco Island (about 33 miles south of Fort Myers) to Key West, by *Key West Shuttle*. Two passenger-only vessels each operate one daily round trip: the *Whale Watcher*, 128 feet in length capable of 38 knots, and the *Capt. Red.*, 110 feet in length and capable of 25 knots. The *Whale Watcher* operates on the 133 nautical mile route between Fort Myers and Key West, with a total one-way travel time of about 4 hours at a service speed of approximately 33 knots. The *Capt. Red* operates on the 90 nautical mile route between Marco Island and Key West, with a total one-way travel time of about 3 hours and 45 minutes at a service speed of approximately 24 knots. Round trip fares on both routes are \$89.00 per passenger. Based on information obtained from the operator, annual ridership on both routes for the 1998-99 operating season is estimated at 24,000 passenger boardings. During the summer, these vessels are repositioned to New England and operated as whale watch and excursion vessels.

Although best characterized as an excursion service, the ferry service operated between Key West and Dry Tortugas National Park is briefly reviewed here since it is an itinerant ferry service operating from Key West, and currently utilizes a newly acquired medium to high speed passenger-only catamaran. Operated since 1977 by Yankee Fleet, this service is currently served by the catamaran *Yankee Freedom II*, which was launched by Gladding-Hearn Shipbuilding, the Duclos Corporation, of Somerset, Massachusetts in February 1999 and put into service between Key West and Dry Tortugas National Park during March 1999. This vessel is a 28 meter medium speed catamaran with Z-bow hulls, with a total passenger capacity of 250 (125 exterior seats, and 125 interior seats). The vessel operates a single round trip daily on the 63 nautical mile route at a speed of up to 26 knots, for a total one-way travel time of 2.5 hours from Key West to the boundary of the national park. Adult fares are \$95.00 round trip, with discounts for senior citizens, students, and children.

During the winter of 1998-99, Bay Ferries Ltd. of Canada introduced high speed passenger and vehicle ferry between Miami and Nassau on New Providence Island in the Bahamas, and between Miami and Freeport on Grand Bahama Island in the Bahamas. These routes serve more than 80% of the total 1996 population of the Bahamas of 284,000, with 191,500 residents (67%) on New Providence Island where Nassau is located, and an additional 41,000 residents (16%) on Grand Bahama Island, where Freeport is located. Operated during the winter season, these routes are served by *The Cat*, a 91 meter high speed RoPax catamaran designed and built by Incat in Australia. Launched in September 1997, this vessel was first introduced into North American service during the 1998 summer season on the route between Bar Harbor, Maine and Yarmouth, Nova Scotia operated by Bay Ferries, Ltd., of Canada. *The Cat* has a passenger capacity of 877 persons, a vehicle capacity of 240 automobile equivalent units (AEU) or a combination of automobiles and up to four motorcoaches, and a service speed of 43 knots. On the 184 nautical mile route between Miami and Nassau, total one-way trip time is 5 hours. Adult fares during 1999 on this route were \$119 roundtrip, with discounts for children, plus an additional \$20 per person for passenger facility charges and U.S. and Bahamian departure taxes. Service is provided on Sunday, Monday, Wednesday and Friday on this route, departing from Terminal 12 at the Port of Miami at 9:00AM and arriving in Nassau at 2:00PM, and then departing Nassau at 4:30PM and arriving back in Miami at 9:30PM. On the 92 nautical mile route between Miami and Freeport, total one-way trip time is 2.5 hours. Fares during 1999 on this route were \$99 roundtrip, with discounts for children, plus an additional \$20 per person for passenger facility charges and U.S. and Bahamian departure taxes. Service is provided on Tuesday, Thursday

and Saturday on this routes, departing from Terminal 12 at the Port of Miami at 9:00AM and arriving in Freeport at 11:30AM, and then departing Freeport at 4:30PM and arriving back in Miami at 6:30PM. On both routes, proof of citizenship in the form of a passport or a driver's license and birth certificate is required to enter the Bahamas and upon return to the U.S.. Also, automobiles are accommodated on both routes, however the vehicle service is focused primarily on the one-way shipment of vehicles, with a substantial one-way automobile fare of \$450.

Other ferry services in the Bahamas connect Freeport with Nassau, and Nassau with North Eleuthera (Gene's Bay and Harbour Island) and Abaco Island (Marsh Harbour). One of these services, serving two routes from Nassau to Eleuthera Island, was just introduced during the summer of 1999 by Bahamas Fast Ferries, and uses a 35 meter high speed passenger catamaran launched in June 1999 by the Pequot River Shipyard in New London, Connecticut. This vessel has a passenger capacity of 177 persons, and a service speed of 35 knots, and was introduced into service during July 1999.

The final existing ferry service reviewed here is a service that operated briefly between Tampa, Florida and Progreso, Yucatan in Mexico, a distance of 564 nautical miles. Service was operated during late 1998 twice weekly by American Viking Lines, with overnight service every Tuesday and Friday, departing from the Berth 202 Cruise Terminal in Tampa on Friday evening and Tuesday morning, and departing from Progreso on Sunday night and Wednesday night. The one-way trip time was 36 hours, and round trip fares were \$144 per person, double occupancy, and \$199 for vehicles.

The *Scotia Prince*, a conventional monohull RoPax ferry with a passenger capacity of 630 persons and a vehicle capacity of 220 AEU, was chartered by American Viking Lines from Prince of Fundy Cruises, who normally operates the vessel between Portland, Maine and Yarmouth, Nova Scotia on overnight cruises during the summer season from early May to late October. Although originally chartered for the 1998-99 winter season through April 15, 1999, only 16 round trip voyages were completed during November and December 1998 before service was discontinued because of financial difficulties. Reportedly, the service was about four weeks away from being financially self sufficient when the primary investor backed out. Despite a late marketing effort, passenger demand on the service was ranging between 80% to 90% of capacity when service was discontinued.

During the spring and summer of 1999, a new management group was, however, pursuing other options, including the charter or purchase of a different vessel. One vessel under consideration is the Vana Tallinn, a 168 meter RoPax vessel operating in the Baltic Sea, with a capacity of 800 passengers and 300 AEU, or a mix of automobiles and up to 40 tractor trailers. This vessel was reportedly available for charter beginning in September 1999. Service could resume on this route sometime during the fall of 1999.

13.2.2 Proposed New Routes

In 1997, Buquebus Florida (a U.S. subsidiary of the South American ferry operator Buquebus) proposed the introduction of service between Fort Myers and Key West, using a 45 meter high speed passenger-only catamaran designed by Nigel Gee and Associates. This vessel, launched in late 1998, is powered by two Detroit Diesel TF80 gas turbine powerplants, with a total passenger capacity of 300 persons. With a full load service speed of up to 50 knots, the one-way travel time on the 117 nautical mile route would have been approximately 3 hours or less. Prior to the introduction of service on the Fort Myers to Key West route, however, the U.S. authorities determined that the U.S. ownership credentials of the operator were not satisfactory, and withheld permission for the introduction of the ferry on the domestic U.S. route.¹⁴⁵

¹⁴⁵ "Derecktor Shipyard delivers first NGA 45m catamaran." *Fast Ferry International*. January-February 1999. Page 21.

The introduction of new high speed ferry service between Tampa and Key West has also been recently proposed. No details could be obtained regarding this proposed service, however, and current information suggests that this proposal is no longer being seriously considered.¹⁴⁶

Beginning during the fall of 1999, two U.S. made Boeing 929 JetFoil, the *SeaJet Kara* and the *SeaJet Kristen*, are set to begin service on the 76 nautical mile route between Palm Beach, Florida and Freeport, Grand Bahama Island. The Palm Beach based operator, *SeaJets*, anticipates annual earnings of approximately \$9 million. Each vessel is 29 meters in length, has a passenger capacity of 250 persons and a service speed of 43 knots. Initially, service will be provided Thursday through Monday, will departures from Palm Beach at 9:00AM and 4:30PM, and departures from Freeport at 11:10AM and 6:40PM. One-way trip time is planned at 1 hour and 40 minutes, and adult round trip fares will be \$99, with a discount for children, plus arrival and departure taxes of \$25. Eventually, plans are for up to four or five trips daily. Based on experience with the operation of hydrofoils between Florida and the Bahamas during the late 1960's and late 1970's as noted earlier, difficulties with ride quality and operational reliability resulting from Gulf Stream related seakeeping issues are likely to be encountered.

In addition to the above proposal for service between Florida and the Bahamas, two additional routes are also being proposed by Fast Ferry Ltd. (d.b.a. Boomerang Fast Ferry), of Fort Lauderdale, Florida, with service to begin in the fall of 1999. Service is planned on two routes, the first on the 81 nautical mile route between Fort Lauderdale and Freeport, Grand Bahama Island, and the second on the 162 nautical mile route between Port Canaveral and Freeport. Boomerang Fast Ferry plans to offer year-round service, with one round trip daily Monday through Thursday on the Port Canaveral to Freeport route, and one round trip daily on Friday and Sunday, and two round trips on Saturday, on the Port Everglades to Freeport route. Although published fares were not available as of late summer 1999, based on the other existing and proposed high speed ferry services between Florida and the Bahamas, it is estimated that an adult round trip fare on the Fort Lauderdale to Freeport route would be approximately \$100, with discounts for children, plus passenger facility charges and departure taxes. On the Port Canaveral to Freeport route, the adult round trip fare is estimated at \$120, with discounts for children, plus passenger facility charges and departure taxes. To service these routes, Boomerang Fast Ferry has chartered a 74 meter RoPax wave piercing catamaran from Tranz Rail, an operator in New Zealand. The *Condor 10* has a service speed of 39 knots, a passenger capacity of 600 persons, and a vehicle capacity of 84 AEU, or a mix of automobiles and up to two motorcoaches. Detailed particulars for this vessel are presented later in this chapter.

In addition to these two proposed routes between Florida and the Bahamas, Boomerang Fast Ferry is also proposing to introduce high speed ferry service between Miami and Key West sometime during late 2000 or 2001. It is this proposal that is the focus of the current case study and the remainder of this chapter.

Between 1995 and 1999, service proposals for this new route were modified significantly on a number of occasions. In October 1995, an application for a U.S. Maritime Administration (MARAD) Title XI loan guarantee was submitted by the proposed prospective vessel owner, Mersea Ships I, Inc.. This application was subsequently approved on August 18, 1997, granting a "letter of commitment" for 87.5% of the total estimated project cost of \$34.17 million. The next step of the loan guarantee process, known as the "guarantee closing," was contingent upon the remaining 12.5% of the estimated project cost being provided by the proposed ship owner. However, after approximately 15 months had passed from the granting of the letter of commitment, these funds were not forthcoming from the prospective ship owner, and in January 1999, MARAD cancelled the letter of commitment for this particular project proposal.

Under this original proposal, service was to have been operated for Mersea Ships by New SeaEscape Ltd. of Key West, using two passenger-only SWATH vessels. The two vessels were a SWATH International, Ltd., 4000 Class design, with a length of 34 meters, beam of 16.1 meters, a draft of 10.4 feet, and a passenger capacity of 300 persons with a service speed of 27 knots. Bollinger Shipyards in Lockport, Louisiana, was to have

¹⁴⁶ U.S. Department of Transportation, Maritime Administration, Title XI application.

been the builder. The planned one-way trip time between Miami and Key West with the SWATH vessels was just over 6 hours, at a service speed of 27 knots over the 168 nautical mile route distance. Service was to have been offered year-round, with one round trip daily per vessel. The original market study conducted by Mersea Ships for the MARAD Title XI application indicated that there was strong demand for ferry service in this market, with a potential requirement for up to 12 similar vessels in the Fort Lauderdale/Miami to Key West market. Despite this, Mersea Ships ultimately concluded that a number of factors worked against the successful application of SWATH vessels on this route. These factors included the excessive trip time on this relatively long distance route, high operating costs due to the higher fuel consumption rates of SWATH vessels, and a relatively benign wave climate, which would not allow the superior seakeeping abilities of SWATH vessels to be realized. Wave climate studies completed by the original applicant indicated that significant wave heights in excess of 3.5 meters (11.4 feet) are experienced less than 3.5% of the time in this area. This is generally consistent with the findings of the Volpe Center wave climate analysis for this area, presented later in this chapter.

With the proposal for SWATH ferry service between Miami and Key West cancelled, in January 1999 some participants from this cancelled SWATH service proposal modified the original Title XI application, this time proposing the use of a high speed RoPax catamaran to service the Miami to Key West route.

The modified January 1999 Title XI application indicates that Boomerang Fast Ferry plans to acquire an 80 meter AMD K50 high speed RoPax catamaran to service this route. Although Boomerang Fast Ferry is currently planning to charter the 74 meter Incat catamaran *Condor 10* for use on its routes between Florida and the Bahamas, the Jones Act prohibits this foreign built and foreign owned vessel from being utilized on the U.S. domestic route between Miami and Key West. The AMD K50 for this route is arranged to accommodate 400 passengers, with a vehicle capacity of 89 AEU, or a mix of automobiles and up to four motorcoaches. Normal service speed is 45 knots. Detailed particulars for this vessel are presented later in this chapter. At a 45 knot service speed, the AMD K50 would have a total one-way travel time of 4 hours on the 168 nautical mile Miami to Key West route, 2 hours less than the 6 hour one-way travel time of the original SWATH proposal.

Service would be provided year-round, with one round trip daily. Based on the operating schedule of the other existing and proposed ferry services to Key West, and from Florida to the Bahamas, the operating schedule for this service would likely include a 9:00AM departure from Miami, with a 1:00PM arrival in Key West, followed by a 4:00PM departure from Key West with an arrival back in Miami at 8:00PM. Although published fares were not yet available for this proposed route, based on the other existing and proposed high speed ferry services in the region between Florida and the Bahamas, and between Fort Myers and Key West, it is estimated that an adult round trip fare on the Miami to Key West route would be approximately \$120, with discounts for children, plus passenger facility charges and departure taxes.

13.3 Proposed Vessels

Based on information presented in the modified January 1999 Title XI application for the proposed Miami to Key West route, the AMD K50 RoPax catamaran is selected here as the baseline vessel type. A 74 meter Incat RoPax catamaran, based on the *Condor 10*, is also reviewed as a comparative high speed vessel type. However, as noted earlier, despite the fact that Boomerang Fast Ferry is currently planning to charter the *Condor 10* for use on its routes between Florida and the Bahamas, the Jones Act prohibits the *Condor 10* from being utilized on the U.S. domestic route between Miami and Key West. The SLICE 600 is selected as the primary SLICE variant for this case study, primarily because it is a RoPax design, and is of a generally similar passenger and vehicle capacity as the baseline and comparative high speed vessels. Finally, the SLICE 400 passenger-only variant is also selected as a secondary SLICE variant for this case study, primarily because the SLICE 400 is generally similar to the passenger-only SWATH vessels that were originally proposed for this route.

Vessel particulars for the AMD K50 catamaran, Incat 74 WPC (meter wave piercing catamaran), SLICE 600 and the SLICE 400 are presented in Table 13-2. The AMD K50 is an aluminum hulled 80 meter high speed conventional catamaran, with a typical capacity of 400 passengers and 89 automobiles, or a combination of up to 4 motorcoaches and 46 automobiles. Although generally referred to as the AMD K50, Incat is also jointly involved in the design of the K50, with AMD responsible for the design of the main structure and propulsion system, while Incat is responsible for the design of the superstructure and engineering. The first AMD K50 to be built was delivered to the Dae A Gosh Ferry Company in South Korea in 1995 by Incat Tasmania. An additional three K50 vessels are to be built under license in China by Afai Ships. The first of these three, designated *Afai08*, was launched in mid 1998. Powered by four marine diesel engines, the AMD K50 has a service speed of 45 knots. Passengers are accommodated on a single passenger deck, divided into two lounge areas with a bar

TABLE 13-2: FLORIDA KEYS CASE STUDY - VESSEL PARTICULARS

Particulars	Baseline Vessels		SLICE Variants	
	AMD K50 ⁽¹⁾	Incat 74m ⁽²⁾	SLICE 600 ⁽³⁾	SLICE 400 ⁽⁴⁾
Vessel Designer	Advanced Multihull Designs / Incat	Incat	Lockheed Marine Systems	Lockheed Marine Systems
Vessel Type	RoPax	RoPax	RoPax	Passenger-Only
Hull Construction	Aluminum	Aluminum	Steel	Aluminum
Purchase Price (1997 US\$)	\$30,000,000	\$28,900,000	\$37,000,000	\$12,000,000
Annual Maintenance Cost ⁽⁵⁾	\$1,050,000	\$1,011,500	\$1,295,000	\$420,000
Principal Dimensions (feet)				
Length Overall	262.7	243.2	213.2	111.5
Beam Overall	62.3	85.3	105.0	61.0
Full Load Draft	7.1	9.6	28.5	15.0
Main Passenger Deck Freeboard	21.0	data not available	31.0	11.8
Vehicle Deck Freeboard	11.0	data not available	21.5	n/a
Capacities				
Passenger Capacity	400	597	600	400
Vehicle Capacity (AEU) ⁽⁶⁾	89	84	90	n/a
Fuel Capacity (gallons)	12,680	10,087	39,087	5,837
Vessel Manning				
Deck Crew Officers	2	2	2	2
General Deck Crew	4	5	5	3
Engineering Officers	1	2	2	1
Engine Crew	2	3	3	0
Onboard Passenger Service	7	8	8	4
Total Crew Complement	16	20	20	10
Weights (long tons)				
Payload	138.9	154.6	177.9	28.6
Total Deadweight	174.0	199.0	355.0	47.1
Displacement	612.0	700.0	1,500.0	220.0
Propulsion				
Main Engines	(4) Ruston 16 RK270 marine diesel engines	(4) Ruston 16 RK270 marine diesel engines	(2) RLM1600 gas turbines or equivalent	(2) TF40 gas turbines
Total Installed Horsepower	29,476	22,025	36,000	6,800
Service Speed (knots)	45	39	30	30
Range at Service Speed (nmi)	390	390	620	340
Fuel Consumption (gallons per hour at indicated speed)				
GPH at service speed	1,439	993	1,891	502
GPH at 30.0 knots	590	557	1,891	502
GPH at 15.0 knots	344	270	1,757	218
GPH at 7.0 knots	246	177	484	142
GPH at 3.5 knots	222	155	450	120
GPH at idle	216	149	284	75

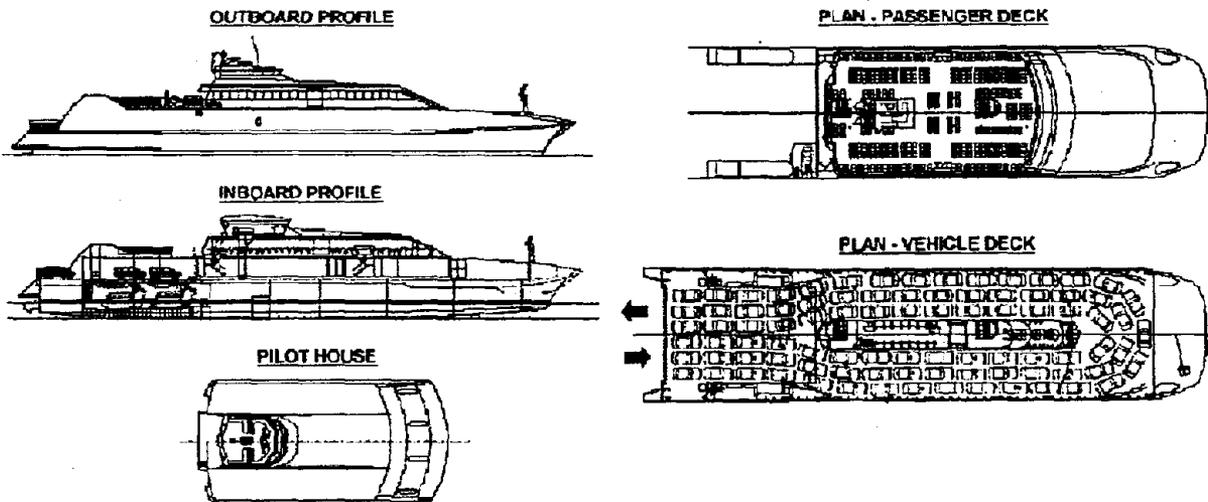
n/a (not applicable)

Sources:

- (1) Advanced Multihull Designs. Also, *Fast Ferry International*, October 1998, pp. 21-24. Also, *Jane's High-Speed Marine Transportation*, 1998-1999. Also, Volpe Center estimates for some data elements, as per discussion in Chapter 8.
- (2) Gladding-Hearn Shipbuilding, the Ducois Corporation. Also, Volpe Center estimates for some data elements, as per discussion in Chapter 8.
- (3) Lockheed Marine Systems. SLICE 600 Passenger Vehicle Ferry. Technical Data Package. April 1995.
- (4) Lockheed Marine Systems. 400 Passenger Slice Ferry. Technical Data Package. April 1995.
- (5) For a nominal vessel operating hours of 3,000 annually, as per discussion in Chapter 8.
- (6) Automobile equivalent unit (AEU), typically a minimum of a 17' x 8.5' space on the vehicle deck.

and snack facilities. A gift shop and other passenger amenities are located in the center of the vehicle deck. As can be seen in the general arrangements presented in Figure 13-3, the vehicle deck is arranged to provide for simultaneous loading and unloading of vehicles.

FIGURE 13-3: AMD K50 GENERAL ARRANGEMENTS



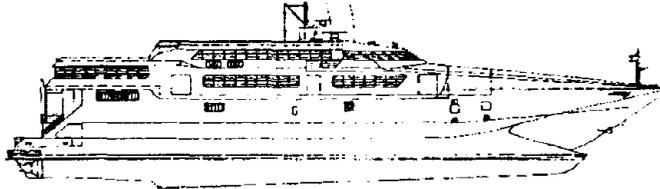
Source: Advanced Multihull Designs (AMD). WWW at URL <http://www.amd.com.au/designs/nf08/nf08.html>.

The Incat 74 meter is an aluminum hulled 74 meter high speed wave piercing catamaran, with a typical capacity of between 350 to 600 passengers and 84 to 106 automobiles. The specific design evaluated here is assumed to have a passenger capacity of 597 and a vehicle capacity of 84 AEU. The Incat 74 meter wave piercing catamaran is generally considered the first large, high speed RoPax catamaran to be designed and built, with a total of nine delivered between 1990 and 1994. These vessels have operated around the world, including Europe, South American, New Zealand, and as of the fall of 1999, the United States and Caribbean, and have served as the basis for the further development of larger vessels in the line of Incat 74, 78, 81, 86, 91 and 96 meter wave piercing catamarans. Powered by four marine diesel engines, the Incat 74 meter WPC has a service speed of 39 knots. For the 74 meter WPC assumed for this case study, passengers are accommodated on two decks, with approximately 500 on the main passenger deck in a mix of economy and first class seating, and approximately 100 on an upper passenger deck in a lounge area. Restrooms, and a bar and snack area are located on each passenger deck, and a gift shop is located on the main passengers deck. Typical general arrangements for the Incat 74 meter WPC are presented in Figure 13-4.

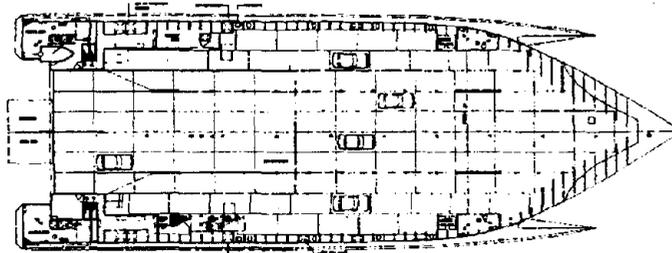
The SLICE 600 is a conceptual design of a steel hulled 65 meter SLICE RoPax ferry. The vessel would accommodate approximately 600 passengers and 90 automobiles, or a combination of 4 motorcoaches and 75 automobiles, with access to the vehicle deck from stern. Passengers are accommodated on two decks, with approximately 422 in economy class seating in two separate compartments on the gallery deck, with each compartment having its own restroom and snack bar. An additional 178 passengers are accommodated on the upper deck in first class or lounge type seating. Two gas turbine engines are to deliver an operating speed of 30 knots. General arrangements for the SLICE 600 are presented earlier in Chapter 4.

FIGURE 13-4: INCAT 74 METER WPC GENERAL ARRANGEMENTS

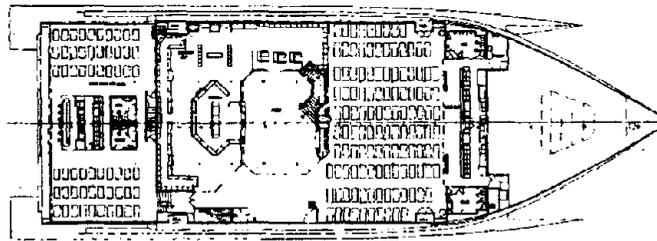
INCAT 74 METER WPC: OUTBOARD PROFILE



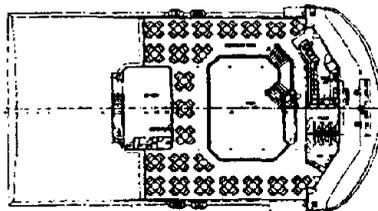
INCAT 74 METER WPC: MAIN VEHICLE DECK



INCAT 74 METER WPC: MAIN PASSENGER DECK



INCAT 74 METER WPC: UPPER PASSENGER DECK



The SLICE 400 is a conceptual design for an aluminum hulled 34 meter passenger-only ferry. The vessel would accommodate a total of approximately 400 passengers on two decks, with the main deck accommodating 268 passengers, and the upper deck 132 passengers. Powered by two gas turbine engines, the SLICE 400 is planned to have a service speed of 30 knots. General arrangements for the SLICE 400 appear in Chapter 4.

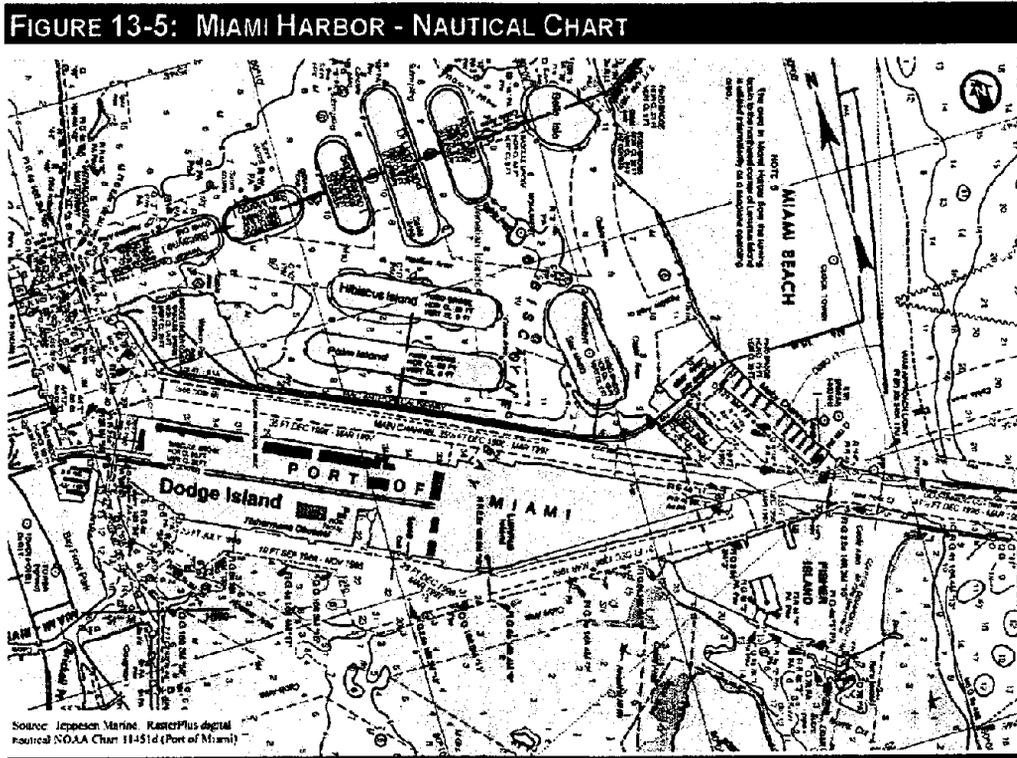
13.4 Related Infrastructure and Facilities

Although no ferry services currently operate between Miami and Key West, both ports are major cruise ship ports-of-call, and as noted earlier, high speed RoPax ferry service currently operates between Miami and the Bahamas. Therefore, suitable facilities for both passenger and RoPax ferry service are very much available in both Miami and Key West. Sources of information for the following discussion are drawn largely from the U.S. Coast Pilot, and the local port authorities.

13.4.1 Miami

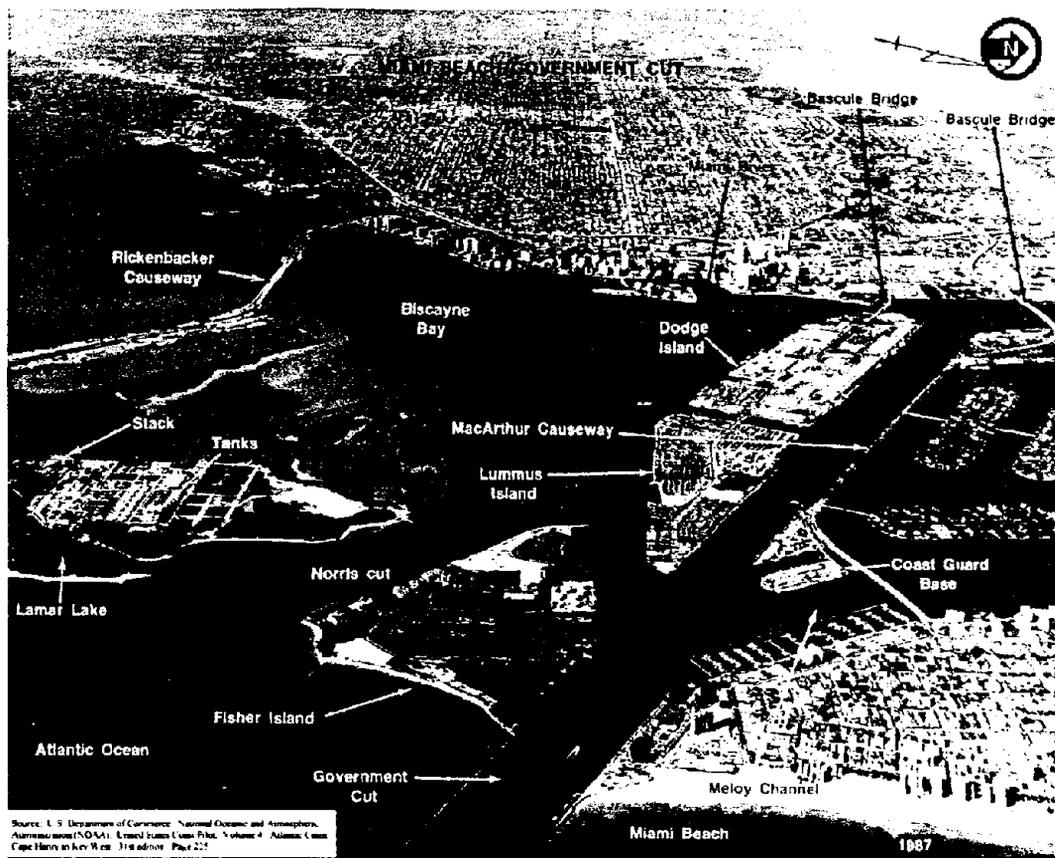
The Port of Miami is a deepwater port under the jurisdiction of the Miami-Dade County Seaport Department. Although principally a consumer port, considerable foreign commerce passes through the port. Miami is also a major cruise ship port of call. During fiscal year 1997, a total of approximately 3,191,885 cruise ship passengers embarked and disembarked in Miami, and the port is home to 18 cruise ships, and has the largest year-round cruise fleet in the world.¹⁴⁷

The Port of Miami has over 30 deep water berths adjacent to the Miami Harbor Main Channel. These include the berths adjacent at the Port of Miami on Dodge Island and Lummus Island, and the privately owned facilities on the north side of Fisher Island and just west of Causeway Island (see Figure 13-5 and Figure 13-6). There are twelve passenger facilities and associated berths. Facilities for the proposed ferry service would likely be located on Dodge Island. All types of supplies and marine services are available in Miami, except for major repair facilities for large vessels, which are available in Jacksonville and Tampa.



¹⁴⁷ Florida Tourism Industry Marketing Association (Visit Florida). 1997 Florida Visitor Study. Page 59. Also, the Miami-Dade County Seaport Department.

FIGURE 13-6: MIAMI HARBOR AERIAL PHOTO



Source: U. S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), General Oceanic Survey, Volume 4, Atlantic Coast, Cape Hatteras to Key West, 31st edition, Page 222

The facilities on Dodge Island and Lummus Island are owned and operated by the Seaport Department of Metropolitan Dade County. As noted earlier, existing facilities used by Bay Ferries for their high speed RoPax service from Miami to the Bahamas are located at Terminal 12 on the south side of Dodge Island. The facilities on Dodge Island can be accessed by major roadways and by the Florida East Coast Railway via a causeway with a bascule bridge over the Intracoastal Waterway. Lummus Island is connected to Dodge Island by a highway causeway. Parking is available for cruise and ferry passengers for \$10 per day.¹⁴⁸ Passenger facility charges for the existing Miami to Bahamas RoPax service provided by Bay Ferries are approximately \$10 per person in Miami, and it is assumed that a similar charge would apply to the proposed Miami to Key West service for the use of facilities in Miami.

Berths on Dodge Island have depths alongside that range from between 25 to 36 feet. On the northwest corner of Dodge Island, there are berths suitable for passenger and RoRo cargo service, with berth 6 at 31 feet alongside, and berth 7 at 25 feet alongside. On the north side of Dodge Island, bays 1-54 are 36 feet alongside, with a deck height of 8 feet, and are used for passenger and cargo service. Berths on the east side and south side of Dodge Island are 25 feet alongside, and are used primarily for general, containerized or RoRo cargo. Controlling depths of channels, which are generally suitable for even the deep draft of the SLICE 600, are addressed in more detail later in the discussion of navigational considerations.

¹⁴⁸ Miami-Dade County Seaport Department.

Given the existing facilities described above, depth alongside and freeboard height may pose a problem for the SLICE 600 in Miami. With a draft of 28.5 feet, the SLICE 600 would be limited to berthing areas on the north-west and north side of Dodge Island. Other areas, with depths alongside of 25 feet, would not be accessible by the SLICE 600 unless significant dredging were undertaken, which is assumed here to be an unlikely scenario. With a mean range of tide of 2 to 2.5 feet, the SLICE 600 would not be able to access these other areas even at high tide. Even if this were the case, the operational constraints that this would impose would likely be unacceptable.

The Incat 91 meter WPC currently operated by Bay Ferries out of Miami appears to have adequately interfaced with existing terminal facilities in Miami, which suggests that neither the AMD K50 nor the Incat 74 meter WPC would face such problems. The SLICE 400 main passenger deck freeboard of 11.8 feet should not pose any operational problems, since the existing passenger facilities in Miami generally have a deck height of 8 feet. The draft of the AMD K50, 74 meter WPC, and the SLICE 400 would all easily be accommodated by both the channels and all berths in Miami harbor.

13.4.2 Key West

The Key West Department of Transportation, Port Department, has direct supervision of city docks, properties, moorings and anchorages in Key West Harbor. Key West is an important cruise ship port of call, and during fiscal year 1997, a total of approximately 536,400 cruise ship passengers embarked and disembarked in Key West.¹⁴⁹ Access to Key West Harbor from the south is via the Main Ship Channel, which has a controlling depth of 34 feet from the Straits of Florida to a turning basin off the Truman Annex, thence 30 feet to an upper turning basin off Key West Bight.

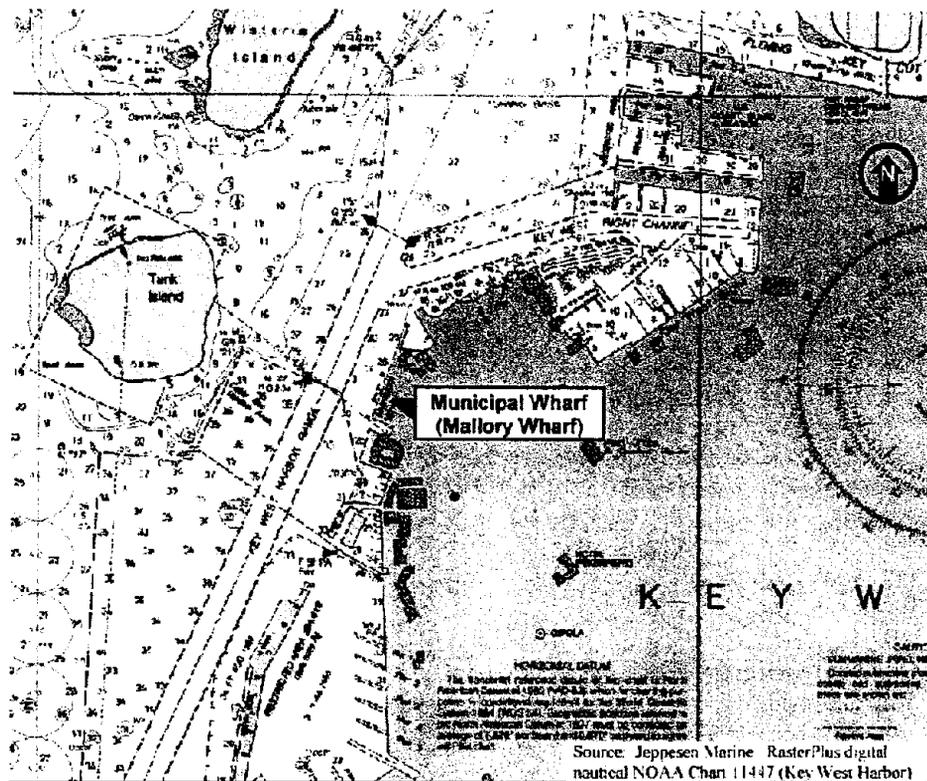
There are three major areas of the Harbor capable of accommodating large vessels such as cruise ships and ferries. Municipal Wharf, also known as Mallory Wharf, is 870 feet long and has a deck height of about 7 feet (see Figure 13-7). The southern half is operated by the Key West Department of Transportation as a cruise ship terminal, with a total of 464 feet of berthing space with a reported depth of 26 feet alongside. The northern half is privately owned by a condominium development. Pier B, south of the Municipal Wharf, is another deepwater berthing facility operated by the Truman Annex Company, with a controlling depth of about 31 feet and a deck height of about 9 feet. South of Pier B is the Outer Navy Mole deepwater berthing facility, which has a controlling depth of approximately 30 feet and a deck height of 7 feet.

Supplies, including diesel fuel, water and other marine supplies are available in Key West, as are limited repair capabilities for large vessels. There is currently no fee structure for ferries, however for cruise ships, there is a disembarkation fee of \$6.50 per passenger, plus a vessel docking fee of \$0.50 per foot of vessel length.¹⁵⁰ It is assumed here that a similar charge would apply to the proposed Miami to Key West ferry service for the use of facilities in Key West.

Given the existing facilities described above, depth alongside and freeboard height may pose a problem for the SLICE 600 in Key West as well. With a draft of 28.5 feet, the SLICE 600 would exceed the controlling depth at the Municipal Wharf cruise ship facility. The Pier B facility and the Outer Navy Mole, with controlling depths alongside in excess of 30 feet, could accommodate the SLICE 600, however passenger terminal facilities at these locations are less developed than at the Municipal Wharf. With a mean range of tide at Key West of 1.3 feet, the SLICE would not be able to access the Municipal Wharf even at high tide, and dredging is assumed not be a feasible scenario.

¹⁴⁹ Florida Tourism Industry Marketing Association (Visit Florida). *1997 Florida Visitor Study*. Page 59.

¹⁵⁰ Key West Department of Transportation, Port Department. September 13, 1999.

FIGURE 13-7: KEY WEST HARBOR - NAUTICAL CHART

13.5 Weather and Wave Climate

The climate of South Florida can be generally characterized as subtropical marine in Broward and Dade counties, and tropical maritime in the Keys. The region is strongly influenced by the adjacent marine environment, and the Florida Current, Gulf of Mexico, the Gulf Stream and the Atlantic Ocean affect terrestrial and marine climate during different seasons. South Florida experiences two general seasons: a warm rainy season from June to October, and a mild dry season from November to May. During the rainy season, rainfall averages 6.24 inches per month, and during the dry season averages 1.97 inches per month. Historical meteorological data for the coastal areas off Miami and Key West are presented in Table 13-3.

Hurricanes are the greatest weather hazard to navigation in this area. The hurricane season runs officially from June 1 through November 30, with September usually being the time of peak hurricane activity. The region is also affected by the trade winds, and winds from the east are persistent throughout the year, with some local effects in the Keys. The trade winds usually blow at 10 to 20 knots, but can be stronger at times. The proximity of the Gulf Stream and the Gulf of Mexico result in a tropical maritime climate. Visibility in the region are usually good, but may be reduced briefly in heavy rain showers.

As discussed earlier in Chapter 8, the Volpe Center conducted a detailed wave climate analysis using a combination of measured wave data sources and modeled hindcast data sources. Data sources used for this region included measured data from NOAA buoys and Florida Coastal Data Network (FCDN) buoys, and hindcast data from the U.S. Army Corps of Engineers, Wave Information Study (WIS) (see Table 13-4). In total, more than 710,000 data records were utilized.

TABLE 13-3: METEOROLOGICAL TABLES FOR THE COAST AREAS OFF MIAMI AND KEY WEST

METEOROLOGICAL TABLE FOR COASTAL AREA OFF MIAMI
Boundaries: 25°N. to 29°N., between 78°W. and the coast

Weather elements	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Wind > 34 knots (1)	1.1	1.3	.8	*	*	*	*	*	.8	1.2
Wave height > 10 feet (1)	5.6	5.5	4.3	2.9	1.7	.9	*	1.0	4.1	6.8
Visibility < 2 naut. mi. (1)	.8	*	*	*	.6	1.0	.5	*	.5	.7
Precipitation (1)	3.1	2.6	2.0	1.7	2.7	3.7	2.5	2.9	4.5	4.4
Temperature > 85°F (1)	*	*	.7	1.2	4.2	13.7	27.0	30.4	18.8	5.9
Mean Temperature (°F)	69.6	70.0	71.7	74.8	78.1	81.1	83.1	83.6	82.3	79.0
Temperature < 32°F (1)	0	0	0	0	0	0	0	0	0	0
Mean relative humidity (%)	75	75	75	75	76	79	78	78	79	76
Sky overcast or obscured (1)	15.5	14.0	15.1	11.3	11.3	13.7	8.5	8.4	14.3	15.1
Mean cloud cover (eighths)	4.2	4.1	4.0	3.7	3.7	4.2	3.9	4.0	4.5	4.3
Mean sea-level pressure (2)	1,020	1,019	1,018	1,018	1,017	1,017	1,018	1,017	1,015	1,015
Extreme max. sea-level pressure (2)	1,034	1,034	1,034	1,032	1,028	1,029	1,027	1,028	1,028	1,030
Extreme min. sea-level pressure (2)	999	977	997	998	999	998	1,001	1,002	997	996
Prevailing wind direction	E	E	E	E	E	E	E	E	E	E
Thunder and lightning (1)	*	.6	.8	1.3	2.1	3.4	4.3	4.8	3.9	2.2

METEOROLOGICAL TABLE FOR COASTAL AREA OFF KEY WEST
Boundaries: 23°N. to 25°N., between 78°W. and 83°W.

Weather elements	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
Wind > 34 knots (1)	.8	*	*	*	0	*	*	*	*	.7
Wave height > 10 feet (1)	2.0	1.9	1.3	2.7	.8	*	*	*	.9	2.3
Visibility < 2 naut. mi. (1)	*	*	*	*	*	.6	*	*	*	.5
Precipitation (1)	2.5	2.2	1.6	1.2	2.1	3.5	2.0	2.0	3.6	4.4
Temperature > 85°F (1)	*	.6	1.2	1.1	7.8	19.9	35.8	41.3	28.3	10.4
Mean Temperature (°F)	72.3	72.5	74.2	76.9	79.7	82.2	83.9	84.3	83.3	80.5
Temperature < 32°F (1)	0	0	0	0	0	0	0	0	0	0
Mean relative humidity (%)	78	77	78	77	77	79	77	77	78	78
Sky overcast or obscured (1)	12.6	11.0	10.2	7.0	8.9	13.4	8.4	5.5	11.1	13.3
Mean cloud cover (eighths)	3.7	3.8	3.4	3.2	3.4	4.2	3.9	3.9	4.3	4.2
Mean sea-level pressure (2)	1,019	1,018	1,018	1,017	1,016	1,016	1,018	1,018	1,014	1,014
Extreme max. sea-level pressure (2)	1,032	1,033	1,030	1,029	1,027	1,033	1,031	1,027	1,030	1,027
Extreme min. sea-level pressure (2)	1,001	1,002	1,002	1,001	1,008	997	1,002	1,003	995	991
Prevailing wind direction	E	E	E	E	E	E	E	E	E	E
Thunder and lightning (1)	*	.6	*	*	1.6	2.7	4.2	4.6	5.6	2.8

(1) Percentage frequency

(2) Millibars

* 0.0-0.5%

These data are based upon observations made by ships in passage. Such ships tend to avoid bad weather when possible, thus bearing the data toward good weather.

Source: U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), United States Coast Pilot, Volume 4, Atlantic Coast, Cape Henry to Key West, 31st edition, Page T-12.

Figure 13-8 presents the location of the particular buoys and stations from which data were obtained. Based on the proposed operating schedule for the Miami to Key West ferry route, and a detailed definition of the location and operating speed on each segment of the route, a distribution of annual vessel operating hours by sea state was developed. The results of this analysis, presented in Figure 13-9, reveal that significant wave heights in excess of sea state 4 (4.1 to 8.2 feet) would be experienced less than 1% of vessel operating hours. These findings are generally consistent with the wave height data presented in the U.S. Coast Pilot, which indicates that

TABLE 13-4: FLORIDA CASE STUDY - WAVE DATA SOURCES

Data Source	Buoy or Station	Time Period Observed	Number of Records
FCDN	UF003	10/78 - 7/88	5,495
NOAA	42025	9/91 - 4/94 & 1/95 - 6/95	3,964
WIS	Au2001	1/56 - 12/75 & 1/76 - 12/95	58,440
WIS	Au2002	1/56 - 12/75 & 1/76 - 12/95	58,440
WIS	Au2003	1/56 - 12/75 & 1/76 - 12/95	58,440
WIS	Au2004	1/56 - 12/75 & 1/76 - 12/95	58,440
WIS	Au2005	1/56 - 12/75 & 1/76 - 12/95	58,440
WIS	Au2006	1/56 - 12/75 & 1/76 - 12/95	58,440
WIS	Au2007	1/56 - 12/75 & 1/76 - 12/95	58,440
WIS	Au2008	1/56 - 12/75 & 1/76 - 12/95	58,440
WIS	Gu1001	1/76 - 12/95	58,440
WIS	Gu1008	1/76 - 12/95	58,440
WIS	Gu1009	1/76 - 12/95	58,440
WIS	Gu1100	1/76 - 12/95	58,440
TOTALS			710,739

waves of 10 feet or more are reported approximately 1.2% to 3.6% of time in this region. The wave climate studies completed by Mersea Ships, the original applicant Title XI applicant for the proposed Miami to Key West SWATH service, also found that significant wave heights in excess of 3.5 meters (11.4 feet) are experienced less than 3.5% of the time in this area. In summary, the relatively benign wave climate of this region does not provide SLICE or SWATH vessels sufficient opportunity to improve ride quality or passenger comfort.

FIGURE 13-8: FLORIDA EAST COAST AND KEYS WAVE DATA STATIONS

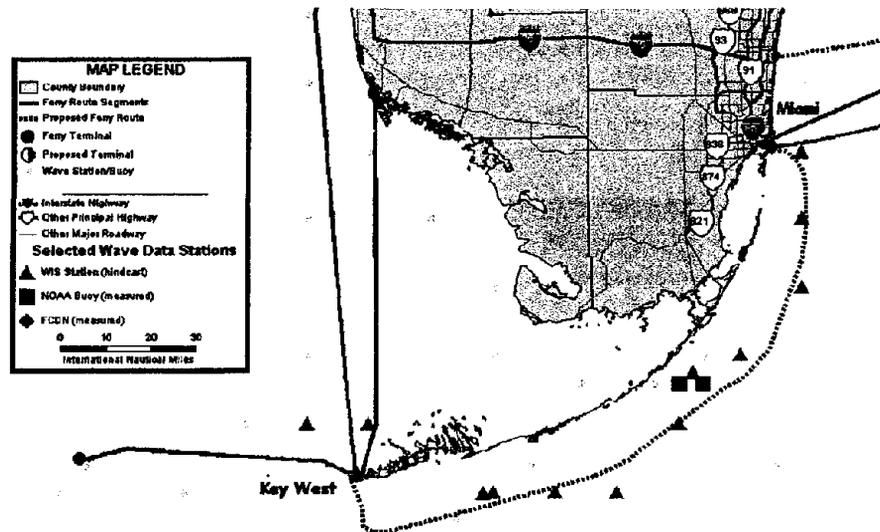
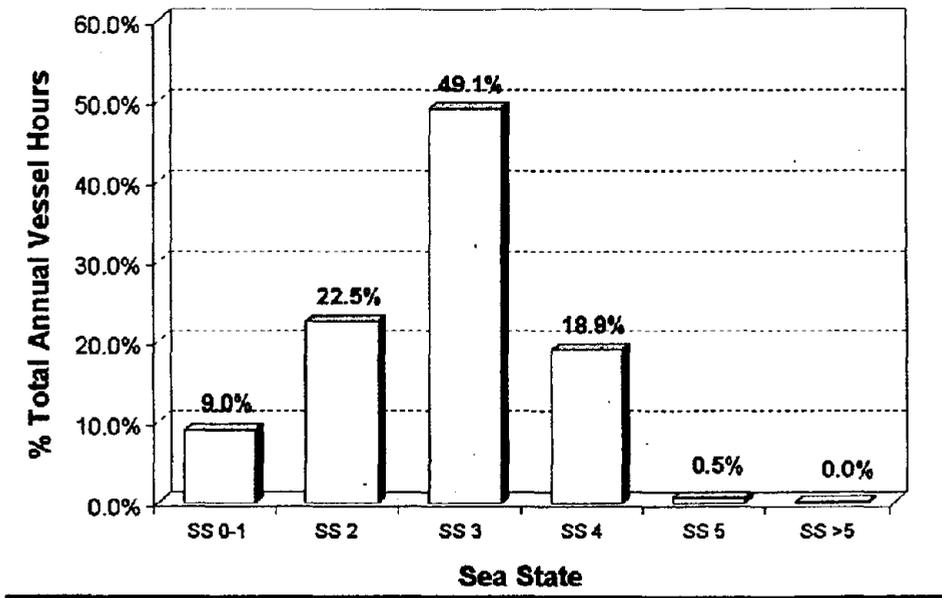


FIGURE 13-9: DISTRIBUTION OF ANNUAL VESSEL OPERATING HOURS BY SEA STATE (MIAMI - KEY WEST ROUTE)



13.6 Navigational Considerations

Utilizing the electronic charting software and digital nautical charts, a detailed representation of the planned Miami to Key West route was created. The total route distance from a Miami ferry terminal on the north side of Dodge Island to a Key West ferry terminal in the vicinity of the Municipal Wharf is 168 nmi. The individual segments of this route are as follows. From the proposed Miami ferry terminal to a point just east of the Main Channel into Miami (known as Government Cut) is 3.7 nmi. It is assumed that operating speed would be limited to 15 knots for all vessels on this route segment. From this point, traveling outside of the Area to Be Avoided (ATBA) to a point in the Key West Harbor Main Ship Channel, about three miles south of Key West, is 161 nmi. On this mainline portion of the route, vessels are assumed to operate at their service speed, as indicated earlier in Table 13-2. From this point in the Main Channel outside of Key West Harbor to a point just west of Fort Taylor in Key West is 2.2 nmi, and on this segment of the route, it is assumed that operating speed would be limited to 30 knots. Finally, from this point to the ferry terminal in the vicinity of the Municipal Wharf is about 1 nmi, during which vessels are assumed to operate at 15 knots. Given this operating profile, total one-way trip time from terminal to terminal with the baseline AMD K50 vessel is estimated at 4 hours. With the Incat 74 meter WPC, total one-way trip time is 4 hours and 30 minutes, and with both the SLICE 600 and SLICE 400 vessels, total one-way trip time is 5 hours and 45 minutes.

The project team consulted the Coast Guard in the matter of navigational safety and restrictions in the operating area associated with this route. There are no restricted navigation areas, for reasons of safety, in the waters between Miami and Key West. The National Oceanic and Atmospheric Administration (NOAA) administers an "Area to be Avoided" (ATBA) in the Florida Keys National Marine Sanctuary. No vessels longer than 50 me-

ters (164 feet) may enter the ATBA without the permission of the Sanctuary managers. The ATBA is discussed further in the review of environmental considerations presented later.

The approach to the Port of Miami would be via the sea buoy (RW "M", Mo (A)) east of Miami Beach and the Port facilities at Lummus Island. There is a precautionary area approximately 2 miles in diameter, centered on the sea buoy, so designated for the safe transfer of pilots and interchange of vessel traffic. The charts advise that all vessels should "exercise extreme care in navigating within this area". The distance from the sea buoy to the Port of Miami, opposite Palm Island, is about 8 nautical miles. There is no speed restriction landward of the sea buoy, but some speed reduction would likely be necessary where the channel runs among Fisher Island, the south tip of Miami Beach, and Lummus Island, since vessels are advised not to operate at a speed which will endanger other vessels or structures. Controlling depths at Miami in the Government Cut are 38 feet from the sea to the inshore ends of the entrance jetties, thence 36 feet to a turning basin with the same depth north of the northwest corner of Dodge Island. These depths are more than sufficient to accommodate the SLICE 600 with its 28.5 foot draft, as well as all other vessels considered for this case study.

The port of Key West would be approached from the south via the main ship channel and the sea buoy "RW".¹⁵¹ The channel is marked by lighted ranges and other aids to navigation from the entrance to the upper turning basin, and extends from the sea buoy northward along the Main Channel range, Cut "A" range, Cut "B" range, and the Key West Harbor Range. Indicated depths along the northern portion of the approach (Cut "B" and Key West Harbor ranges) and in the harbor's turning basin are from 29' to 36', barely adequate relative to the 28.5 foot draft of the SLICE 600.

Navigation of the open water portion of the route is unrestricted except for the Florida Keys National Marine Sanctuary ATBA, as indicated on the charts and in the Coast Pilot. The SLICE 600 and comparative high speed vessels would travel south of the ATBA. The Coast Guard states that there is an abundance of recreational fishing and diving craft in the area, and that there will likely be crossing issues for the master to deal with. Visibility is generally good as fog occurs only rarely in this area.

13.7 Environmental Considerations

South Florida and the Florida Keys region supports one of the most diverse ecosystems of marine plants and animals in North America. In November 1990, Florida Keys National Marine Sanctuary was designated in order to protect the unique marine environment of the Florida Keys. The geographic extent and various areas of the sanctuary are presented in Figure 13-10. In addition to regulations that generally prohibit the operation of vessels in any manner within the sanctuary that may result in damage the environment, an "Area to Be Avoided" (ATBA) has also been established off the coast of Florida in order to reduce the risk of large vessel groundings which can represent a serious threat to the continued vitality of the marine environment in the region. Tanks vessels and vessels greater than 50 meters (164 feet) in length are prohibited from operating within the ATBA. Therefore, the AMD K50, Incat 74 meter WPC, and SLICE 600 would all be required to operate outside of the ATBA. In addition, it is assumed here that the deep draft of the SLICE 400 relative to other vessels of similar size and capacity would result in its being operated outside of the ATBA as well.

The ATBA was established under the authority of the Florida Keys National Marine Sanctuary and Protection Act of 1990. The ATBA is coterminous with the Florida Keys National Marine Sanctuary, and has four main areas: the vicinity of the Florida Keys, the vicinity of Key West Harbor, the area surrounding Marquesas Keys, and the area surrounding Dry Tortugas (see Figure 13-11). The ATBA in the vicinity of the Florida Keys extends east and north along the Keys, extending seaward from the Keys an average of approximately 10 nmi. Figure 13-11 shows the position of the ATBA relative to the proposed route location.

¹⁵¹ Telephone contact. MSO Miami, CDR Michael Miles (Port Operations). August 11, 1999.

13.8 Market Forecasts and Financial Analysis

As noted earlier in this chapter, the baseline operating scenario for the proposed RoPax service between Miami and Key West consists of year-round service, with one round trip daily, to be operated by Boomerang Fast Ferry with service beginning sometime during late 2000 or 2001. Boomerang Fast Ferry would acquire one AMD K50 high speed RoPax catamaran to service this route, operating a single round trip daily. The vessel would be designed to accommodate 400 passengers and 89 AEU, or a combination of up to 4 motorcoaches and 46 automobiles, with a service speed of 45 knots.

13.8.1 Baseline Ferry Patronage

The operating schedule for this service would likely include a 9:00AM departure from Miami, with a 1:00PM arrival in Key West, followed by a 4:00PM departure from Key West with an arrival back in Miami at 8:00PM. Although published fares are not yet available for this proposed route, based on the other existing and proposed high speed ferry services in the region between Florida and the Bahamas, and between Fort Myers and Key West, it is estimated that an adult one-way fare would be approximately \$63.25, including passenger facility charges of \$10 at Miami and \$6.50 at Key West. With the baseline AMD K50 vessel, total one-way travel time would be 4 hours.

Regarding passenger and vehicle patronage, note that on many conventional RoPax ferry services, the observed ratio of vehicle boardings to passenger boardings ranges from between 0.28 to about 0.40, with an average of approximately 0.34.¹⁵² However, the three RoPax vessels reviewed here (AMD K50, Incat 74 meter WPC, and SLICE 600) have a ratio of AEU vehicle capacity to passenger capacity ranging between 0.14 and 0.22. It is unclear whether there would be substantial demand for vehicle ferry service to Key West. The limited physical size of Key West, and the sizable number of cruise ship passengers calling on Key West each year, would both seem to suggest that although automobile travel is currently a dominant mode of travel to Key West, once in Key West use of an automobile is not a strict necessity. However, it is possible that travelers may want to visit other destinations in the Florida Keys in addition to Key West (as can be seen in the NOAA travel study which shows persons who visited two or more of the four major areas of the Keys), or combine a one-way trip by ferry with a return trip by automobile along Route 1. Therefore, it is assumed for this case study that for each vessel type analyzed, vehicle boardings will be equal to 80% of the ratio of AEU vehicle capacity to passenger capacity. For example, for the AMD K50, the ratio of AEU vehicle capacity to passenger capacity is 400/89, or 0.22, 80% of which equals 0.176. For example if 240 passengers board the AMD K50 on a given trip, 43 vehicles are also assumed to board on that trip.

Based on the market and financial analysis that follows, and utilizing the market analysis and financial analysis methods described in Chapter 8, baseline annual equilibrium (year 3 and beyond) passenger boardings would total 231,060, and baseline annual equilibrium vehicle boardings would total 41,129 under the baseline case using the AMD K50 (see the baseline vessel portion of Table 13-5). In order to evaluate this baseline patronage estimate in the context of the overall travel market between Miami and Key West, a review of the existing travel between these two areas is performed below. Modes of travel that currently service this market include auto, air, bus and other ferry services.

Baseline Travel Market - Auto

Key West is accessible by highway from Miami via U.S. Route 1, also known as the Overseas Highway. Driving distance from Miami to Key West is approximately 160 statute miles total, with about 133 miles of travel in the Keys, and remainder in Dade County. The highway largely follows the route of the former Florida East

¹⁵² Based on observed total passenger boardings and vehicle boardings for BC Ferries, Washington State Ferries, Cape May - Lewes ferry, Alaska Marine Highway System, Lake Michigan Carferry, and Bay Ferries service between Saint John and Digby.

Coast Railroad, however current intercity rail service in Florida, provided by Amtrak, extends only as far south as Miami. Amtrak does provide a Thruway bus connection from Miami to Key West, called the Florida Keys Shuttle, however this service is operated by Greyhound as part of Greyhound's regular bus service between Miami and Key West, which is described later.

Drive time one-way from Miami to Key West is about 3.5 hours minimum, under free flow conditions, and about 4 hours under normal traffic conditions. Assuming an out of pocket cost of \$0.32 per vehicle mile, and an average vehicle occupancy of 2 persons, the 160 statute mile trip between Miami and Key West by automobile would cost approximately \$26 one-way per person.

For the one year period between June 1995 and May 1996, there were 2.5 million person trips by automobile to the Florida Keys and Key West, and of these, it is estimated that 2 million (80%) were for non-business purposes, and 500,000 (20%) were for business purposes.¹⁵³ Of this total of 2.5 million auto trips, approximately 33% are made to Key West, and of these, about half are trips to Key West only, with the remainder comprised of trips that include Key West in combination with one of the other three major areas of the Keys.¹⁵⁴ Therefore, there are about 440,000 auto trips to Key West only annually, which represents a total 880,000 one-way auto trips to and from Key West annually.

As for the origin of these auto trips to Key West, the state of Florida is the number one origin of visitors to the Keys, and Dade County and Broward County alone represent 47% of visitors originating in Florida and going to the Keys, and 14% of all visitors to the Keys.¹⁵⁵ Assuming that this distribution of trip origins for all trips is applicable to auto trips, then it is estimated that there are approximately 131,000 one-way origin-destination auto trips between Key West and the Miami metropolitan area annually.

Baseline Travel Market - Air Travel

There are four commercial service airports that service the Key West and the Miami metropolitan areas. These are (1) Key West International Airport, (2) Marathon Airport, (3) Miami International Airport, and (4) Fort Lauderdale/Hollywood International Airport. Because the ferry terminals for the proposed route are located in Miami and Key West, Miami International Airport and Key West International Airport are the focus of the air travel market analysis presented here.

Key West International Airport is located approximately 2 miles east of Key West. Total passenger enplanements in 1996 for Key West International were 275,911, composed of 208,000 commuter air carrier enplanements, with the remainder being major air carrier enplanements. Total passenger enplanements in 1996 for Miami International were 16,338,062, composed of approximately 15.1 million domestic and international major air carrier enplanements, and approximately 1.2 million commuter air carrier enplanements.

Airlines that offer flights from Miami to Key West include US Air (US Express), Continental Connection (Gulfstream International Airlines), American Eagle, Comair, United Airlines (through Continental Connection), and Caribbean Air Service, Inc. (from Opa-Locka Airport about 20 minutes from Miami International Airport). Flights are often overbooked during peak seasons, especially during January and February. In Key West, car rentals are available from a number of major companies.

One-way travel time from gate-to-gate is 45 to 50 minutes, and information from airline reservation systems for the month of October 1999 indicates that round trip coach air fares range from between \$188 up to \$259 in this

¹⁵³ Leeworthy, Vernon R., and Peter C. Wiley. *Linking the Economy and Environment of Florida Keys/Florida Bay. Visitor Profiles: Florida Keys / Key West* November 1996. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. Page 7.

¹⁵⁴ Leeworthy, Vernon R., and Peter C. Wiley. *Linking the Economy and Environment of Florida Keys/Florida Bay. Visitor Profiles: Florida Keys / Key West* November 1996. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. Page 102.

¹⁵⁵ Leeworthy, Vernon R., and Peter C. Wiley. *Linking the Economy and Environment of Florida Keys/Florida Bay. Visitor Profiles: Florida Keys / Key West* November 1996. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. Page 18.

market, and that aircraft types typically used in this market include the Beechcraft B100 turboprop (9 seats), Saab 340 (34 seats), ATR-42 turboprop (46 seats).

Air travel data for calendar year 1995, developed from a combination of Form 41, Form 298-C and 10% Sample data obtained from the U.S. Department of Transportation, Office of Airline Information, reveal that there were approximately 16,600 origin-destination passengers that flew direct in each direction between Miami International Airport and Key West International Airport in 1995, for a total of 33,200 direct origin-destination air trips between these two airports. An additional 190,000 transfer passengers also flew between Miami and Key West, with 95,000 passengers flying from Key West to Miami, where they connected with flights beyond Miami, and 95,000 passengers arriving at Miami from another airport, where they then connected with flights on to Key West.

Baseline Travel Market - Bus

Russel's Official National Motorcoach Guide for the U.S. and Canada for August 1999 was referenced to identify intercity bus companies offering service between Miami and Key West. Motorcoach bus service is provided on this route by Greyhound, which offers three round trips daily between Key West depot at the Key West airport, with a fourth round trip on Sundays and Fridays. Major stops in Miami include Miami International Airport, the Miami Amtrak station and downtown Miami, and there are approximately 15 stops along the way between Miami and Key West. One-way travel time by Greyhound from Key West to Miami International Airport is 4 hours and 20 minutes, and adult round-trip fares for travel between Key West and Miami are currently \$55.

This operating schedule indicates a total of approximately 2,400 one-way vehicle trips are made annually. Given that a typical intercity motorcoach has a seating capacity between 46 and 55 seats, with a fleet average of about 49 seats, this equates to a total of approximately 59,000 one-way bus passenger trips annually, assuming an average load factor of 50%, which is typical of scheduled intercity motorcoach service nationwide..

In addition to this schedule intercity service, excursion charter service is provided by Party Tours, which operates two round trips weekly with a round trip fare of \$79. This level of service equates to approximately 7,600 one-way passenger trips annually at a somewhat higher load factor of 75%, typical of most charter bus operators.

Baseline Travel Market - Other Ferry Service

As noted earlier, seasonal ferry service is operated from October to early April on two routes between Palm Grove Marina in Fort Myers and Key West, and between Factory Bay Marina on Marco Island (about 33 miles south of Fort Myers) to Key West, by *Key West Shuttle*. Although not directly serving the Miami to Key West market, these routes are reviewed here in order to gauge current demand for ferry travel in general to Key West. Two passenger-only vessels each operate one daily round trip. The vessel *Whale Watcher* operates on the 133 nautical mile route between Fort Myers and Key West, with a total one-way travel time of about 4 hours at a service speed of approximately 33 knots. The vessel *Capt. Red* operates on the 90 nautical mile route between Marco Island and Key West, with a total one-way travel time of about 3 hours and 45 minutes at a service speed of approximately 24 knots. Round trip fares on both routes are \$89.00 per passenger. Based on information obtained from the operator, annual ridership on both routes for the 1998-99 operating season is estimated at 24,000 passenger boardings. During the summer, these vessels are repositioned to New England and operated as whale watch and excursion vessels.

Baseline Travel Market - All Modes

Based on the above analysis of baseline travel by mode, it is estimated that total travel by all modes between Miami and Key West is approximately 230,800 one-way trips annually, comprised of 131,000 one-way person trips by auto, 33,200 one-way trips by air, and 66,600 trips by bus. In addition to diversion from these existing modes of travel, it is possible that the introduction of high speed ferry service could result in some level of in-

duced travel demand, which is typically defined as trips that are new to the overall travel market, and that are not currently being made on other existing modes, and that would not otherwise be made absent the introduction of the new transportation service. Assuming here a modest level of induced travel resulting from the introduction of high speed ferry service equal to 5% of the overall travel market, the estimated baseline equilibrium passenger boardings of 231,060 in the baseline case using the AMD K50, and based on the proposed Boomerang Fast Ferry operating profile and vessel, would represent approximately 95% of the existing total travel market between Miami and Key West.

As a further point of reference regarding estimate patronage, as noted earlier, there were 3 million person trips to the Florida Keys overall between June 1995 and May 1996, by all modes of travel and from all origins, with about 83% of these non-business and the remainder business trips.¹⁵⁶ Of these 3 million, 43% visited Key West, with 69% of these visitors to Key West visiting Key West only, and the remainder visiting one or more of the other three major parts of the Florida Keys in addition to Key West.¹⁵⁷ Therefore, it is estimated that in total, for persons visiting Key West only, by all modes of travel and from all origins, there are a total of 890,000 person trips annually. This translates into 1,780,000 one-way trips to and from Key West annually, for persons visiting Key West only, by all modes of travel and from all origins. The estimated baseline equilibrium passenger boardings of 231,060 in the baseline case using the AMD K50 represent 13% of this much broader universe of potential trips from which the new ferry service could conceivably divert passengers from. However, much of the 1,780,000 universe of trips to and from Key West represents persons whose travel originates from areas outside of Florida, and outside of the Miami metropolitan area, thus largely excluding them from consideration as possible candidates for diversion to the proposed ferry service.

Other than the current Boomerang Fast Ferry market study, which was not made available by Boomerang Fast Ferry or by MARAD for review, the only other high speed ferry market study performed for this Miami to Key West market is the original SWATH proposal performed by Mersea Ships I, Inc. Reportedly, the original market study conducted by Mersea Ships for its MARAD Title XI application indicated a total market for up to twelve 300 passenger SWATH vessels. However, the fact that Mersea Ships ultimately chose not to pursue the implementation of this service with an initially planned two SWATH vessels would indicate that these original market estimates were far too optimistic.

Although the baseline patronage, as estimated from the baseline vessel type and operating schedule proposed by Boomerang Fast Ferry, appears to exceed what would seem reasonable given the baseline overall travel market and the level of service attributes of the other modes of travel in the Miami to Key West market, the estimate of 231,060 is nevertheless used here as the basis for comparison of the use of SLICE and other comparative high speed vessels.

13.8.2 Financial Analysis

The economic performance of the various vessel types and operating scenarios is first estimated at a break-even level of patronage for the proposed operating schedule. The break-even level is defined here as the level of passenger and vehicle patronage required to achieve an internal rate of return of 15% with the baseline fare. This is then followed by a baseline fare scenario, in which the baseline fare is utilized in conjunction with the estimated patronage for each vessel type. Finally, a profit maximizing fare scenario is conducted in which fare levels are varied to achieve the maximum internal rate of return, or minimum annual net cash deficit, possible.

¹⁵⁶ Leeworthy, Vernon R., and Peter C. Wiley. *Linking the Economy and Environment of Florida Keys/Florida Bay. Visitor Profiles: Florida Keys / Key West* November 1996. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. Page 7.

¹⁵⁷ Leeworthy, Vernon R., and Peter C. Wiley. *Linking the Economy and Environment of Florida Keys/Florida Bay. Visitor Profiles: Florida Keys / Key West* November 1996. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service. Page 11.

Break Even Scenario

As noted above, the estimate of the baseline annual equilibrium passenger and vehicle patronage is based upon the level of patronage that would be required to return a 15% internal rate of return given the proposed baseline vessel, and the proposed baseline operating schedule and fares. This is referred to here as a "break-even" financial analysis. Again, applying this methodology to the baseline case using the AMD K50, annual equilibrium (year 3 and beyond) passenger boardings are estimated at 231,060, and annual equilibrium vehicle boardings at 41,129 (see Table 13-5). Therefore, to achieve this minimum level of profitability using the AMD K50, an average passenger capacity utilization rate, or load factor, of 82.3% would be required.

This break-even methodology was next extended to the other comparative vessel types analyzed for this case study, with the results also presented in Table 13-5. This type of analysis is illuminating because it identifies how much patronage an operator would be required to attract to attain a minimum level of profitability, for a given type of vessel and given operating scenario. If all else held equal, a baseline vessel requires an operator to attract a significantly greater number of passengers or achieve an unrealistically high annual load factor to attain the same level of minimum profitability possible with some alternative vessel, then this indicates that the alternative vessel would likely be viewed as superior by the potential operator.

The Incat 74 meter WPC, although able to attain the break-even internal rate of return of 15% with a load factor of 59.8%, requires 250,670 annual passenger boardings and 28,216 annual vehicle boardings to do so. Relative to the AMD K50 baseline, this is an increase of 8.5% in passenger boardings and a decrease of 31.4% in vehicle boardings. Major differences in operating expenses and revenues between the Incat 74 meter WPC and the baseline AMD K50 include an increase in salaries, wages and benefits for both deck and engine crew and for passenger service crew. This is due to both a somewhat greater overall crew compliment for the Incat 74 meter WPC, compounded by an increase in total annual operating hours for the Incat 74 meter WPC of about 14% because of its somewhat slower service speed relative to the AMD K50. Fuel and lubricant expenses are lower by about 20%, with the lower fuel consumption rates per hour of the Incat 74 meter WPC outweighing the overall increase in operating hours of the Incat 74 meter WPC, resulting in a net decrease in fuel and lubricant expense. Vehicle revenues are also lower by 31.4%, reflecting the fact that of the three RoPax vessels reviewed in this case study, the Incat 74 meter WPC has the lowest ratio of AEU vehicle capacity to passenger capacity.

To achieve the break-even 15% internal rate of return, the SLICE 600 requires 409,450 annual passenger boardings, and 49,134 vehicle boardings, which represent substantial increases relative to the AMD K50 baseline of 77.2% and 19.5%, respectively. This represents an average annual passenger load factor of 97%, far in excess of what could reasonably be achieved in practice. Major differences in SLICE 600 operating expenses relative to the AMD K50 include an increase in salaries, wages and benefits for both deck and engine crew (92% increase) and for passenger service crew (66% increase), which as in the case of the Incat 74 meter WPC, is due to both a somewhat greater overall crew compliment for the SLICE 600, compounded by a substantial increase in total annual operating hours for the SLICE 600 because of its much slower service speed relative to the AMD K50. Vessel fuel and lubricant expenses for the SLICE 600 are double (103.5% increase) what they are for the AMD K50, reflecting the substantial increase in total annual operating hours for the SLICE 600, as well as a high fuel consumption rate per hour for the SLICE 600 relative to the AMD K50. Of note here is that the fuel consumption rate of the AMD K50 is 1,439 gallons per hour at its 45 knot operating speed, where as the hourly fuel consumption rate of the SLICE 600 is 31% greater at 1,891 gallons per hour, but at a 30 knot operating speed. Vessel maintenance expense is significantly greater for the SLICE 600, reflecting the greater number of annual operating hours, and the higher purchase price of the vessel. Vessel debt repayment expense for the SLICE 600 is also 23% greater than for the AMD K50, a reflection of its greater purchase price. All passenger related expense and revenue elements are greater by about 77% relative to the AMD K50 baseline, commensurate with the 77% increase in passenger boardings that would be required to achieve the 15% internal rate of

return. Overall, total direct operating costs are 84% greater, total indirect operating costs are 73.1% greater, but total revenues are only 66.6% greater for the SLICE 600 relative to the AMD K50 baseline.

For the passenger-only SLICE 400 to achieve the break-even 15% internal rate of return, a total of 167,350 annual passenger boardings are required. This represents an average annual passenger load factor of 59.6%, similar to that of the Incat 74 meter WPC, but requiring far fewer total passengers because of the smaller passenger capacity of the SLICE 400 relative to the Incat 74 meter WPC. Salaries, wages and benefits for both deck and engine crew for the SLICE 400 are about the same as for the AMD K50, with the greater total operating hours for the SLICE 400 offset by its smaller total crew complement. Fuel and lubricant expense for the SLICE 400 is 47% less than for the AMD K50, and only about 25% of that for the SLICE 600. Vessel debt repayment expense for the SLICE 400 is 60% less than for the AMD K50, a reflection of its much more modest purchase price. All passenger related expense and revenue elements are less by about 27% relative to the AMD K50 baseline, commensurate with the 27% reduction in passenger boardings that would be required to achieve the 15% internal rate of return, and vehicle revenues are of course zero. Vessel maintenance expense is also about half that for the AMD K50 baseline, reflecting the SLICE 400's modest purchase price and the smaller powerplant relative to the other three vessels.

Baseline Fare Scenario

For the next set of market and financial analyses, presented in Table 13-6, the baseline AMD K50 annual ridership of 231,060 passengers and 41,129 vehicles serves as the basis from which patronage estimates for the other comparative vessel types are made, according to the observed demand elasticities for RoPax ferry travel with respect to total travel time, fare and frequency of service, and based on sea state and seakeeping analyses, as discussed in Chapter 8. Table 13-6 presents what is referred to here as the "baseline fare scenario," in which the AMD K50 baseline patronage is varied as a function of the comparative vessel travel times, and the relative seakeeping performance of each vessel under the wave climate conditions present in this case study region, but fares are kept the same for all vessel types at the baseline fare levels. The relative financial performance of the comparative vessels are generally the same for the direct operating cost categories such as crew and fuel, as described earlier under the break-even scenarios.

Under this scenario, for the Incat 74 meter WPC it is estimated that there would be approximately 24,000 fewer passenger boardings than in the baseline case with the AMD K50 because of the increase in total one-way travel time relative to the AMD K50 of 13.9%, a travel time increase of about 30 minutes. Based on the seakeeping analysis presented in Chapter 5, both the AMD K50 and Incat 74 meter WPC are assumed to have generally similar seakeeping performance, and therefore there is no change in estimated ridership due to relative seakeeping performance for the Incat 74 meter WPC. The resulting annual patronage of 206,930 passengers and 23,293 vehicles yields an internal rate of return under this scenario for the Incat 74 meter WPC of only 3.33%, significantly less than the 15% baseline internal rate of return achieved with the AMD K50.

For the SLICE 600, it is estimated that there would be approximately 78,000 fewer passenger boardings than in the baseline case with the AMD K50 because of the 45% increase in one-way travel time relative to the AMD K50, or about 1 hour and 45 minutes. Based on the seakeeping analysis presented in Chapter 5 and the methodology presented in Chapter 8 regarding the impact of seakeeping performance on patronage, it is estimated that about 1,150 additional passengers would board the SLICE 600 relative to the baseline case with the AMD K50. The resulting annual patronage of 153,971 passengers and 18,477 vehicles yields no meaningful figure for the internal rate of return, because there are no positive net cash flows generated in any of the years analyzed under this scenario. The annual net cash flow for years 3 through 15 for the SLICE 600 is a deficit of \$9.5 million.

For the SLICE 400, there would be similar changes to the baseline patronage as for the SLICE 600, because of the same operating speed and travel time as the SLICE 600, and similar seakeeping characteristics. The resulting annual patronage of 153,971 passengers yields an internal rate of return 8.97%, much better than that for the SLICE 600, but still less than the 15% baseline internal rate of return achieved with the AMD K50.

Profit Maximizing Fare Scenario

In Table 13-7, an extension of the baseline fare scenario referred to as the "profit maximizing fare scenario" is presented. Under this scenario, fares for the comparative vessel types were varied to determine if a fare level other than the baseline fare could yield an internal rate of return higher than that under the baseline fare scenario. Therefore, in addition to changes in the baseline patronage resulting from different travel times and seakeeping performance, changes in patronage resulting from different fare levels are also considered in combination with these other level of service parameters. As can be seen in Table 13-7, somewhat higher fare levels result in a greater internal rate of return of 9.06% for the Incat 74 meter WPC, and 11.61% for the SLICE 400. However, these are still lower than the 15% internal rate of return achieved with the AMD K50.

TABLE 13-5: MIAMI - KEY WEST "BREAK-EVEN" FINANCIAL ANALYSIS

Results from Discounted Cash Flow Analysis (Amounts and Percent Difference from Baseline)

Vessel Type	Baseline		Scenarios	
	AMD K50	Incat 74m	SLICE 600	SLICE 400
Internal Rate of Return (IRR) ⁽¹⁾	15.00%	15.00%	15.00%	15.00%
Equity Investment - Vessel Purchase	-\$6,000,000	-\$5,780,000	-\$7,400,000	-\$2,400,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	-\$2,147,053	-\$2,172,476	-\$3,577,679	-\$1,270,302
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$5,424,936	-\$5,321,395	-\$9,025,840	-\$2,970,550
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL OPERATING PROFILE⁽²⁾				
Vessel Type	AMD K50	Incat 74m	SLICE 600	SLICE 400
Passenger Capacity Per Vessel	400	597 (49.3%)	600 (50.0%)	400 (0.0%)
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	89	84 (-5.6%)	90 (1.1%)	0 (-100.0%)
Number of Vessels	1	1 (0.0%)	1 (0.0%)	1 (0.0%)
One-Way Vessel Travel Time	3 hrs, 57 min.	4 hrs, 30 min. (13.9%)	5 hrs, 44 min. (45.1%)	5 hrs, 44 min. (45.1%)
Total Annual One-Way Vessel Trips Performed	702	702 (0.0%)	702 (0.0%)	702 (0.0%)
Annual Operating Hours per Vessel	2,773	3,159 (13.9%)	4,025 (45.1%)	4,025 (45.1%)
Adult One-Way Passenger Fare (including ptc's) ⁽³⁾	\$63.25	\$63.25 (0.0%)	\$63.25 (0.0%)	\$63.25 (0.0%)
Total Annual One-Way Passenger Boardings	231,060	250,670 (8.5%)	409,450 (77.2%)	167,350 (-27.6%)
Passenger Capacity Utilization Rate	82.3%	59.8% (-27.3%)	97.2% (18.1%)	59.6% (-27.6%)
Automobile One-Way Fare	\$85.00	\$85.00 (0.0%)	\$85.00 (0.0%)	n/a
Total Annual One-Way Vehicle Boardings	41,129	28,216 (-31.4%)	49,134 (19.5%)	n/a
Vehicle Capacity (AEU) Utilization Rate	72.4%	49.3% (-31.9%)	80.1% (10.6%)	n/a
ANNUAL VESSEL DEBT REPAYMENT				
Vessel Debt Repayment (combined principal and interest)	\$3,094,863	\$2,981,384 (-3.7%)	\$3,816,997 (23.3%)	\$1,237,945 (-60.0%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)				
Direct Operating Costs				
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$1,159,819	\$1,746,563 (50.6%)	\$2,225,250 (91.9%)	\$1,180,350 (1.8%)
Vessel Fuel and Lubricants	\$3,908,196	\$3,112,961 (-20.3%)	\$7,953,580 (103.5%)	\$2,057,943 (-47.3%)
Vessel Maintenance Costs	\$1,018,206	\$1,032,944 (1.4%)	\$1,471,949 (44.6%)	\$477,389 (-53.1%)
Marine Hull Insurance	\$750,000	\$722,500 (-3.7%)	\$925,000 (23.3%)	\$300,000 (-60.0%)
Direct Operating Costs Subtotal	\$6,836,221	\$6,614,967 (-3.2%)	\$12,575,779 (84.0%)	\$4,015,682 (-41.3%)
Indirect Operating Costs				
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$466,594	\$607,500 (30.2%)	\$774,000 (65.9%)	\$367,000 (-17.1%)
Marketing and Advertising	\$780,747	\$789,991 (1.2%)	\$1,300,974 (68.6%)	\$461,928 (-40.8%)
Reservations & Sales	\$598,239	\$599,121 (0.1%)	\$987,880 (65.1%)	\$342,686 (-42.7%)
Docking Fees / Passenger Facility Charges / Shore Operations	\$1,998,453	\$2,153,405 (7.8%)	\$3,452,796 (72.8%)	\$1,419,774 (-29.0%)
Protection and Indemnity (P&I) Insurance	\$69,318	\$75,201 (8.5%)	\$122,835 (77.2%)	\$50,205 (-27.6%)
General Administration	\$1,911,245	\$2,073,028 (8.5%)	\$3,382,983 (77.0%)	\$1,385,638 (-27.5%)
Outside Professional Services	\$230,928	\$250,470 (8.5%)	\$408,371 (76.8%)	\$167,377 (-27.5%)
Onboard Food & Beverage Sales - Cost of Sales	\$750,945	\$814,678 (8.5%)	\$1,330,713 (77.2%)	\$543,888 (-27.6%)
Gift Shop - Cost of Sales	\$311,931	\$338,405 (8.5%)	\$552,758 (77.2%)	\$225,923 (-27.6%)
Onboard Gaming - Cost of Sales	\$286,825	\$313,338 (8.5%)	\$511,813 (77.2%)	\$209,188 (-27.6%)
Indirect Operating Costs Subtotal	\$7,407,223	\$8,015,134 (8.2%)	\$12,825,100 (73.1%)	\$5,193,605 (-29.9%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL REVENUES				
Passenger Fares	\$13,518,454	\$14,665,782 (8.5%)	\$23,955,384 (77.2%)	\$9,791,021 (-27.6%)
Vehicle Fares	\$3,574,082	\$2,451,981 (-31.4%)	\$4,269,745 (19.5%)	\$0 (n/a)
Ancillary Sales - Onboard Food & Beverage Sales	\$1,155,300	\$1,253,350 (8.5%)	\$2,047,250 (77.2%)	\$836,750 (-27.6%)
Ancillary Sales - Gift Shop Sales	\$693,180	\$752,010 (8.5%)	\$1,228,350 (77.2%)	\$502,050 (-27.6%)
Ancillary Sales - Onboard Gaming	\$577,650	\$626,675 (8.5%)	\$1,023,625 (77.2%)	\$418,375 (-27.6%)
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0 (n/a)	\$0 (n/a)	\$0 (n/a)
Total Revenues	\$19,518,666	\$19,749,778 (1.2%)	\$32,524,354 (66.6%)	\$11,548,196 (-40.8%)
EQUILIBRIUM YEARS 3 THROUGH 15 NET CASH FLOW BEFORE TAXES				
Equilibrium Year 3 Net Cash Flow Before Taxes	\$2,180,359	\$2,138,292 (-1.9%)	\$3,306,477 (51.6%)	\$1,100,964 (-49.5%)

Notes:

"no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning.

(1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.

(2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years.

Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years

3 through 15 are presented in the above summary of the discounted cash flow analysis.

(3) Passenger facility charges (pfc).

TABLE 13-6: MIAMI - KEY WEST BASELINE FARE SCENARIO FINANCIAL ANALYSIS

Results from Discounted Cash Flow Analysis (Amounts and Percent Difference from Baseline)

Vessel Type	Baseline	Scenarios		
	AMD K50	Incat 74m	SLICE 600	SLICE 400
Internal Rate of Return (IRR) ⁽¹⁾	15.00%	3.33%	no meaningful figure	8.97%
Equity Investment - Vessel Purchase	-\$6,000,000	-\$5,780,000	-\$7,400,000	-\$2,400,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	-\$2,147,053	-\$1,793,398	-\$1,345,362	-\$1,188,745
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$5,424,936	-\$7,554,557	-\$24,678,258	-\$3,440,754
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL OPERATING PROFILE⁽²⁾				
Vessel Type	AMD K50	Incat 74m	SLICE 600	SLICE 400
Passenger Capacity Per Vessel	400	597 (49.3%)	600 (50.0%)	400 (0.0%)
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	89	84 (-5.6%)	90 (1.1%)	0 (-100.0%)
Number of Vessels	1	1 (0.0%)	1 (0.0%)	1 (0.0%)
One-Way Vessel Travel Time	3 hrs, 57 min.	4 hrs, 30 min. (13.9%)	5 hrs, 44 min. (45.1%)	5 hrs, 44 min. (45.1%)
Total Annual One-Way Vessel Trips Performed	702	702 (0.0%)	702 (0.0%)	702 (0.0%)
Annual Operating Hours per Vessel	2,773	3,159 (13.9%)	4,025 (45.1%)	4,025 (45.1%)
Adult One-Way Passenger Fare (including pfc's) ⁽³⁾	\$63.25	\$63.25 (0.0%)	\$63.25 (0.0%)	\$63.25 (0.0%)
Total Annual One-Way Passenger Boardings	231,060	206,930 (-10.4%)	153,971 (-33.4%)	153,971 (-33.4%)
Passenger Capacity Utilization Rate	82.3%	49.4% (-40.0%)	36.6% (-55.6%)	54.8% (-33.4%)
Automobile One-Way Fare	\$85.00	\$85.00 (0.0%)	\$85.00 (0.0%)	n/a
Total Annual One-Way Vehicle Boardings	41,129	23,293 (-43.4%)	18,477 (-55.1%)	n/a
Vehicle Capacity (AEU) Utilization Rate	72.4%	40.7% (-43.8%)	30.1% (-58.4%)	n/a
ANNUAL VESSEL DEBT REPAYMENT				
Vessel Debt Repayment (combined principal and interest)	\$3,094,863	\$2,981,384 (-3.7%)	\$3,816,997 (23.3%)	\$1,237,945 (-60.0%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)				
Direct Operating Costs				
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$1,159,819	\$1,746,563 (50.6%)	\$2,225,250 (91.9%)	\$1,180,350 (1.8%)
Vessel Fuel and Lubricants	\$3,908,196	\$3,112,961 (-20.3%)	\$7,953,580 (103.5%)	\$2,057,943 (-47.3%)
Vessel Maintenance Costs	\$1,018,206	\$1,032,944 (1.4%)	\$1,471,949 (44.6%)	\$477,389 (-53.1%)
Marine Hull Insurance	\$750,000	\$722,500 (-3.7%)	\$925,000 (23.3%)	\$300,000 (-60.0%)
Direct Operating Costs Subtotal	\$6,836,221	\$6,614,967 (-3.2%)	\$12,575,779 (84.0%)	\$4,015,682 (-41.3%)
Indirect Operating Costs				
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$466,594	\$607,500 (30.2%)	\$774,000 (65.9%)	\$387,000 (-17.1%)
Marketing and Advertising	\$780,747	\$652,145 (-16.5%)	\$489,222 (-37.3%)	\$424,998 (-45.6%)
Reservations & Sales	\$598,239	\$494,580 (-17.3%)	\$371,485 (-37.9%)	\$315,289 (-47.3%)
Docking Fees / Passenger Facility Charges / Shore Operations	\$1,998,453	\$1,792,552 (-10.3%)	\$1,345,093 (-32.7%)	\$1,309,396 (-34.5%)
Protection and Indemnity (P&I) Insurance	\$69,318	\$62,079 (-10.4%)	\$40,191 (-33.4%)	\$46,191 (-33.4%)
General Administration	\$1,911,245	\$1,712,175 (-10.4%)	\$1,275,260 (-33.3%)	\$1,275,260 (-33.3%)
Outside Professional Services	\$230,928	\$208,869 (-10.4%)	\$154,020 (-33.3%)	\$154,020 (-33.3%)
Onboard Food & Beverage Sales - Cost of Sales	\$750,945	\$672,524 (-10.4%)	\$500,405 (-33.4%)	\$500,405 (-33.4%)
Gift Shop - Cost of Sales	\$311,931	\$279,356 (-10.4%)	\$207,861 (-33.4%)	\$207,861 (-33.4%)
Onboard Gaming - Cost of Sales	\$288,825	\$258,683 (-10.4%)	\$192,464 (-33.4%)	\$192,464 (-33.4%)
Indirect Operating Costs Subtotal	\$7,407,223	\$6,738,443 (-9.0%)	\$5,358,000 (-27.7%)	\$4,812,883 (-35.0%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL REVENUES				
Passenger Fares	\$13,518,454	\$12,106,717 (-10.4%)	\$9,008,257 (-33.4%)	\$9,008,257 (-33.4%)
Vehicle Fares	\$3,574,082	\$2,024,132 (-43.4%)	\$1,605,608 (-55.1%)	\$0 (n/a)
Ancillary Sales - Onboard Food & Beverage Sales	\$1,155,300	\$1,034,652 (-10.4%)	\$769,854 (-33.4%)	\$769,854 (-33.4%)
Ancillary Sales - Gift Shop Sales	\$693,180	\$620,791 (-10.4%)	\$461,913 (-33.4%)	\$461,913 (-33.4%)
Ancillary Sales - Onboard Gaming	\$577,650	\$517,326 (-10.4%)	\$384,927 (-33.4%)	\$384,927 (-33.4%)
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0 (n/a)	\$0 (n/a)	\$0 (n/a)
Total Revenues	\$19,518,666	\$16,303,617 (-16.5%)	\$12,230,559 (-37.3%)	\$10,624,951 (-45.6%)
EQUILIBRIUM YEARS 3 THROUGH 15 NET CASH FLOW BEFORE TAXES				
Equilibrium Year 3 Net Cash Flow Before Taxes	\$2,180,359	-\$31,177 (-101.4%)	-\$9,518,218 (-536.5%)	\$558,441 (-74.4%)

Notes:

"no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning.

(1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis.

(2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years.

Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years

3 through 15 are presented in the above summary of the discounted cash flow analysis.

(3) Passenger facility charges (pfc)

TABLE 13-7: MIAMI - KEY WEST PROFIT MAXIMIZING FARE SCENARIO

Results from Discounted Cash Flow Analysis (Amounts and Percent Difference from Baseline)

Vessel Type	Baseline	Scenarios		
	AMD K50	Incat 74m	SLICE 600	SLICE 400
Internal Rate of Return (IRR) ⁽¹⁾	15.00%	9.06%	no meaningful figure	11.61%
Equity Investment - Vessel Purchase	-\$6,000,000	-\$5,780,000	-\$7,400,000	-\$2,400,000
Equity Investment - Start-Up Expenses & Provision of Working Capital	-\$2,147,061	-\$1,776,152	-\$1,310,098	-\$1,129,120
Equity Investment - Cash Deficits (if any) Years 1 & 2	-\$5,424,911	-\$6,239,767	-\$24,412,428	-\$3,155,609
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL OPERATING PROFILE⁽²⁾				
Vessel Type	AMD K50	Incat 74m	SLICE 600	SLICE 400
Passenger Capacity Per Vessel	400	597 (49.3%)	600 (50.0%)	400 (0.0%)
Vehicle Capacity Per Vessel (Automobile Equivalent Units)	89	84 (-5.6%)	90 (1.1%)	0 (-100.0%)
Number of Vessels	1	1 (0.0%)	1 (0.0%)	1 (0.0%)
One-Way Vessel Travel Time	3 hrs, 57 min.	4 hrs, 30 min. (13.9%)	5 hrs, 44 min. (45.1%)	5 hrs, 44 min. (45.1%)
Total Annual One-Way Vessel Trips Performed	702	702 (0.0%)	702 (0.0%)	702 (0.0%)
Annual Operating Hours per Vessel	2,773	3,159 (13.9%)	4,025 (45.1%)	4,025 (45.1%)
Adult One-Way Passenger Fare (including pfc's) ⁽³⁾	\$63.25	\$86.00 (36.0%)	\$73.00 (15.4%)	\$74.00 (17.0%)
Total Annual One-Way Passenger Boardings	231,060	156,234 (-32.4%)	132,244 (-42.8%)	130,016 (-43.7%)
Passenger Capacity Utilization Rate	82.3%	37.3% (-54.7%)	31.4% (-61.8%)	46.3% (-43.7%)
Automobile One-Way Fare	\$85.00	\$115.58 (36.0%)	\$98.10 (15.4%)	n/a
Total Annual One-Way Vehicle Boardings	41,129	17,586 (-57.2%)	15,869 (-61.4%)	n/a
Vehicle Capacity (AEU) Utilization Rate	72.4%	30.7% (-57.6%)	25.9% (-64.3%)	n/a
ANNUAL VESSEL DEBT REPAYMENT				
Vessel Debt Repayment (combined principal and interest)	\$3,094,863	\$2,981,384 (-3.7%)	\$3,816,997 (23.3%)	\$1,237,945 (-60.0%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL CASH EXPENSES (OTHER THAN INTEREST)				
Direct Operating Costs				
Salaries, Wages and Benefits (Deck and Engine, Officers & Crew)	\$1,159,819	\$1,746,563 (50.6%)	\$2,225,250 (91.9%)	\$1,180,350 (1.8%)
Vessel Fuel and Lubricants	\$3,908,196	\$3,112,961 (-20.3%)	\$7,953,580 (103.5%)	\$2,057,943 (-47.3%)
Vessel Maintenance Costs	\$1,018,206	\$1,032,944 (1.4%)	\$1,471,949 (44.6%)	\$477,389 (-53.1%)
Marine Hull Insurance	\$750,000	\$722,500 (-3.7%)	\$925,000 (23.3%)	\$300,000 (-60.0%)
Direct Operating Costs Subtotal	\$6,836,221	\$6,614,967 (-3.2%)	\$12,575,779 (84.0%)	\$4,015,682 (-41.3%)
Indirect Operating Costs				
Salaries, Wages and Benefits (Onboard Passenger Service Crew)	\$466,594	\$607,500 (30.2%)	\$774,000 (65.9%)	\$387,000 (-17.1%)
Marketing and Advertising	\$780,749	\$645,874 (-17.3%)	\$476,399 (-39.0%)	\$410,589 (-47.4%)
Reservations & Sales	\$598,241	\$507,723 (-15.1%)	\$368,250 (-38.4%)	\$311,485 (-47.9%)
Docking Fees / Passenger Facility Charges / Shore Operations	\$1,998,453	\$1,374,309 (-31.2%)	\$1,165,845 (-41.7%)	\$1,111,784 (-44.4%)
Protection and Indemnity (P&I) Insurance	\$69,318	\$46,870 (-32.4%)	\$39,673 (-42.8%)	\$39,005 (-43.7%)
General Administration	\$1,911,245	\$1,293,931 (-32.3%)	\$1,096,012 (-42.7%)	\$1,077,628 (-43.6%)
Outside Professional Services	\$230,828	\$156,280 (-32.3%)	\$132,319 (-42.7%)	\$130,093 (-43.7%)
Onboard Food & Beverage Sales - Cost of Sales	\$750,845	\$507,761 (-32.4%)	\$429,783 (-42.8%)	\$422,550 (-43.7%)
Gift Shop - Cost of Sales	\$311,931	\$210,916 (-32.4%)	\$178,529 (-42.8%)	\$175,521 (-43.7%)
Onboard Gaming - Cost of Sales	\$288,825	\$195,293 (-32.4%)	\$165,305 (-42.8%)	\$162,519 (-43.7%)
Indirect Operating Costs Subtotal	\$7,407,229	\$5,548,456 (-25.1%)	\$4,826,126 (-34.8%)	\$4,228,154 (-42.9%)
EQUILIBRIUM YEARS 3 THROUGH 15 ANNUAL REVENUES				
Passenger Fares	\$13,518,454	\$12,428,423 (-8.1%)	\$9,929,770 (-33.9%)	\$8,899,561 (-34.2%)
Vehicle Fares	\$3,574,150	\$2,077,958 (-41.9%)	\$1,591,649 (-55.5%)	\$0 (n/a)
Ancillary Sales - Onboard Food & Beverage Sales	\$1,155,300	\$781,171 (-32.4%)	\$661,220 (-42.8%)	\$650,078 (-43.7%)
Ancillary Sales - Gift Shop Sales	\$693,180	\$469,702 (-32.4%)	\$396,732 (-42.8%)	\$390,047 (-43.7%)
Ancillary Sales - Onboard Gaming	\$577,650	\$390,585 (-32.4%)	\$330,610 (-42.8%)	\$325,039 (-43.7%)
Federal, State or Local Operating or Non-Operating Subsidy	\$0	\$0 (n/a)	\$0 (n/a)	\$0 (n/a)
Total Revenues	\$19,518,734	\$16,146,839 (-17.3%)	\$11,909,980 (-39.0%)	\$10,264,724 (-47.4%)
EQUILIBRIUM YEARS 3 THROUGH 15 NET CASH FLOW BEFORE TAXES				
Equilibrium Year 3 Net Cash Flow Before Taxes	\$2,180,422	\$1,004,031 (-54.0%)	-\$9,308,922 (-526.9%)	\$782,943 (-64.1%)

Notes

"no meaningful figure" means that there were no positive net cash flows in any of the years analyzed, and therefore the calculation of the internal rate of return has no meaning

(1) The return on equity investment over the entire project life, calculated on a discounted cash flow basis

(2) From years 16 to 25, vessel debt repayment expenses is zero for all vessel type scenarios because the loan term is 15 years.

Rather than duplicate the above for years 16 to 25 when vessel debt repayment expenses is zero for all vessel types, only years

3 through 15 are presented in the above summary of the discounted cash flow analysis.

(3) Passenger facility charges (pfc)

13.9 Conclusions

Estimates of the baseline passenger and vehicle patronage for the Miami to Key West ferry route, as reflected in the proposed Boomerang Fast Ferry baseline AMD K50 vessel and their proposed operating profile of one round trip daily, appear overly optimistic. Because of its much higher direct operating costs, and much greater overall travel time, the SLICE 600 is not profitable under any of the scenarios considered, however the SLICE 400 appears to be better suited for this market, with a passenger capacity consistent with what appear to be actual travel market conditions, and lower operating costs. Even so, the SLICE 400 is less profitable than the baseline AMD K50 in all scenarios considered, but more profitable than the 74 meter WPC. Although draft constraints with the SLICE 600 are not as severe as in some other case study markets, its 21.5 foot main vehicle freeboard height would likely not interface adequately with the planned ferry terminal facilities. There would be relatively little additional ridership due to the superior seakeeping ability of SLICE because of the relatively benign sea state conditions encountered in this region. The one-way travel time of nearly 6 hours for both the SLICE 400 and SLICE 600 would decrease ridership relative to the other boats considered, and would also severely limit the possibility of any type of "day trip" travel on the route (the same constraint would hold for the 4 hour baseline travel time with the AMD K50). Round trip day travel would likely be only a small fraction of overall trips. The deep draft of the SLICE 600 would also result in marginally acceptable operating conditions in both Key West Harbor and the Port of Miami at certain berths and in certain channels.

Chapter 14: Case Study #6 Offshore Oil Industry Crew Boat

14.1 Introduction

As offshore oil exploration and production has pushed to greater depths and correspondingly greater distances offshore, transportation of personnel to the rigs has become a more challenging problem. With greater distances to cover, not only has vessel speed become of greater importance in keeping transport times down to a reasonable level, but reliability of vessel speed, especially in the higher sea states common offshore, can also be a factor in determining operational effectiveness. Ride quality for the rig crews has become a greater concern as the recognition of the effects of fatigue has increased. The ability of SLICE vessels to operate comfortably and at near full speed in rough seas is a possible advantage over other vessel types for this application. This case study quantifies the benefits of superior seakeeping performance in the context of the operating economics of a typical oil rig crewboat.

For the purposes of the study, a hypothetical SLICE crewboat is evaluated versus a comparable monohull, a high-speed catamaran and a SWATH (small waterplane area twin hull). The evaluation assumes a Gulf of Mexico setting, as the vast majority of North American off-shore oil rigs are located there (see Figure 14-1), and uses the appropriate sea state data for this region. A detailed description of the sea state data and its implications for the sea conditions a vessel would face during a voyage appears in Chapter 8.

The conventional monohull has been the vessel of choice for crew transportation, with speeds ranging from 16-20 knots for some vessels and up to 30 knots for "fast" crewboats. Although monohulls are capable of relatively high speeds, in rough seas monohulls must slow down due to safety concerns relating to overloading of the structure and dangerous motions for personnel, as well as the additional power consumed passing through the waves. Even at lower speeds, the ride in higher sea states can be uncomfortable for monohull passengers.

Catamarans are now in common use as high-speed ferries around the world and would appear to make a good candidate for transportation of passengers to oil rigs. However, even wave piercing designs are not particularly effective in rough seas. Ride quality in such conditions can be poor with passengers experiencing jarring impacts, inducing fatigue and motion sickness quickly. As with monohulls, even at low speeds higher sea states can lead to fairly uncomfortable rides.

SWATH vessels have been in use for many years for specialized applications requiring the excellent seakeeping characteristics of the hullform. Trico Marine recently commissioned the high-speed SWATH crewboat *Stillwater River* for use in the oilfields off the Atlantic coast of Brazil. This vessel is capable of 29 knots and is reported to maintain a speed of 28 knots even in ten-foot head seas, demonstrating the exceptional seakeeping characteristics identified with the SWATH hullform.

The SLICE crewboat is essentially equivalent to the SLICE 400, with the same dimensions and two Lycoming TF40 gas turbine powerplants driving two controllable pitch propellers. The four crewboat study vessels differ in hull form, installed power, powerplant type, maximum cruise speed and acquisition cost. The vessels are comparable on the basis of carrying capacity (rig crew passengers) and overall gross dimensions. The particulars of the three study vessels being compared to the SLICE crewboat are based on existing real world vessels. Table 14-1 summarizes the vessel particulars.

FIGURE 14-1: GULF OF MEXICO OIL AND GAS FIELD LOCATIONS

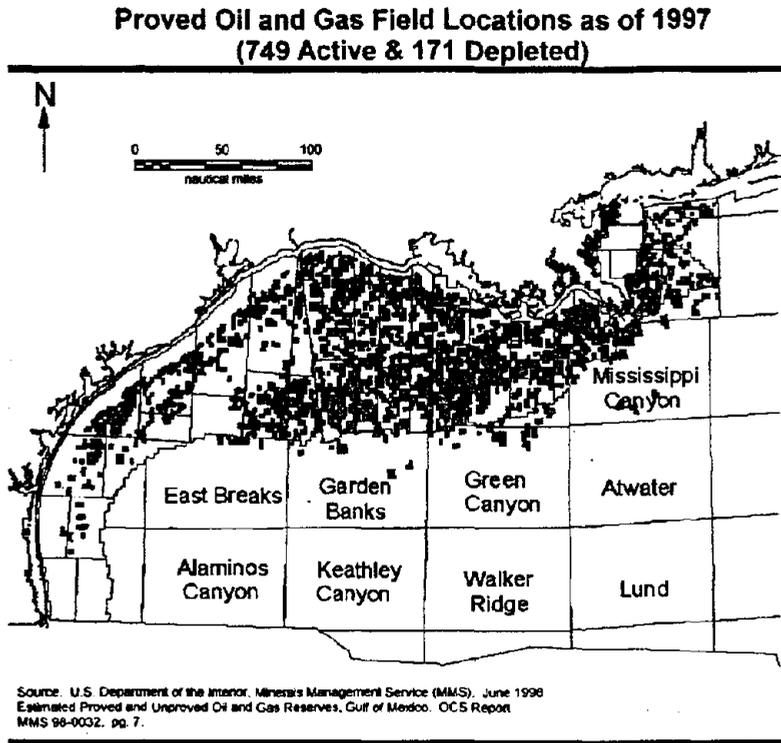


TABLE 14-1: CREWBOAT STUDY VESSELS

Vessel Type	Baseline Crewboat Case				Specific Fuel Consumption	
	Purchase Price (US \$)	Speed (kts)	Length (ft)	MCR Power (HP)	High speed (g/kW-hr)	Low speed (g/kW-hr)
Conventional monohull	\$5,000,000	24	125	4,000	235	294
Catamaran	\$7,000,000	34	120	5,500	235	294
SWATH	\$12,800,000	27	110	10,700	251	439
SLICE	\$12,000,000	30	110	6,800	300	525

14.2 Comparative Cost Analysis

A spreadsheet model was developed as a means of side-by-side comparison of the economic factors involved in operating each of the four vessel types addressed above. It was considered outside the scope of this study to develop revenue projections for this case, so a Net Present Value (NPV) analysis typically used in support of capital investment decisions is not provided. However the cost estimation model presents data in a form that is meaningful in immediate terms to an operator, i.e., the breakdown of average daily costs associated with operation.

The SLICE crewboat is compared against other hull types carrying an equivalent nominal passenger capacity. Costs estimated include those associated with vessel financing and insurance, fuel and lube oil, vessel mainte-

nance, crew compensation, and compensation of the passengers, the rig crews riding to and from the rigs. The results presented reflect what was considered to be the “most probable” case for each variable.

14.2.1 Study Description

The four representative vessels are assumed to have the same trip profile, with the exception of differing cruise speeds for block segments. The trip profile consists of a 20 nmi harbor leg, followed by a 100 nmi leg to shuttle rig workers from shore to an offshore rig, and then 6 short “hops” between rigs within close geographic proximity to each other before a return leg to the shore base. All vessels were assumed to complete three round trips per week, for a total of 150 annual round trips. Table 14-2 describes the financial assumptions made in the spreadsheet as well as the definition of the crewboat trip.

TABLE 14-2: CREWBOAT STUDY FINANCIAL ASSUMPTIONS AND TRIP DEFINITION

	Value	Units	Assumptions
Financing period	8	Years	
Look period	8	Years	Assume first few years of life, corresponding to loan period
Amount financed	100	Percent	100% of delivery price financed
Annual Interest Rate	8	Percent	
Vessel crew size	5	Persons	
Avg. vessel crew rate	50	\$/hour	Burdened rate
Rig crew transport size	75	Persons	
Avg. rig crew rate	50	\$/hour	Burdened rate
Voyages per week per vessel	3		
Fuel Cost	0.9	\$/gallon	Marine grade diesel oil, based on bulk quantity
Number of trips per year:	150	trips	3 trips per week
Leg "0" (Harbor)	20	NM	Low speed = 8 knots
Leg 1	100	NM	High speed
Leg 2	10	NM	90% distance high-spd; 10% low spd; + 30 min station keeping
Leg 3	10	NM	90% distance high-spd; 10% low spd; + 30 min station keeping
Leg 4	15	NM	90% distance high-spd; 10% low spd; + 30 min station keeping
Leg 5	10	NM	90% distance high-spd; 10% low spd; + 30 min station keeping
Leg 6	10	NM	90% distance high-spd; 10% low spd; + 30 min station keeping
Leg 7	100	NM	High speed
Leg 8 (Harbor)	20	NM	Low speed = 8 knots

Comparison between the four crewboat vessels is done on the basis of average daily costs associated with operation, with the assumption that independent of the vessel type, each trip has the same value to the user: delivering 75 rig crew members from shore to off-shore rigs, as well as stopping at the 6 rigs included in a single trip. The average daily cost includes costs associated with vessel financing and insurance, fuel and lubrication oil, vessel maintenance, crew compensation, and compensation of the passengers, the rig crews riding to and from the rigs.

Purchase Cost

The model examines costs over the first several years of life of the vessel. The cost calculation routine simply calculates an annual loan repayment factor based on the standard formula, given an 8% annual interest rate and an 8 year loan repayment period.

Insurance Cost

The annual cost of insurance on the vessel is assumed to equal 2% of its value, which is taken to be the construction cost. As a conservative assumption, depreciation is ignored.

Fuel and Lubricants Cost

Fuel consumption is based on the estimated power requirement for each vessel at the operating conditions for particular trip segment. For the sake of simplifying the spreadsheet model, power requirements were broken into high speed segments and low speed segments. It was assumed that vessels operated at 100% of their maximum continuous rating (MCR) during high speed segments and at an average rating of 33% of the particular vessel's MCR power during low speed segments. Fuel flows for each vessel were therefore also stratified into two values: one at MCR and one at 33% of MCR. For the diesel powered monohull and catamaran, the known specific fuel consumption at MCR (usually at or near the minimum SFC for an engine) was multiplied by 1.25 at the low power setting. For the gas turbine, powered SWATH and SLICE vessels, the SFC was multiplied by 1.75 to reflect the steep increase in specific fuel consumption for gas turbines as part power settings. For a discussion of this phenomenon, please see Section 5.2.

Cost of lubricants consumed is assumed to be directly proportional to the cost of fuel consumed. This assumption is based on two factors: first, that lubricant consumption is roughly proportional to the engine output, which is also roughly proportional to fuel consumption; and second, that lubricant pricing exhibits the same trends as fuel oil pricing because most lubricants are petroleum based. Lubricant cost is assumed to be equivalent to $4/10^{\text{th}}$ of a percent of fuel cost for all four study vessels. This factor is consistent with the lubricant cost estimate used in the route case studies.

Maintenance Cost

Maintenance cost was estimated from two components; one based on the vessel acquisition cost, and the other a function of vessel acquisition cost and annual vessel operating hours. The first component represents maintenance that takes place as a function of vessel age, such as painting, interior refurbishment and hull maintenance. The second component takes into account maintenance costs which are driven by hours of usage, which primarily involve the vessel engines and drive system. Chapter 8 contains a more complete explanation of maintenance cost estimation. The methodology used for the crewboat case study is consistent with the route case studies.

Ship's Crew Compensation Cost

Crew compensation is estimated by multiplying the vessel hours needed to complete one trip by the number of crew aboard and by a "work factor" coefficient which estimates the percent of time spent aboard that a crew member is actually working. The value for this coefficient is 0.625, or 15 out of every 24 hours. This is based on an assumed 12 hours-on/12 hours-off watchstanding schedule. It also assumes that during the 12 hours off, each crew member may spend an additional three hours performing chargeable tasks, such as cooking, cleaning, or maintenance. A crew size of five with an average burdened labor rate of \$50 is assumed for all the crew boat study vessels. The time to complete a trip varies as a function of vessel cruising speed, consequently each of the four crewboat study vessels have differing crew costs.

Port Costs

All vessels compared are assumed to be within the same Gross Registered Tonnage (GRT) bracket and therefore charged equal port fees. Attempts to quantify port fees would have been very difficult since they vary widely from port to port. Another argument against the inclusion of such costs in this model is that the costs themselves would most likely be accounted as separate from vessel operating expenses.

Passenger (Rig Crew) Compensation During Transit

Cost of compensation for the rig crew passengers has the potential to be the largest cost variable that the service of transporting crew can impact. It does not necessarily show up as a cost to the operator because often crew boat services are provided on a contract basis to the oil companies who operate the rigs, but it does have an enormous bearing on the overall competitiveness of any one boat over another. The passengers' time spent aboard per round trip is defined as the time needed to transit from shore to the first stopping point, and then back again. To simplify the calculation it ignores the time spent "hopping" from rig to rig. This omission is justified because, given the shorter distances and the maneuvering requirements involved in rig hopping, a speed difference between hulls will result in a relatively small difference in passenger time spent aboard. The model multiplies number of passengers times the "out-and-back" time to calculate a number of man-hours spent per voyage.

Delay and Seasickness Cost Due to Sea Conditions

The cost of delays and loss of productivity due to kinetosis (seasickness) in rough sea conditions for a crew boat quantifies the possible benefits of a SLICE-type vessel's seakeeping ability. High sea states could cause delays either by causing cancellation of a trip due to safety concerns, or cause the crew boat to proceed at a slower pace due to either safety or powering limitations in high sea states. The later is more likely, except in the event of a major tropical storm, which might entirely halt rig support operations.

The cost of any sea condition caused delay was quantified as being equal to the cost of additional ships crew wages and rig crew (passenger) wages during the delay time. The average sea state caused delay is derived from significant wave height data and sea state frequency estimations described in Section 8.2.5, along with predicted vessel motions as modeled by SeaSpeed discussed in Section 5.3, combined with ISO 2361 standards for vessel motions and kinetosis.

Table 14-3 reflects the results of the combined analysis in predicting how often a crewboat of a particular hull type operating in the Gulf of Mexico year round would face "delaying" sea states.

TABLE 14-3: SEA STATE DELAY FREQUENCY

Gulf of Mexico	Delay Frequency	Other Factors
Monohull	28.1 % of time	Delay Factor 0.25
Catamaran	28.1 % of time	Kinetosis Frequency in Delay Sea States 0.1
SWATH	14 % of time	Kinetosis Recovery time (hours) 1
SLICE	0.1 % of time	

Because adverse sea conditions probably will only cause a delay, and rarely an outright cancellation, a delay factor equal to 0.25 was incorporated into the crew boat spreadsheet. This delay factor implies that trip time is increased on average 25% when the sea state causes the vessel motions to exceed ISO 2361 standards for kinetosis criteria during a trip. See Section 5.3.2 for a further discussion of the relationship between sea states, vessel motions and kinetosis.

In addition to the cost of delays caused by high sea states, a cost due to seasickness induced loss of productivity was also included, as it was felt this would also vary between vessel types. The basic premise is that for trips where sea states are severe enough to cause delay to crewboats, that 10% of the rig crew being transported will suffer from sea sickness severe enough to prevent them from carrying out their work for 1 hour on average after

they reach their rig. The cost was calculated by multiplying the annual number of trips by the severe sea state frequency that is appropriate for a given crewboat type, and then by the number of rig crew members per trip (75), multiplied by the hourly burdened rig crew rate and the 0.10 sea sickness occurrence factor.

14.2.2 Case Study Results

Figure 14-2 and Figure 14-3 present the results for the daily average cost for the four study crewboats in the Gulf of Mexico, using the cost estimation methods and assumptions described in the previous section. The average daily cost was derived simply by calculating a total annual cost of ownership and operation and dividing by 365.

FIGURE 14-2: CREW BOAT AVERAGE DAILY COSTS (INCLUDING RIG CREW COST DURING TRANSIT)

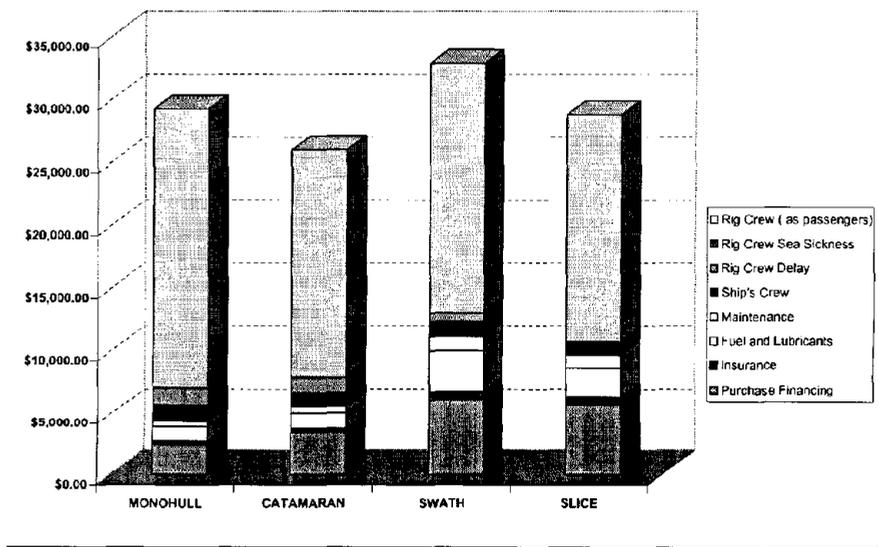


FIGURE 14-3: CREW BOAT AVERAGE DAILY COSTS (NOT INCLUDING RIG CREW COST DURING TRANSIT)

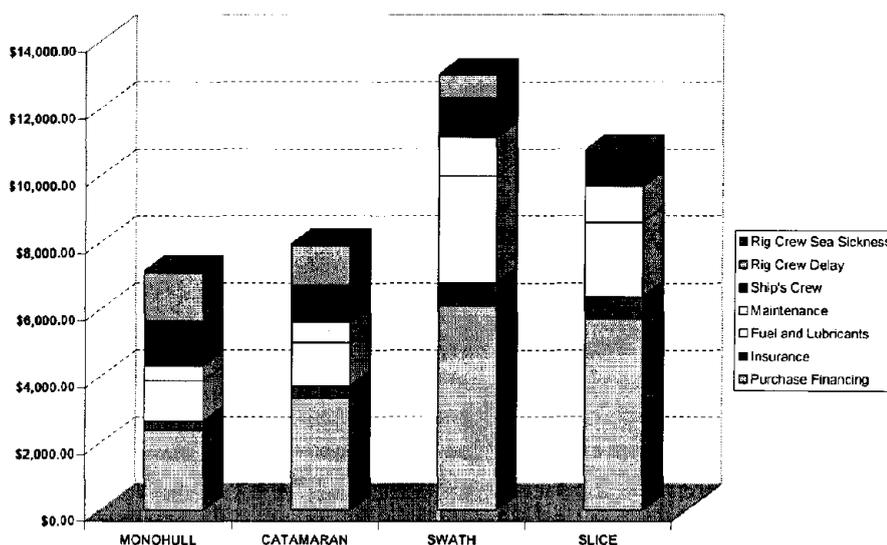


Figure 14-2 includes the cost of paying the rig crew *during transit* as a part of the overall crew boat cost. Clearly in this case rig crew costs comprise the single largest expense for all four crew boat types. While rig crew compensation would be paid by the rig owner as opposed to the crew boat operator, for the purpose of estimating the overall cost of transporting the rig crews and operating the crew boat, it is relevant to include the cost of the rig crew during transit as a cost component. In some cases, crewboats are operated by the rig owner so this method of accounting makes even more sense.

It can be seen that when the rig crew compensation is included in overall costs, the SWATH crewboat is the most expensive vessel, both because its operating expenses are the highest and because it does not offer a substantial savings in transit time with its 27 knot cruise speed. It is interesting to note that the monohull has the lowest operating and ownership costs, however, its slower cruise speed and substantial delay penalty combine to make it the second most expensive vessel on a daily basis. The catamaran has the lowest daily cost, due to moderate operating and ownership costs and its high cruise speed, which gives it the lowest rig crew transit cost component.

Figure 14-3 presents the daily costs of the four crewboats, minus rig crew compensation during *normal* (non-delayed) transit. This allows more detailed examination of the operation and ownership cost components, as well as the sea state delay and kinetosis related costs.

Figure 14-3 illustrates the capital cost financing and insurance together are the largest contributor to cost of ownership. Fuel and lubricant costs are the second greatest contributor to daily average costs, with the highly powered SWATH vessel running up the highest costs in this area. The lower powered SLICE is quite a bit more

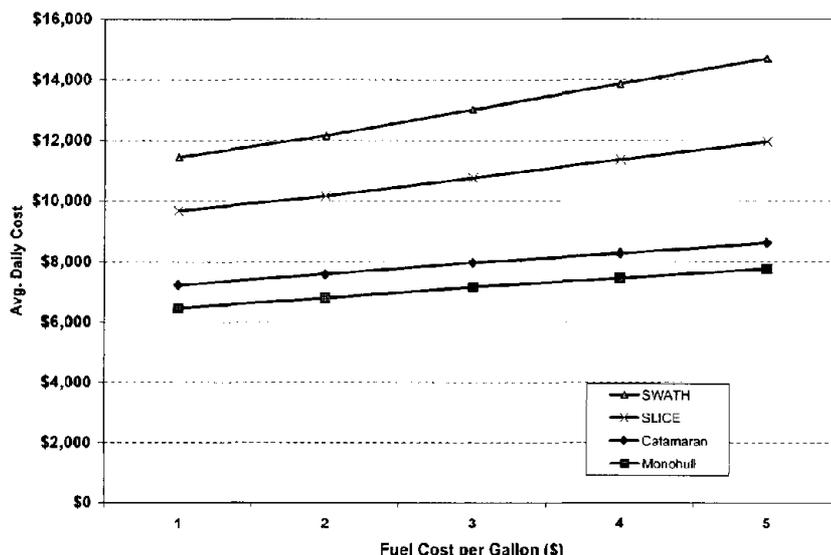
fuel efficient than the SWATH with roughly a 30% lower cost for fuels and lubricants combined. However, the fuel and lubricant cost for both the monohull and catamaran crew boats are nearly 50% lower than the SLICE.

The seakeeping capabilities of the four crew boats imply a significant cost differential due to delays of rig crews, to the detriment of monohull and catamaran operations. SWATH costs here are much lower and SLICE costs essentially non-existent. However, sea sickness productivity loss is hardly noticeable even for the monohull and catamaran, the two most sea state sensitive vessels. Table 14-4 includes the results plotted in Figure 14-2 and Figure 14-3.

TABLE 14-4: CREW BOAT AVERAGE DAILY COSTS

	MONOHULL	CATAMARAN	SWATH	SLICE
Purchase Financing	\$2,383.76	\$3,337.27	\$6,102.44	\$5,721.03
Insurance	\$273.97	\$383.56	\$701.37	\$657.53
Fuel and Lubricants	\$1,212.41	\$1,297.33	\$3,173.50	\$2,233.99
Maintenance	\$465.87	\$611.17	\$1,164.27	\$1,070.23
Ship's Crew	\$1,327.40	\$1,109.00	\$1,181.78	\$1,060.19
Rig Crew Delay	\$1,443.49	\$1,178.15	\$669.24	\$4.49
Rig Crew Sea Sickness	\$43.30	\$43.30	\$21.58	\$0.15
TOTAL w/o rig crew transit cost	\$7,150.22	\$7,959.78	\$13,014.16	\$10,747.63
Rig Crew (as passengers)	\$22,034.74	\$17,992.20	\$19,811.82	\$17,984.10
TOTAL w/ rig crew	\$29,184.96	\$25,951.98	\$32,825.97	\$28,731.73

The fuel price sensitivity analysis, presented in Figure 14-4 showed that fuel price has a relatively minor bearing on overall cost of operation, with SLICE and SWATH still being significantly more expensive to operate regardless of the fuel cost. Fuel cost was assumed to range between forty cents and \$1.40 per gallon for bulk quantity marine grade diesel oil in increments of twenty-five cents. The relative positioning of the four crew boat types did not change greatly, other than the SWATH and SLICE becoming even more expensive to operate as fuel price rose.

FIGURE 14-4: CREW BOAT OVERALL DAILY COST SENSITIVITY TO FUEL PRICE

14.3 Conclusions

Vessel purchase price and vessel cruise speed are the apparently most significant cost drivers. A faster, relatively cheap monohull would seem to offer operating and ownership costs low enough to offset the occasional sea state caused delay. Similarly, if rig crew transit costs were included in the average daily cost accounting, a faster transit time in calm states would offset the delay costs in rough sea states and the sea sickness induced losses seem trivial in all cases. A similar case could be made for a capable catamaran, if the purchase price can be kept near the cost for a monohull, or a significant cruise speed advantage can be realized.

The SLICE and SWATH vessels do not appear to offer significant advantages over less expensive, more fuel efficient and faster monohull and catamaran crew boats. This evaluation is based on fairly reasonable assumptions on the response of operators and rig crew passengers to operations in statistically determined sea state conditions, and the overall effect is not very significant in terms of average daily operating costs.

Better information on the actual operating practices of crew boat owners in response to high sea states might shed more light on the oil industry's valuation of kinetosis prevention and timeliness of rig crew delivery. The difference in crew work effectiveness and, perhaps, the need to take action to enhance the safety on board the rigs by improving the comfort level on the transport may be the motivation behind the commissioning of vessels such as the *Stillwater River* mentioned in the introduction to this section.

Chapter 15: Case Study #7 ▣ Excursion Boat Case Study

15.1 Introduction

Passenger excursion vessels have grown considerably more popular in recent years, following the general trend of marine travel in the United States. Excursion vessels have proliferated into many services, including gambling vessels, whale watching boats, scuba diving boats, tour boats, and charter offshore fishing vessels. Chapter 6 showed that many could be candidates for SLICE because of ride quality, weather reliability, and sustained speed in seaways. The gaming boat was chosen because of its high revenue potential, the strong incentive to operate to schedule, and the current growth in that particular service.

SLICE's operating performance offers two clear inducements to excursion boat operators. Its seakeeping characteristics are superior to those of the conventional monohull and most other high speed hullforms and surpass even those of the SWATH. The results of the seakeeping analysis in Chapter 5 indicate a clear advantage for SLICE, particularly at high speed and also at slow speed and in hove to condition. The passenger comfort can be clearly measured, at least in comparative terms, by the ISO 2631 kinetosis standard, which SLICE easily attains in all but the most challenging conditions.

This case study is a gaming boat service in South Florida, the key to which is passenger comfort on the SLICE and other platforms and the resulting likelihood of spending money for on-board services, and repeating as customers on subsequent trips. Another potentially important benefit to the operator from SLICE is the enhanced reliability of the service offered, especially as the public gains awareness of the comfort available even in rough weather. The experience of the Navatek SWATH excursion operators in Hawaii has been that booking agents and the public at large learned of the vessels' reliability over time and that business improved as a result.

The U.S. excursion market is currently dominated by monohulls, which are found in services from charter fishing to whale watching to luxury dinner cruises. Catamarans are now making inroads, particularly in whale watching where speed to the viewing area is essential. The Navatek SWATHs have been in the dinner cruise market for some time, and there is now a SWATH casino boat operating in Florida, the CLOUD X. This market is the case study selection because of its high revenue, year round schedule demands, and ocean service aspect. South Florida is among the most likely markets for this service because of its population density and high tourist trade. Its sea state characteristics are quite typical among those examined in Chapter 8. It is, in short, both a realistic market opportunity and an appropriate SLICE application.

The analysis continues with a comparison of limited scope to four other markets. All factors are held constant except for the sea state characteristics, which are varied to those found in other markets considered in this study: Milwaukee-Muskegon, Saint John-Digby, Gulf of Mexico, and Miami-Key West.

15.1.1 Approach

This case is unique among those herein because it includes significant onboard revenue projections and the effects on revenue of vessel performance. The sea state data reported in Chapter 8 are compared to the results of the ISO 2631 kinetosis analysis in Chapter 5 and combined for results showing the frequency of loss of service reliability or serious degradation of passenger comfort. The economic outcome is measured in lost revenue. Daily operating costs are found, including capital debt service, personnel, consumables, and maintenance. Net income for the four vessel types is the final result after the average daily reliability based revenues are accounted for.

15.1.2 The Competition

As seen in Chapter 5, each vessel type offers advantages and drawbacks which must weigh into the operator's decision for providing a service. Monohulls have low capital cost and good efficiency at lower speeds, but high wavemaking resistance and poor seakeeping at high speeds. Catamarans offer the capability of high speed at reasonable cost and installed horsepower levels, but like monohulls, do not perform as well as SLWATH/SLICE types in rough seas.

SWATHs have been in use for many years for specialized applications, mostly government and military, and are now gaining wider acceptance as passenger vessels. In some cases, their excellent seakeeping characteristics outweigh the higher construction cost posed by its structurally complex form, weight sensitivity, and limitations associated with its increased draft. Its powering characteristics have generally limited speeds to the low-20 knot range with some notable exceptions. At higher speeds, the SWATH's high frictional resistance (caused by relatively large wetted surface area), combined with its high wavemaking resistance, results in the need for relatively large power plants, with their increased acquisition cost, maintenance costs, and fuel consumption.

SLICE has excellent ride quality characteristics, even relative to the SWATH, but with only marginally improved powering characteristics at higher speeds. SLICE would likely have higher structural assembly costs than a similar sized SWATH due to the greater complexity of the structural arrangement, but this may be somewhat offset by the reduced cost associated with a smaller propulsion plant. The technical unknown of the SLICE's maneuvering characteristics would need to be defined, but does not appear to be a major risk considering SWATH's performance in this regard with the addition of a bow thruster.

Passenger comfort is a priority in the passenger excursion market. Capital cost ratchets progressively upwards from monohulls, to catamarans, to SWATH and SLICE vessels. The premise to be tested in this case study is whether owners will be willing to pay the extra capital for SLICE or SWATH, with their superior seakeeping characteristics, and to see to what extent there are niche markets where speed and comfort in rough seas are important.

15.2 Gaming Boat Case Conditions

This case takes account of both costs and estimated revenues, and the influence upon the latter of seakeeping signatures of the four boats examined. Costs are calculated by the straightforward methods applied in other cases. Revenue calculations follow a set of similar assumptions for all boats, with the imposed effects of seakeeping performance. Exceedance of the ISO 2631 kinetosis 2-hour threshold has assumed effects on the weather reliability (service cancellations) and ride quality (reduced revenue in bad conditions resulting in passenger discomfort). The following are the substantive assumed conditions of the South Florida gaming boat case study:

- Four boats are compared in this service: monohull (\$5.0M, 24 knots); catamaran (\$7.0M, 34 knots); SWATH (\$10.8M, 27 knots); SLICE (\$12.0M, 30 knots).
- Two 5-hour voyages per day, six days per week, two nautical miles at low speed for harbor clearance, twelve nautical miles at high speed to the jurisdiction boundary.
- Identical cost factors for all boats for financing structure, crew and casino staff (staffing levels and compensation), and fuel and consumables prices.
- Revenue stream for each boat based on average 60% passenger capacity, and \$75/passenger.
- South Florida sea state signature per Chapter 13, Figure 13-9, i.e., sea state 2 and less: 31.5%, sea state 3: 49.1%, and sea state 4 and above: 19.4%.
- In conditions where vessel motions cause exceedance of the ISO 2631 kinetosis limits, reductions in revenue as described in 15.2.3.

- Casino staff number 50 (at \$25/hour burdened labor rate) and their non-revenue time in pay status, that is during transit in the harbor and to the jurisdiction line, is counted as an expense.

15.2.1 Craft and Service Particulars

The particulars of the craft selected for this comparison appear in Table 15-1.

TABLE 15-1: EXCURSION CASE STUDY - VESSEL PARTICULARS

Vessel Type	Purchase Price (U.S. dollars)	Speed (knots)	Length (feet)	Installed Power (bHP)	SFC (g/KW-hr)	
					High Speed	Low Speed
Conventional monohull	\$5,000,000	24	125	4,000	235	294
Catamaran	\$7,000,000	34	120	5,500	235	294
SWATH	\$10,800,000	27	110	7,500	251	314
SLICE	\$12,000,000	30	110	7,000	300	375

15.2.2 Cost Analysis

All cost components and calculations are identical to those in Chapter 8, unless otherwise noted below. The results in this case are expressed as daily cost, which data appear following the description of those cost factors which are at variance with Chapter 8 (all others are equal to Chapter 8 values).

Vessel Crew

Crew compensation is estimated by multiplying the vessel hours needed to complete one voyage by the number of crew aboard (five), and by a “work factor” coefficient estimating the proportion of time aboard that the crew member actually works. The default value for this coefficient is 1.25, which, for voyages of less than 8 hours, posits only one watch (no off-time), and extra time for voyage preparation and post-voyage securing of the vessel and its systems. This result is multiplied by the annual number of voyages and the average crew compensation rate (\$65/hour), and then divided by 365 to calculate average daily cost.

Non-Revenue Time Compensation for Casino Staff Calculation

The cost of compensation for the casino staff during non-revenue operating hours is included as a significant practical matter which also sheds light on the impact of vessel speed on cost of operations. The model calculates the time per voyage that is spent in transit from the pier to the jurisdiction limit and back again and then multiplies by the number of casino staff on board (50) to estimate the total labor per voyage. Average daily cost is the result of multiplying the first result by annual voyages and the average casino staff hourly compensation (\$25/hour burdened), dividing by 365.

Port Costs

For these purposes, a relatively remote port location is assumed, where the attraction to the operator includes no assessment of port fees.

Cost Summary

The daily cost summary for all four craft types appears in Table 15-2.

TABLE 15-2: GAMING SERVICE DAILY COSTS BY VESSEL TYPE

Cost Category	Monohull	Catamaran	SWATH	SLICE
Vessel Debt Repayment	\$1,441	\$2,017	\$3,112	\$3,458
Insurance	\$274	\$384	\$592	\$658
Fuel and Lubricants	\$1,141	\$1,797	\$2,656	\$2,941
Maintenance	\$479	\$671	\$1,036	\$1,151
Ship's Crew	\$3,205	\$3,205	\$3,312	\$3,339
Casino Staff Lost Time	\$4,932	\$3,965	\$4,566	\$4,274
Total	\$11,473	\$12,039	\$15,274	\$15,820

As seen in previous cases, SLICE and SWATH costs are higher than those of other types, driven primarily by capital debt service and fuel items. SLICE's middling service speed also adds engine hours, maintenance cost and casino staff expenses relative to the fastest craft.

15.2.3 Reliability and Ride Quality

Passenger comfort in the excursion service may be even more important than in the ferry business because of the leisure aspect of the customers' time. The seakeeping performance of high speed craft, reported in Chapter 5, bears directly on the profitability and success of excursion service. Those results, combined with relevant sea state data for the operating area, have a financial impact which is modeled by positing given incidences of trip cancellations and onboard revenue losses due to passenger discomfort.

The analysis of the gaming service case includes two sets of operating conditions: running at both service speed (for each craft) and at 5 knots while in gaming mode beyond the jurisdictional limits. The quantification of revenue impact includes two assumptions:

- Exceedance of the ISO 2631 2-hour kinetosis standard in a given sea state will result in a 50% reduction of revenue, whether through cancellation of service or reduced spending onboard by passengers in such conditions.
- Exceedance of the ISO 2631 30 minute kinetosis standard in a given sea state will result in a 100% reduction of revenue, due to cancellation of service.
- A marginal result relative to the ISO 2631 2-hour standard (e.g., just at or over the line as with SWATH at sea state 4) results in a 10% revenue reduction.

Vessel reliability and revenue impact data appear in the following two tables. Table 15-3 shows the distribution of sea conditions (summing to 1.00) for each operating area. Table 15-4 and Table 15-5 indicate the "revenue reliability" of each craft by sea state, i.e., the proportion of projected revenue each may expect to garner in each sea state operating at service speed and low speed (5 knots), respectively. The reader should note that the monohull in question here was not part of the seakeeping analysis. The assumption is made that its motions approximate those of the catamaran; neither are known as seakindly in rough water.

At service speed, the values given follow the bulleted criteria shown above with one exception: the monohull and catamaran slightly exceed the ISO 2631 30 minute standard in sea state 4 but cannot be presumed to cancel service in all such conditions. They are therefore assigned a value of 0.5 in recognition of the facts that 1) ride control might improve matters and 2) no operator could be expected to cancel in the low end of sea state 4 conditions. At low speeds, only the SWATH was indicated to exceed even the lower of the two limits, and then

TABLE 15-3: REGIONAL SEA STATE CONDITIONS

	SS 1,2,3	SS 4	SS 5	SS 6
Milwaukee - Muskegon	0.826	0.167	0.006	0.000
Miami - Key West	0.806	0.189	0.005	0.000
Gulf of Mexico	0.719	0.280	0.001	0.000
South Florida Atlantic coast	0.717	0.267	0.016	0.000
St. John - Digby	0.589	0.347	0.060	0.004

TABLE 15-4: VESSEL "REVENUE RELIABILITY" AT SERVICE SPEED

Sea State	MONOHULL	CATAMARAN	SWATH	SLICE
1,2,3	1.0	1.0	1.0	1.0
4	0.5	0.5	0.9	1.0
5	0.0	0.0	0.5	0.9
6	0.0	0.0	0.0	0.0

TABLE 15-5: VESSEL "REVENUE RELIABILITY" AT 5 KNOTS

Sea State	MONOHULL	CATAMARAN	SWATH	SLICE
1,2,3	1.0	1.0	1.0	1.0
4	1.0	1.0	0.9	1.0
5	0.5	0.9	0.9	1.0
6	0.0	0.0	0.0	0.0

only slightly. Table 15-5 indicates far better "revenue reliability" numbers for the catamaran and monohull craft; SLICE still has the advantage, but it is quite narrow.

15.3 Revenue and Income Analysis

The known data and assumed conditions for this gaming boat case are the basis of the calculations for net daily income, the results of which are found for each boat in each of five operating areas. The conditions vary further by investigating two speeds of operation outside the line of jurisdiction: service speed (unique for each craft) and a low speed, chosen as five knots. In all cases, the daily net income for each boat in each service results from multiplying the relevant factors in Table 15-3 and Table 15-4 (revenue reliability per sea state X sea state incidence), then by projected revenue as posited (average 60% passenger capacity, and \$75/passenger boat capacity), minus daily costs. The results appear in and Table 15-6 and Table 15-7.

It is seen in both cases that the income from a SLICE or SWATH (particularly SLICE) operation would be very consistent, no matter the operating conditions. The net income from a monohull and catamaran would clearly be much more sensitive to sea operating conditions at service speeds, as motions are presumed to force service cancellations and sickness onboard. SLICE is therefore shown to have an advantage in the worst set of conditions

TABLE 15-6: VESSEL DAILY NET INCOME AT LOW SPEED

	MONOHULL	CATAMARAN	SWATH	SLICE
Milwaukee - Muskegon	\$17,998	\$17,502	\$13,774	\$13,739
Miami - Key West	\$18,043	\$17,535	\$13,741	\$13,769
Gulf of Mexico	\$18,102	\$17,547	\$13,484	\$13,769
South Florida Atlantic coast	\$17,880	\$17,502	\$13,478	\$13,769
St. John - Digby	\$17,110	\$17,254	\$12,993	\$13,651

TABLE 15-7: VESSEL DAILY NET INCOME AT SERVICE SPEED

	MONOHULL	CATAMARAN	SWATH	SLICE
Milwaukee - Muskegon	\$15,439	\$14,872	\$13,703	\$13,722
Miami - Key West	\$15,172	\$14,606	\$13,682	\$13,754
Gulf of Mexico	\$13,944	\$13,378	\$13,472	\$13,766
South Florida Atlantic coast	\$13,693	\$13,126	\$13,289	\$13,722
St. John - Digby	\$11,089	\$10,522	\$12,283	\$13,473

(Saint John-Digby) of the lot, to operate on a virtual par with the others in the Gulf of Mexico and south Florida, and to perform at a significant disadvantage in the Milwaukee and Miami services.

Operations at low speed yield a different result. The presumed performance improvement (“revenue reliability”) by the competition at low speeds results in much improved revenues and net income. SLICE would not compete successfully in any of the markets chosen given this set of operating conditions.

15.4 Whale Watching Boat Case

The case of a whale watching boat offers some insight into the excursion market as a whole because the presumed per passenger income is less than for a gaming boat, i.e., closer to the normal expected value. All other parameters and conditions remain the same as for the gaming boat. Only the full service speed condition is considered, although whale watchers are likely to operate on station at low speeds. The net income results appear in Table 15-8.

The whale watching service is clearly not as profitable as gaming for any operator. SLICE, again, returns very consistent numbers whatever the sea conditions. However, it is not the leader in terms of net income in any of the five markets considered here; even in Saint John-Digby, with the worst sea conditions and where the year-round service suggested here is highly unlikely anyway, SLICE cannot out-compete a monohull or catamaran. As stated in previous case studies, the capital cost and the time and consumable factors driven by SLICE’s performance characteristics (fuel, maintenance, crew costs) cannot be overcome.

TABLE 15-8: WHALE WATCHING BOAT CASE, NET INCOME

	MONOHULL	CATAMARAN	SWATH	SLICE
Milwaukee - Muskegon	\$5,146	\$4,208	\$1,722	\$1,484
Miami - Key West	\$4,969	\$4,030	\$1,708	\$1,506
Gulf of Mexico	\$4,150	\$3,212	\$1,568	\$1,514
South Florida Atlantic coast	\$3,982	\$3,044	\$1,445	\$1,484
St. John - Digby	\$2,247	\$1,308	\$775	\$1,318

15.5 Summary

Excursion service may offer some niches where SLICE has an appreciable advantage. The data in this chapter indicate that such niches are likely to be quite small and narrowly defined. Only under circumstances where a high end service (expensive) must operate reliably year round in demanding sea conditions can SLICE offer inducement to the operator relative to the high speed competition today.

Chapter 16: Conclusions and Recommendations

16.1 Conclusions

SLICE is at this time an unproven commercial quantity. Its development for the Navy was focused on a narrow set of operating parameters, resulting in problematic, if unforeseen, design features affecting its usefulness in the commercial market environment. Until recently, SLICE's owners have not had an integrated commercial design or a rigorously derived newbuilding cost (the proposal prepared for Washington State Ferries in summer 1999 was not included in this study). The commercial outlook for SLICE and its variants is not rosy at this point; the technology, however, is not yet fully mature and design improvements may change the picture.

16.1.1 *Technical*

SLICE offers a unique set of operational capabilities with both positive and negative aspects. Its design affords superior seakeeping at service speed in high sea states. The drawbacks are the capital and operational cost differentials expected of a SWATH-type hull, less than premium service speeds, and a deep draft restricting its availability from many service and terminal areas. SLICE's closest competitor in fact appears to be the SWATH, higher speed versions (up to 30+ knots) of which have recently appeared. In SLICE, the tradeoff between seakeeping and power is taken even further than by SWATH. This analysis, and at least one other before it, shows that SLICE does not compete well against modern monohulls and catamarans, except where especially high incidence of high sea states occur. The particulars of the analysis of SLICE and other high speed craft follow.

Power and Efficiency

"Transportation efficiency" is a performance measure relating installed power to the payload and speed delivered by the craft; it conveys quite a bit about the operating costs and potential revenue of various high speed craft. In 5.2.1, three SLICE variants were shown by this measure to perform poorly relative to their competitors, failing to provide speed and payload comparable to most catamarans and high speed monohulls now in the market.

The SLICE 250 and 400 variants performed at the low end of the scale among passenger only craft, while SWATHs in this group fare only slightly better. Among high speed RoPax craft, the SWATH types, including SLICE 600, do not compare favorably to their competitors using this measure.

SLICE has two seriously conflicting design requirements: the limited space within the displacement pods for machinery arrangements and the need for higher powered engines relative to other high speed craft. The solutions advanced thus far by SLICE designers are (1) pod mounted gas turbines probably because of their compact geometry relative to marine diesels, and (2) deck mounted marine diesels connected by Z-drives to the propellers below.

The first option results in higher fuel consumption, particularly at lower speeds. It is also problematic for maintenance, as routine 2000 hour checks of gas turbines' "hot sections" may be impossible within the tight confines of the pod and could possibly require more drastic measures to gain the necessary access. The gearing required for deck mounted marine diesels would result in less efficient power transmission and greater capital and maintenance costs relative to the standard configuration found on most high speed craft.

The SLICE 400 and 600 variant designs employ gas turbine engines mounted within the forward pods. These engines for the 400 are intended to run at slightly derated power because of the relatively limited variety of suitable engine models. Pod mounted diesels are not an optimum choice, as may be seen in the SLICE demonstra-

tor, which has two re-conditioned marine diesels. These fit snugly into the pods but are under powered, providing a speed of only 23-25 knots at 85% mcr.

Seakeeping

The ship motions analysis shows clearly that SLICE would fulfill its promise of superior seakeeping at high operating sea states. Weather reliability and ride quality would be marked advantages to an operator for whom the service area conditions are rough enough to cause recurrent problems for other craft types. By every measure of passenger comfort and safety, and cargo safety, SLICE outperformed its competition.

Ride quality for passengers is the focus for the case studies appearing in subsequent chapters. SLICE's seakeeping performance margin relative to other craft is greatest at service speeds, implying that the operational advantage would be greatest for scheduled ferry service or for excursions requiring long exposed runs. The margin narrows appreciably at low "hoteling" speed with less fortunate implications for SLICE in many types of excursion service. Finally, all these considerations must be predicated on the presence of sea conditions severe enough to bring consideration of SLICE into the operator's picture.

The analysis included an assessment of motion ride quality and passenger comfort based upon the ISO 2631 standards for seaborne kinetosis. At service speeds in head seas at sea states 4, 5, and 6, both the SLICE 400 and 600 met both the 30 minute and 2-hour exposure standards for the full frequency range of vertical accelerations. The competing craft failed in this respect, although the passenger-only SWATH was very close to acceptable. At the lower speed of five knots, all the craft passed, although SLICE was again the clearly superior seakindly boat.

Other Features

Waves and wash from high speed vessel wakes have emerged as the most important environmental issue arising from their operation. A recent test of the SLICE demonstrator in San Francisco Bay showed excellent (low value) results relative to known data for other high speed craft.

Seakeeping was the obvious driver in the design of SLICE and the deep draft displacement pods and small waterplane area are the result (wake and wash are the secondary benefit). The draft, however, is a serious drawback with regard to both commercial services and a number of non-military government missions. SLICE drafts at values two and three times higher than most monohulls and catamarans, and higher even than comparable SWATHs. This restricts to a great extent its access to waterways and ports and terminals.

16.1.2 Economic

SLICE failed to show advantageous economic performance relative to competition in all the ferry market case studies, and, in all but narrowly defined circumstances, in the crew boat and excursion services. The high capital and operating expense of SLICE are the critical cost drivers. Construction cost analysis indicates that SLICE would be slightly more expensive than SWATH and well above the newbuilding cost of comparable high speed monohulls and catamarans. In addition, its relatively slow speed adds operating hours and, therefore, higher fuel consumption (its unit fuel consumption is high at the outset), personnel, and maintenance costs. The seakeeping and ride quality advantage was factored in as extra passengers relative to other craft (derived from local sea spectra data and ISO kinetosis standards), but did not result in significantly higher revenue.

Ferry Case Studies

The SLICE variant and competition selected for each case were compared on three bases: (1) assumed constant internal rate of return of 15% ("break even"); (2) baseline fare reflecting current conditions on the route; and (3) optimized fares for each individual vessel resulting in the best cash flow. Additional service variegation was investigated as appropriate, e.g., the options of sending Lake Michigan ferries to the Caribbean for seasonal winter service or not.

The Caribbean case (French Leeward and Windward Islands) was not completed due to the lack of available economic and environmental data, although the inference from other cases is that SLICE would not demonstrate an advantage there. The results of a previous Hawaii service study prepared for Pacific Marine are repeated, with the indication that prospects for a successful inter-island SLICE service are good.

Southeast Alaska

Of the mainline AMHS southeast route segments, the SLICE 600 would be best suited for the Juneau to Skagway route, which is well patronized, experiences relatively difficult sea states despite its location protected from the open ocean, and has fewer navigational issues related to controlling depths of channels and at berths than some of the other route segments in southeast Alaska. Although most channel depths in the area are suitable for the SLICE 600, the controlling depths along side of 26 feet at Juneau (Auke Bay), 23 to 25 feet at Haines, and 17 feet at Skagway are marginal with respect to the SLICE 600, but would be more than adequate for the 78 meter WPC or other WPC designs being evaluated by AMHS. In addition to draft constraints, operational difficulties are also likely to be encountered with the SLICE 600 because of the deck heights at the existing ferry terminals throughout southeast Alaska, which allow a maximum freeboard height at the main vehicle deck entrance/exit of 8 feet. The SLICE 600 main vehicle deck freeboard height of 21.5 feet would be incompatible with existing southeast Alaska ferry terminal facilities. Although the 78 meter WPC returns an economic performance that is superior to the SLICE 600, both the 78 meter WPC and the SLICE 600 would result in an increase in the required financial support from the state of Alaska, which does not meet the stated goals of the Alaska Marine Highway System and the state of Alaska to reduce the financial burden upon the state by reducing the operating costs of AMHS ferry services.

Bay of Fundy

The Canadian federal government would not meet its goal of reducing and phasing out the current subsidy on this route with the SLICE 600, or the other high speed vessels analyzed. The existing baseline operation with the *Princess of Acadia* now operates at an annual net cash deficit that is less than that calculated for the SLICE 600, AMD K50, and the Incat 74 meter WPC. For the baseline fare scenario, the AMD K50 returns the best economic performance, with an annual net cash deficit of \$5,915,905. The Incat 74 meter WPC shows an annual net cash deficit of \$6,463,450, and the SLICE 600 a deficit of \$11,827,879. Fare optimization, while likely not a politically acceptable approach, results in smaller though still significant deficits for all three high speed types, with the SLICE 600 still the worst performer.

It is likely that the deep draft of the SLICE 600 would impose constraints on vessel operations, with the depth alongside at the existing ferry terminals in Saint John and Digby unsuitable for the SLICE 600 except perhaps during high tides. Some channel depths, such as the main channel into Saint John Harbor, are also of unsuitable or marginal controlling depth with respect to the 28.5 draft of the SLICE 600. Operational difficulties might also be encountered with the SLICE 600 because of the deck heights at the existing ferry terminals, which are approximately 10 feet at both Saint John and Digby, and the SLICE 600 main vehicle deck freeboard height of 21.5 feet.

Although wave climate conditions are the worst here among the case study regions, it is estimated that the additional patronage of approximately 4,600 passengers and their vehicles that might be realized due to the superior weather reliability and ride quality of SLICE is insignificant relative to both the baseline and forecast scenario patronage levels on this route. Tractor trailers are not accommodated on either the SLICE 600 or the other comparative high speed vessels. This would reduce fare revenues, particularly in light of the consistent and relatively high level of existing commercial vehicle traffic. More importantly, the exclusion of oversize commercial vehicles from this route would likely be politically unacceptable, as RoPax ferry services in Atlantic Canada are generally regarded as an economic necessity and in the public interest.

Hawaii

The difficult wave climate of the Hawaiian Islands is well suited to the application of SLICE vessels, providing SLICE ample opportunity to improve ride quality and passenger comfort for a substantial number of vessel operating hours annually relative to other vessel designs. Projected income before interest expense and taxes for Phase A of the inter-island SLICE ferry are conservatively estimated to be \$1.7 million during the first year of operation and \$2.4 million annually thereafter.

Lake Michigan

The SLICE 600 did not project profitable returns under any of the scenarios considered, including those in which the vessel would be repositioned in the off-season (draft issues would likely limit repositioning opportunities). SLICE would accrue little added ridership due to its superior seakeeping ability, since local sea state conditions are relatively benign. The single SLICE 600, offering three round trips daily, would provide service less frequently than the two smaller baseline Incat 72 meter WPC vessels. None of the craft considered could accommodate tractor trailers, a serious political disadvantage. The operating speed restrictions in both Milwaukee Harbor and Muskegon Harbor limit the speed advantage of SLICE's competitors.

Both the Incat 72 meter and AMD K50 (two of each) outperformed the single SLICE 600 financially in all six all scenarios examined. Repositioning of the vessel or vessels in either the baseline case or the other scenario cases including SLICE helps somewhat, but the resulting increase in profit is relatively small. The deep draft of the SLICE 600 would also result in unacceptable or marginally acceptable operating conditions in both Milwaukee Harbor and Muskegon Harbor

Florida Keys

The SLICE 600 does not project as a profitable option for any of the scenarios considered, due to higher direct operating costs, and much greater overall travel time. However, the SLICE 400 appears to be better suited for this market, with a passenger capacity consistent with what appear to be actual travel market conditions, as well as lower operating costs; it is less profitable than the baseline AMD K50 in all scenarios considered, but more profitable than the 74 meter WPC in all scenarios considered.

Estimates prepared by the prospective operator of the Miami to Key West ferry route, as reflected in the proposed baseline for the AMD K50 and the proposed operating profile of one round trip daily, appear overly optimistic. There would be relatively little additional ridership due to the superior seakeeping ability of SLICE because of the relatively benign sea state conditions encountered in this region. Transit time for both SLICE craft is nearly 6 hours one-way, limiting the possibility of any type of "day trip" travel on the route. Such a prospect is only slightly better for the 4 hour transit time of the AMD K50. SLICE 600's draft would also result in marginally acceptable operating conditions in both Key West Harbor and the Port of Miami at certain berths and in certain channels.

Caribbean

The economic, transportation, and wave/climate data proved very difficult to obtain for this route. It may be inferred, however, that SLICE would have difficulty competing against other high speed craft here. The service would be characterized as passenger only in relatively benign sea spectra, with route lengths of 44 to 100 nautical miles. It may be inferred from the results of the other cases that the SLICE seakeeping advantage would be minimal at best and its lower speed, particularly over the longer routes, would result in several categories of higher operating costs.

Other Service Cases

Crew Boat Case

Vessel purchase price and vessel cruise speed appear to be the biggest drivers of overall costs. A faster, relatively cheap monohull would seem to offer operating and ownership costs low enough to offset the occasional sea state caused delay. Similarly, if rig crew transit costs were included in the average daily cost accounting, a faster transit time in calm states would offset the delay costs in rough sea states and the sea sickness induced losses seem trivial in all cases. A similar case could be made for a capable catamaran, if the purchase price can be kept near the cost for a monohull, or a significant cruise speed advantage can be realized.

The SLICE and SWATH vessels do not appear to offer significant advantages over less expensive, more fuel efficient and faster monohull and catamaran crew boats. This evaluation is based on fairly reasonable assumptions on the response of operators and rig crew passengers to operations in statistically determined sea state conditions, and the overall effect is not very significant in terms of average daily operating costs.

Better information on the actual operating practices of crew boat owners in response to high sea states might shed more insight into the oil industry valuation of kinetosis prevention and timeliness of rig crew delivery. The difference in crew work effectiveness and, perhaps, the need to take action to enhance the safety on board the rigs by improving the comfort level on the transport may be the motivation behind the commissioning of vessels such as the *Stillwater River* mentioned in the introduction to this section.

Excursion Boat Case

Excursion service may offer opportunities where SLICE has an appreciable advantage, although such niches are likely to be quite small and narrowly defined. Only under circumstances where a high end service (expensive) must operate reliably year round in demanding sea conditions can SLICE offer inducement to the operator relative to the high speed competition today. SLICE and SWATH costs are higher than those of other types, driven primarily by capital debt service and fuel consumption. SLICE's middling service speed also adds engine hours and maintenance cost and casino staff expenses relative to the fastest craft. The premise to be tested was that SLICE reliability and ride quality would yield revenues outweighing the cost disadvantage.

The model developed to test the premise gives great weight to seakeeping and ride quality aspects, positing substantial service and revenue degradation when the ISO 2631 kinetosis 2-hour threshold is exceeded. The first excursion case was for a gaming boat, a high revenue service. Despite the model's emphasis on seakeeping and the obvious advantage to the SLICE 400, the best seakeeping craft considered, the financial margin expressed as net income was only slightly better for SLICE under the worst of five sets of sea spectra for different regions. In the other regions where the seas are more benign, SLICE 400 was shown to net considerably less for its owners.

The additional case of a whale watching boat offered insight into the excursion market as a whole because the presumed per passenger income is closer to the normal expected value. With all other parameters and conditions the same as for the gaming boat, SLICE shows no advantage in any service region considered.

The whale watching service is clearly not as profitable as gaming for any operator. SLICE, again, returns very consistent numbers whatever the sea conditions. However, it is not the leader in terms of net income in any of the five markets considered here; even in St. John's-Digby, with the worst sea conditions and where the year-round service suggested here is highly unlikely anyway, SLICE cannot out-compete a monohull or catamaran. As stated in previous case studies, the capital cost and the time and consumable factors driven by SLICE's performance characteristics (fuel, maintenance, crew costs) cannot be overcome.

16.2 Recommendations

The results of the market case studies preclude any recommendations of a marketing type. The narrow definition of a viable market niche in the excursion service appears to fit the demands of the tourist economy and sea conditions in Hawaii, the very type of service under consideration by Pacific Marine Inc. One or two SLICE craft could be built to enter this service, not a sufficient number for a long shipyard production run.

There are indications that technical improvements would enhance SLICE's performance and marketability. Advanced propulsion components and innovative arrangement, as well as upgraded and more effective ride control, would improve speed and ride quality (although the latter is already superior in its class). The major drawbacks noted herein—relatively high fuel consumption and low speed and extremely deep draft—will, even if marginally mitigated, remain. Radical changes such as reduction of draft and wetted area to improve speed, economy, and operability in shallow waterways would seriously degrade SLICE's signature feature, superior seakeeping.

There is possible success in the future for SLICE as transportation system congestion forces the utilization of more modal alternatives, including ocean transport in exposed waters with challenging wave spectra. Although indications are that the right combination and waterway do not currently exist in North America, population growth and modernizing economies overseas may result in favorable market conditions in the future.

Bibliography

- Alaska Department of Transportation and Public Facilities. Alaska Marine Highway System. *Owner's Requirements. Ocean Class RO-RO Passenger Vessel*. Project No. 75409/NH-9500(44). Section 1A, Table 1A-1, "Southeast Alaska Operating Profile." April 1996.
- Alaska Department of Transportation and Public Facilities. Division of Statewide Planning. *Southeast Alaska Transportation Plan*. March 1999.
- Alaska Department of Transportation and Public Facilities, Southeast Region. Federal Highway Administration, Alaska Division. *Juneau Access Improvements Draft Environmental Impact Statement*. Report # FHWA-AK-EIS-97-01-D. 1997.
- Alaska Marine Highway. *Annual Financial Report*. Fiscal Year Ended June 30, 1997.
- Alaska Marine Highway. *Annual Financial Report*. Fiscal Year Ended June 30, 1998.
- Alaska Marine Highway System. *1997 Annual Traffic Volume Report*.
- Alaska Marine Highway System. *1998 Annual Traffic Volume Report*.
- Applebee, Terrence R., and Dennis A. Woolaver. *Summary of Seakeeping Trials Aboard SLICE*. Naval Surface Warfare Center, Carderock Division. Report # NSWCCD-50-TR-1999/002. January 1999.
- Art Anderson Associates. *Study of Marketing Possibilities for Two Variants of the SLICE Design*. June 1995.
- Atlantic Provinces Transportation Commission. *1997 Annual Transportation Review*.
- Baker, T. Brent, and Raymond G. Deardorf. "Development and Application of a Revenue and Ridership Forecasting Model for Ferry Service." *Transportation Research Record 1608*. 1997.
- Berkowitz, Carl. "Modeling Waterborne Transportation User Characteristics." *Transportation Research Record 1263*. 1990.
- Bureau of Economic and Business Research. *Projections of Florida Population by County, 1993-2020*.
- Canadian Coast Guard. *Ferry Services. Service Profile 96*.
- Carter, D.J.T. "WAVSAT: Background. Marine Climate Information for Design and Operational Planning." Satellite Observing Systems (SOS), Surrey, United Kingdom. February 1997.
- Cottrill, Ken. "Invitation to Cuba." *Traffic World*. December 14, 1998. Page 31.
- Decision Paper #1. Alternative Hull Types. AMHS Ocean Class Ferry. MT-759/Agreement No. 37-003-21. Submittal to State of Alaska, Department of Transportation and Public Facilities, Alaska Marine Highway System. Revision A. September 23, 1992.*
- Dehghani, Youssef, Krishnan Saranathan, and Celine Gihring. "Comprehensive Planning Model for Ferry Ridership Forecasting Analysis in Puget Sound Region." *Transportation Research Record 1608*. 1997.

"Derecktor Shipyard delivers first NGA 45m catamaran." *Fast Ferry International*. January-February 1999. Page 21.

Fast Ferry International. *Fast Ferry International*. Various editions.

Fast Ferry International. *Operators Directory*. 1997.

Florida Tourism Industry Marketing Association (Visit Florida). *1997 Florida Visitor Study*.

Fox Associates. *Wake Wash Measurement Trials: M/V SLICE*. Conducted for Lockheed Martin, Inc.. April 1999.

Hawkins, Lee, Jr. "Port official says ferry possible in 2002." *Milwaukee Journal Sentinel*. April 17, 1999.

Jeppesen Marine. *RasterPlus* digital nautical charts.

Karppinen, Tuomo, and Timo Aitta. Technical Research Centre of Finland. *Seakeeping Performance Assessment of Ships*. NSTM. Stockholm. 1986.

Karr, Kari and Thomas Hawley. "Charting the Course of Car Ferry History." *Crossings: The Magazine of the Lake Michigan Carferry Service*. 1999.

Key West Department of Transportation, Port Department. September 13, 1999.

Khisty, C.J. "Level-of-Service Measures for Ferry Systems." *Transportation Research Record 1222*. 1989.

Leeworthy, Vernon R., and Peter C. Wiley. *Linking the Economy and Environment of Florida Keys/Florida Bay. Visitor Profiles: Florida Keys / Key West* November 1996. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

Library of Michigan. *Michigan in Brief*.

Lockheed Marine Systems. *SLICE ATD Weights Summary*.

Lockheed Marine Systems. *400 Passenger SLICE Ferry. Technical Data Package*. April 1995.

Lockheed Marine Systems. *SLICE 600 Passenger Vehicle Ferry. Technical Data Package*. April 1995.

Marine Digest and Transportation News. "Ferries pollute more than cars, Bay environmentalists say." August 1999.

Miami-Dade County Seaport Department.

New Brunswick. *The New Brunswick Economy. A Report to the Legislative Assembly*. 1999.

New York City Department of Transportation. *An Assessment of the Potential for Ferry Services in New York Harbor*. FTA # NY-08-0179. July 1992.

Nigel Gee and Associates, Ltd.. *Sea SLICE Marketing Study for Pacific Marine. Volume 2 - Stena HSS Case Study*. June 1995.

Nigel Gee and Associates, Ltd.. *Sea SLICE Marketing Study for Pacific Marine. Volume 3 - Route Studies.* June 1995.

Nova Scotia, Department of Finance, Statistics Division. *Nova Scotia Facts at a Glance.*

Pacific Marine & Supply Company, Ltd. *Hawaii Inter-Island Ferry Business Plan. Phase A.* July 1995.

Pacific Marine presentation, "The Hydrodynamics of SLICE Ships or Why Short and Fat Might Outperform Long and Slender Hulls."

Phillips, Stephen J., editor. *Jane's High-Speed Marine Transportation.* Thirty-first Edition. 1998-99. Jane's Information Group Limited.

Porter, Anne. "Seasons Ends Friday for High Speed Cat." *The Ellsworth American, Ellsworth American.com.* October 29, 1998.

R.A.M. *Transport Risk Study.*

Roess, Roger P., and Philip J. Grealy. "The Use of High-Speed Vessels in Urban Ferry Service: Issues and Economic Evaluation." *Transportation Research Record 925.* 1983.

Sailing Directions: Nova Scotia (Atlantic Coast) and Bay of Fundy. First Edition 1990. Canadian Hydrographic Service.

Savage, Joseph P., Jr. "Ferry Route Level of Service." *Transportation Research Record 1608.* 1997.

Savage, Joseph P., Jr. "Simplified Approaches to Ferry Travel Demand Forecasting." *Transportation Research Record 1608.* 1997.

SeaSpeed Technology Limited. *High Speed Craft Sea Performance Comparative Study for the Volpe National Transportation Systems Center.* September 1999.

South Florida Regional Planning Council. *Regional Profile and Identity.*

State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 2: Existing Transportation Conditions and Travel Characteristics in SE Alaska. Final Memorandum.* June 3, 1997.

State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 3: Potential Implications of Technological Improvements.* September 29, 1997.

State of Alaska Department of Transportation and Public Facilities. *Technical Memorandum 10: Existing and Future Demand for Inter-Community Travel in Southeast Alaska.* May 14, 1998.

Statistics Canada. 1996 Census.

"Three sites in race for Lake Michigan ferry dock." *Milwaukee Journal Sentinel,* April 12, 1999.

Transport Canada. Marine Policy and Programs. Yearly financial statement 1990 to 1996 for Princess of Acadia operations by Marine Atlantic between Saint John and Digby.

High Speed Vessels to Market: Comparative Case Studies in the Passenger Trade

Transportation and Economic Research Associates, Inc. *Phase I Report on Feasibility Study of a Cross-Lake Passenger Auto Air Cushion Ferry Service*. Prepared for the Board of Harbor Commissioners, City of Milwaukee. August 1980.

U.S. Department of Commerce. *1997 County Business Patterns for Alaska*.

U.S. Department of Commerce. *1996 County Business Patterns for Florida*.

U.S. Department of Commerce. *1996 County Business Patterns for Michigan*.

U.S. Department of Commerce. *1996 County Business Patterns for Wisconsin*.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration (NOAA). *United States Coast Pilot. Volume 4. Atlantic Coast: Cape Henry to Key West*. 31st edition.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration (NOAA). *United States Coast Pilot. Volume 6. Great Lakes*. 29th edition.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration (NOAA). *United States Coast Pilot. Volume 7. Pacific Coast: California, Oregon, Washington, and Hawaii*. 31st Edition.

U.S. Department of Commerce. National Oceanic and Atmospheric Administration (NOAA). *United States Coast Pilot. Volume 8. Pacific Coast Alaska: Dixon Entrance to Cape Spencer*. 22nd Edition.

U.S. Department of Transportation. *An Assessment of the U.S. Marine Transportation System. A Report to Congress*. September 1999.

U.S. Department of Transportation, Bureau of Transportation Statistics CD-ROM product entitled "Travel Demand Forecasting: A Compilation of Transportation Plans, Reports and Data." BTS-CD-11. 1997.

U.S. Department of Transportation, Federal Transit Administration. *Assessment of Ferries as Alternatives to Land-Based Transportation. Volumes I-III*. FTA-MA-06-0197-01-03. Performed by C.R. Norris, University of Massachusetts at Boston, Urban Harbors Institute. 1994.

U.S. Department of Transportation, Federal Transit Administration. *National Transit Database*.

U.S. Department of Transportation, Federal Transit Administration. *Section 15 data*.

U.S. Department of Transportation, Federal Transit Administration, Office of Technical Assistance and Safety. *The Impact of a Ferry System Upon Its Communities*. FTA-MA-06-0197-94-1. Prepared by Pilsch, Martin C., Jr. and Andrew Held. Urban Harbors Institute, University of Massachusetts at Boston. May 1994.

U.S. Department of Transportation, Federal Transit Administration, Office of Technical Assistance and Safety. *National Waterborne Passenger Transportation Data Base*. FTA-MA-06-0197-95-1. January 1995.

U.S. Department of Transportation, Maritime Administration. *Functional Design of Ferry Systems. Phase I*. DOT-I-87-28. July 1990.

U.S. Department of Transportation, Maritime Administration. *Some Critical Aspects of Ferry Planning. Final Report - Phase II*. DOT-I-87-29. February 1982.

U.S. Department of Transportation, Office of the Secretary of Transportation. *Report to Congress. Study of High Speed Waterborne Transportation Services Worldwide*. August 1984.

U.S. Department of Transportation, Urban Mass Transit Administration. *An Assessment of High Speed Waterborne Vessels and Their Builders*. UMTA-IT-32-0001-5. August 1984.

U.S. Department of Transportation, Urban Mass Transit Administration. *Bibliography. High Speed Waterborne Passengers Operations and Craft*. UMTA-IT-32-0001-84-2. August 1984.

U.S. Department of Transportation, Urban Mass Transit Administration. *Existing and Former High Speed Waterborne Passenger Transportation Operations in the United States*. August, 1984. Report # UMTA-IT-32-0001-84-3.

U.S. Department of Transportation, Urban Mass Transit Administration. *A Review of Selected High Speed Waterborne Operations Worldwide*. UMTA-IT-32-0001-4. August 1984.

U.S. Department of Transportation, Urban Mass Transit Administration. *UMTA High Speed Water Transportation Study, Vols. I-VI*. UMTA-IT-32-0001-I-VI. Advanced Marine Systems Associates and Pcat, Marwick, Mitchell. 1984.

U.S. Department of Transportation, Urban Mass Transit Administration. *Urban Over-the-Water Transportation: Vols. I-III*. UMTA-INT-RDC-8-71-1-(I-III). R. Krzyckowski et al. Interplan Corp., Santa Barbara, CA, 1971.

U.S. Department of Transportation, U.S. Coast Guard Headquarters G-MOR, Office of Response. *Response Plan Equipment Caps Review*. May 1999.

Wisconsin Department of Tourism. *1998 Economic Impact of Traveler Expenditures on Wisconsin*.

Wisconsin Department of Transportation. *Passenger Ferry Service: An overview and study proposal for passenger ferry service in Wisconsin*. June 1994.

List of Acronyms

AAA	American Automobile Association
AEU	automobile equivalent unit (generally an area of vehicle deck space 9' x 20')
AMD	Advanced Multihull Designs
AMHS	Alaska Marine Highway System
APTA	American Public Transit Association
ASTM	American Society for Testing and Materials
ATBA	area to be avoided
ATD	Advanced Technology Demonstrator
Cat	catamaran
CDIP	Coastal Data Information Program
CEDRS	Coastal Engineering Data Retrieval System
CFCC	Census Feature Class Code
CFOA	Canadian Ferry Operators Association
CFR	Code of Federal Regulations
CGC	Coast Guard Cutter
COR	Circular of Requirements
CPP	controllable pitch propeller
DCF	discounted cash flow
DEIS	Draft Environmental Impact Statement
FCDN	Florida Coastal Data Network
FFI	Fast Ferry International
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GIS	Geographic Information Systems
HAZMAT	hazardous materials
hp	horsepower (metric), equivalent to 1.35962 kilowatts
HSC	high speed craft
HSC Code	High Speed Craft Code
HYSWAS	hydrofoil small waterplane area ship
IISNC	Inter-Island Steam Navigation Co.
IMO	International Maritime Organization
IRR	internal rate of return
ISO	International Standards Organization
kW	kilowatt
LCG	longitudinal center of gravity
LMC	Lake Michigan Carferry, Inc.
LMS	Lockheed Marine Systems
LoLo	Lift-on/Lift-off
lt	long tons (2,240 pounds)
MARAD	Maritime Administration
mcr	maximum continuous rating
MSIS	Marine Safety Information System
MSO	Marine Safety Office
MTS	Marine Transportation System
MV	motor vessel
MWT	Michigan-Wisconsin Transportation Company
NEMO	Network for Engineering Monitoring of the Ocean

NIMA	National Imagery and Mapping Agency
nmi	nautical mile (1,852 meters, or about 6,076 feet)
NOAA	National Oceanic and Atmospheric Administration
ONR	Office of Naval Research
OSRO	Oil Spill Response Organization
rms	root mean square
RoPax	RoRo-Passenger (a vessel that accommodates both passenger and vehicles)
RoRo	Roll-on / Roll-off
RSPA	Research and Special Programs Administration
SES	surface effect ship
SFC	specific fuel consumption
SIO	Scripps Institution of Oceanography
SOLAS	Safety of Life at Sea
SS	steam ship
SWATH	small waterplane area twin hull
TE	Transportation Efficiency
TEA-21	Transportation Equity Act for the 21 st Century
UHI	Urban Harbors Institute
UMTA	Urban Mass Transit Administration
USCG	U.S. Coast Guard
WIS	Wave Information Study
WPC	wave piercing catamaran
WSF	Washington State Ferries
WTLUS	Waterborne Transportation Lines of the United States
WWW	World Wide Web

Appendix A

HIGH SPEED CRAFT SEA PERFORMANCE COMPARATIVE STUDY FOR THE VOLPE NATIONAL TRANSPORTATION SYSTEMS CENTER

SEASPEED TECHNOLOGY LIMITED
REPORT STL/225/01
SEPTEMBER 1999

**HIGH SPEED CRAFT SEA PERFORMANCE
COMPARATIVE STUDY FOR THE
VOLPE NATIONAL TRANSPORTATION
SYSTEMS CENTER**

**SEASPEED TECHNOLOGY LIMITED
REPORT STL/225/01
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HIGH SPEED CRAFT SEA PERFORMANCE COMPARATIVE STUDY

FOR THE USDOT VOLPE NATIONAL TRANSPORTATION SYSTEMS CENTER

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Approved for release:

Report ID : STL/225/01, September 1999
Name : S.Phillips
Position : Director, Seaspeed Technology Ltd
Signed : *S.Phillips*
Date : 16 Sept 99
Copy to : 1 - VNTSC
: 2 - VNTSC
: 3 - File

SEASPEED TECHNOLOGY LIMITED
UNIT 2 CITY BUSINESS CENTRE BASIN ROAD
CHICHESTER WEST SUSSEX PO19 2DU UK
TEL +44 1243 784222 FAX +44 1243 784333
Email seaspeed@compuserve.com

HIGH SPEED CRAFT SEA PERFORMANCE COMPARATIVE STUDY

1. INTRODUCTION

This comparative sea performance study was undertaken at the request of the US Department of Transport, Volpe National Transportation Systems Center (VNTSC), under contract number DTRS57-99-80695.

The scope of the study was so defined as to provide realistic information on which to compare the powering and seakeeping performance of the SLICE concept with other modern high speed craft (HSC) of a similar speed and payload capacity. Seaspeed Technology Limited undertook the study between July and September 1999.

The powering characteristics of a number of comparable HSC's were derived from Seaspeed's database of model test and full scale trials results which cover a wide range of fast ferries and fast patrol craft. Whilst the identification of each craft studied has been kept confidential, they all appear within the industry reference source Jane's High Speed Marine Transportation (Ref 1).

The seakeeping characteristics of a smaller range of HSC's, and for the SLICE craft themselves, were derived from Seaspeed's seakeeping software suite, CATMO. A description of this programme, with data from a verification exercise, are presented in an Annex to this report. The results of the seakeeping study were compared with full scale trials data and operational criteria in order to establish the level of performance achieved by the vessels studied.

2. HSC SAMPLE POPULATION

A range of ten fast ferries for which Seaspeed had relevant model test data and/or sea trial performance data were selected from Ref 1. This was done to provide assurance that the craft used in the study were currently in operation. Most are under five years old with the oldest being a wave piercing catamaran at 14 years old. An eleventh craft, a pentamaran, was also described at the request of VNTSC although this craft is still at the design stage.

The main characteristics of the eleven vessels are presented in Table 1 which includes descriptions of:

- a. Craft Type : Five craft types were covered including four wave piercing catamarans (WPC), three conventional catamarans (CAT), two small waterplane area twin hull craft (SWATH), a monohull (MONO) and a pentamaran (PENT), giving eleven craft in total.
- b. Length Overall (LOA) : The overall length of the craft is presented to the nearest metre in order to avoid definitive identification of the craft.
- c. Length Waterline (LWL) : The waterline length of the craft is presented to the nearest 0.5 metre.

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- d. **Beam** : The beam or width of the craft is provided to the nearest 0.5 metre.
- e. **Draft** : The draft of the vessel is presented as accurately as possible but does not include appendages. The craft with T-foil ride control systems should have an extra 0.8 metres added to their defined draft.
- f. **Displacement - Full Load** : The full load displacement is that at which the vessel operates with a full complement and with full fuel and water.
- g. **Payload** : This is calculated on the basis of the weights of the crew, passengers, baggage and vehicles that the vessel is designed to carry. It does not include fuel or any other fluids.
- h. **Pax Nos** : Passenger numbers quoted are based on the number of passenger for which the craft was designed.
- i. **Service Speed** : This is the speed in knots at which the vessel operates during normal operations.
- j. **Fuel Consumption** : This is the average rate of fuel consumption from use of the main engines and generators when operating at the service speed. Engine manufacturer's figures were used for this calculation.
- k. **Range** : This is the approximate range based on the fuel consumption and the amount of fuel carried, allowing for 5% non pumpable fuel.
- l. **Power Plant** : A description of the prime mover and propulsors are provided without disclosing the manufacturer (for reasons of craft confidentiality).

SEA PERFORMANCE STUDY - COMPARISON OF EXISTING FAST FERRY STATISTICS														
LOA	Length overall (to nearest 1.0 metre)											Speed	Typical continuous speed at which the vessel operates	
LWL	Length waterline (to nearest 0.5 metres)											Fuel	Fuel consumption is quoted at the service speed	
Beam	Beam overall (to nearest 0.5 metres)											Range	Range is quoted at the service speed	
Draft	Draft without ride control fins. Hulls 5 & 6 are typically 0.8 metres deeper with T-folios											FP	Fixed pitch	
Disp	Full load displacement											CP	Controllable pitch	
Payload	Includes crew, passengers, baggage and vehicles only											Ratings	Engine ratings quoted as maximum continuous	
Craft ID	Craft	LOA	LWL	Beam	Draft	Disp	Full Load	Payload	Pax	Service	Fuel	Fuel	Range	Power Plant
	Type	(m)	(m)	(m)	(m)	(tonnes)	(tonnes)	(tonnes)	Nos	Speed	Cons	Cons	(Approx)	(Maximum Continuous Ratings)
										(knots)	(Kg/hour)	(nm)		
Hull 1	WPC	30.00	26.00	11.00	1.50	75	18.5	200	27.0	320	-	-	Two 16v diesels each rated at 755 kw @ 2200 rpm. Two FP propellers.	
Hull 2	WPC	39.00	31.50	15.50	1.30	145	31.0	340	25.0	525	150	Two 16v diesels each rated at 1230 kw @ 1800 rpm. Two waterjets.		
Hull 3	WPC	49.00	40.50	18.50	1.90	270	45.0	450	34.0	1340	350	Four 16v diesels each rated at 1600 kw @ 1800 rpm. Four waterjets.		
Hull 4	Cat	35.00	28.50	10.00	1.00	100	23.0	250	34.0	680	480	Two 16v diesels each rated at 1675 kw @ 1800 rpm. Two waterjets.		
Hull 5	Cat	45.00	40.00	12.00	1.50	185	29.0	310	43.0	2171	160	Two gas turbines each rated at 4200 kw @ 13000 rpm. Two waterjets.		
Hull 6	Cat	53.00	47.50	13.00	1.60	240	43.5	500	40.0	2160	450	Two gas turbines each rated at 4444 kw @ 13000 rpm. Two waterjets.		
Hull 7	SWATH	37.00	30.00	13.00	2.70	190	41.0	400	30.0	857	450	Two 16v diesels each rated at 2040 kw @ 1940 rpm. Two FP propellers.		
Hull 8	SWATH	37.00	32.50	18.00	3.40	320	37.5	365	28.5	1420	220	Two gas turbines each rated at 2870 kw @ 15400 rpm. Two CP propellers.		
Hull 9	Mono	70.00	62.00	10.50	2.00	510	80.0	925	38.0	3000	500	Four 16v diesels each rated at 3800 kw @ 1700 rpm. Four waterjets.		
Hull 10	Pent	66.00	59.50	14.00	1.20	240	33.0	375	65.0	4850	200	Three gas turbines each rated at 6900 kw @ 15000 rpm. Three waterjets.		
Hull 11	Ro-Pax	74.00	60.00	26.00	3.00	700	150.0	600 pax	35.0	3200	180	Four 16v diesels each rated at 4050 kw @ 720 rpm. Four waterjets.		
	WPC							80 cars						

Table 1. HSC Sample Population

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3. POWERING PERFORMANCE

For each of the eleven craft selected within the sample population described in Section 2, the powering characteristics were derived and are presented in Table 2. The powering of the SLICE 400 and 600 craft were supplied by VNTSC in Ref 2 and 3 respectively.

For the sample vessels studied, the naked hull effective power (the product of naked hull resistance and speed in consistent units) was derived from calm water model test results pertinent to each craft at the design full load displacement at level trim. The scaling process used to provide full scale predictions relates to the ITTC 1957 approach without form factors. The speed range over which the data has been provided covers the design speed down to approximately 20 knots (although data was not available for all craft down to this speed).

A further analysis was then undertaken at the craft's service speed to provide an assessment of the brake power required to meet this speed at the full load displacement. This analysis made the following assumptions:

- a. The Appendage Drag was calculated using Ref 4 for roll stabiliser fins, T-Foils, rudders and bossings where appropriate.
- b. Air Drag was calculated on the basis of frontal area, speed and typical air drag coefficients from wind tunnel experiments.
- c. Total Effective Power was then calculated by summing the Effective Power and the Appendage and Air resistances.
- d. The Hull Efficiency was assumed to be unity for waterjet propelled craft. For craft with propellers, data was derived from model test self propulsion experiments on similar craft.
- e. Propulsor Efficiency was assessed from manufacturers data for waterjets and from Ref 5 for propellers.
- f. Transmission Efficiency was assumed to be 98% for all propulsion and transmission system arrangements.
- g. Correlation Factor. This has been derived from the comparison of full scale trial data with model test predictions where possible or from published data.
- h. Brake Power. This was calculated from the division of the Total Effective Power by all the relevant propulsion efficiencies and then multiplication by the Correlation Factor.
- i. The percentage of Installed power figure is calculated by dividing the required Brake Power at the design speed by the Installed Power (using manufacturers data). This is indicative of the percentage installed power required by fast ferries to meet their service speeds at full load. A lower power maybe used since it is unusual on most craft to have a full load condition for all voyages, however with the inevitable weight growth that occurs over the first few years, the percentage installed power required could also be higher.

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In order to provide a realistic powering comparison with the SLICE 400, the HSC sample hulls with passenger capacities between 200 and 500 were selected to be studied in more detail. The brake power (at the operational speed) per tonne of passenger and baggage payload was calculated and plotted on a base of speed in Figure 1. An additional line on which brake power per payload tonne is proportional to the design speed to the power of 2.5 is presented for interest. It can be seen that the SLICE 400 requires approximately 50% more power than the equivalent current fast ferry standard. It is worth noting that the SWATH (Hull 8) which has a similar overall efficiency to the SLICE, carries substantial additional outfit weight over and above that required for ferry operations since it is outfitted for dinner cruise and gambling activities. This has not been accounted for in these calculations but would of course reduce the power per payload tonne.

The equivalent figures for the SLICE 600 and the 75M WPC are 140 kw/tonne at 30kts and 96.6 kw/tonne at 35kts respectively. Assuming that the kw/tonne figure is proportional to speed to the power 2.5, then this indicates that the SLICE 600 requires approximately twice the power of a WPC to achieve the same speed at the same carrying capacity. This of course does not account for the considerable benefits of the SLICE in terms of seakeeping which would effect these calculations should they be undertaken in more realistic sea conditions rather than in calm water conditions.

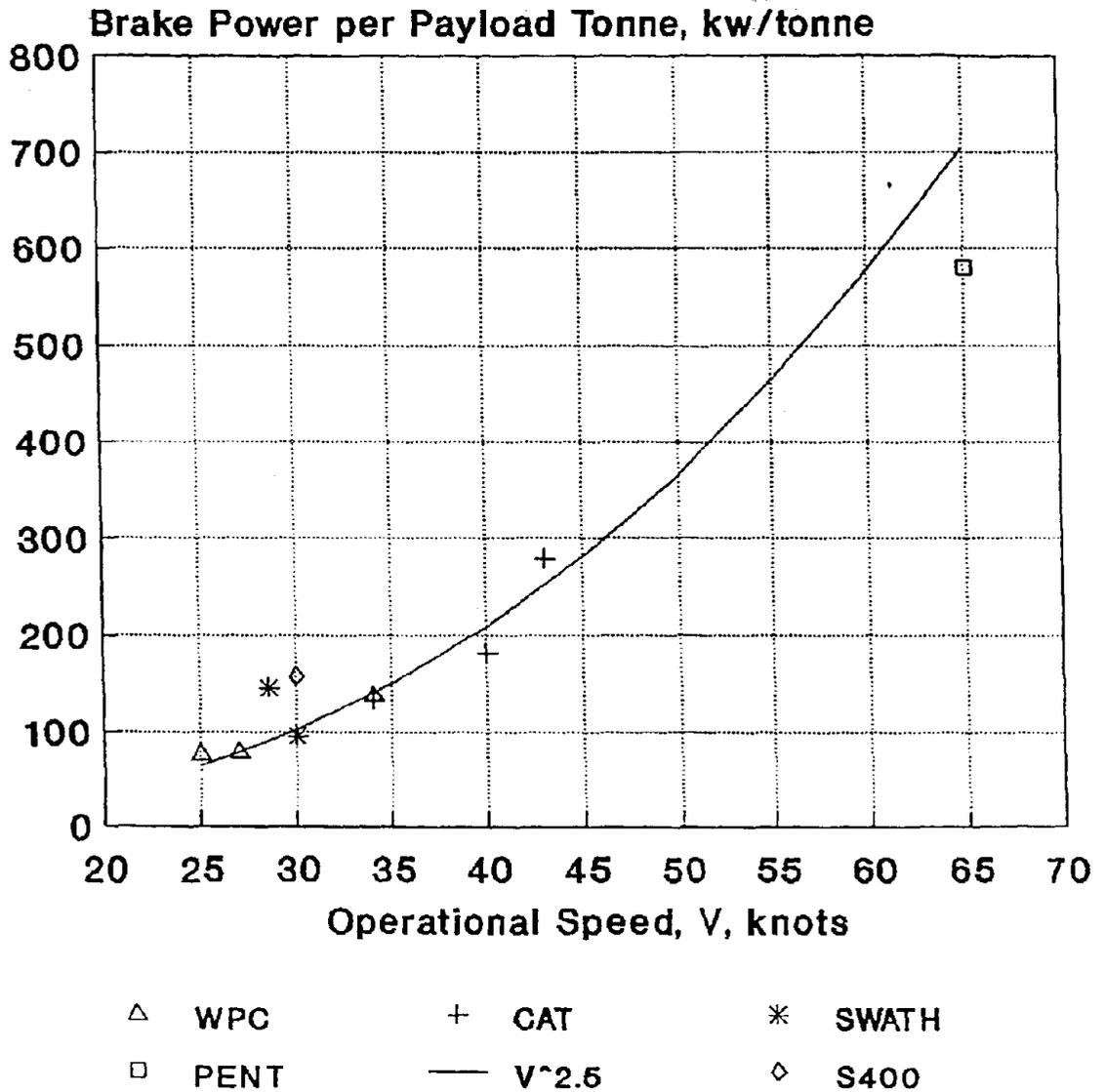
SEA PERFORMANCE STUDY - COMPARISON OF EXISTING FAST FERRY RESISTANCE DATA																		
Craft ID	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50	60	70
1	Effective Power is quoted for a naked hull																	
2	Vessel is assumed to be at level trim																	
3	Effective power data is taken from model test results																	
Hull 1	460	556	666	797	979	1213	-	-	-	-	-	-	-	-	-	-	-	-
Hull 2	967	1117	1303	1526	1786	2009	-	-	-	-	-	-	-	-	-	-	-	-
Hull 3	-	-	1739	2057	2332	2733	3299	3839	4444	5100	-	-	-	-	-	-	-	-
Hull 4	681	817	927	1090	1284	1444	1690	1935	2207	2562	-	-	-	-	-	-	-	-
Hull 5	-	1210	1340	1550	1815	2100	2510	2800	3316	380	4325	4815	5510	6400	-	-	-	-
Hull 6	-	-	1752	1961	2231	2571	2963	3408	3905	4445	5002	5556	6362	-	-	-	-	-
Hull 7	1116	1358	1629	1858	2212	2706	3298	-	-	-	-	-	-	-	-	-	-	-
Hull 8	1827	2205	2709	2856	3129	3738	-	-	-	-	-	-	-	-	-	-	-	-
Hull 9	-	-	-	-	4112	4794	5514	6340	7101	7994	8840	9799	-	-	-	-	-	-
Hull 10	950	1090	1320	1650	2000	2280	2490	2725	3060	3425	3860	4300	4850	5445	6765	10870	16230	-
Hull 11	-	-	-	-	-	6405	7350	8400	9555	11025	-	-	-	-	-	-	-	-

Table 2. HSC Sample Population Effective Powers

SEA PERFORMANCE STUDY - COMPARISON OF EXISTING FAST FERRY POWERING DATA											
1	Effective Power is quoted from model tests for a naked hull at optimum trim.										
2	Appendage Drag is taken from model tests or assessed by calculated where data is unavailable										
3	Air Drag is calculated on the basis of above water frontal area										
4	Total Pe is the sum of Effective power, Appendage Drag and Air Drag										
5	Hull Efficiency is quoted from model tests for propeller driven craft but is effectively accounted for in the correlation factor for the wj craft										
6	Propulsor efficiency has been taken from manufacturers data for waterjets and propeller chart data for propellers										
7	Transmission efficiency has been taken as 98% throughout										
8	The correlation factor is quoted as a typical value for the class of craft or from trial results where available										
Craft ID	Service Speed (knots)	Effective Power, Pe (kw)	Appendage Drag (kw)	Air Drag (kw)	Total Pe (kw)	Hull Effy (nh x nr)	Propulsor Effy, (no)	Trans Effy (nt)	Correlation Factor	Brake Power, Pb (kw)	Percentage of Installed Power (%)
Hull 1	27	882	25	65	972	0.97	0.71	0.98	1.00	1440	95.4
Hull 2	25	1398	0	76	1474	1.00	0.63	0.98	0.98	2340	95.1
Hull 3	34	3839	94	234	4167	1.00	0.68	0.98	0.98	6128	95.7
Hull 4	34	1935	0	106	2041	1.00	0.68	0.98	1.00	3063	91.4
Hull 5	43	5250	115	338	5703	1.00	0.72	0.98	1.00	8082	96.2
Hull 6	40	5002	140	314	5456	1.00	0.70	0.98	1.00	7953	89.5
Hull 7	30	2706	50	122	2878	1.05	0.72	0.98	1.00	3885	95.2
Hull 8	28.5	3281	135	204	3620	1.02	0.68	0.98	1.02	5432	94.6
Hull 9	38	7994	330	320	8644	1.00	0.69	0.98	1.05	13422	88.3
Hull 10	65	13210	0	1607	14817	1.00	0.79	0.98	1.00	19138	92.5
Hull 11	35	8977	180	500	9657	1.00	0.68	0.98	1.00	14491	89.5

Table 3. HSC Sample Population Design Speed Brake Powers

Comparison of Power Required per Tonne of Pax and Baggage Payload



**Note - The comparison is made between
passenger-only ferries with a capacity
of between 200 and 500 passengers.**

Figure 1. Comparison of Power Required per Payload Tonne

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4. SEAKEEPING PERFORMANCE

4.1. Vessel Data Input

Four vessels from the HSC sample population described above were selected for detailed seakeeping studies. Three of these craft have a similar payload capacity to the SLICE 400 design and one to the SLICE 600 design.

The seakeeping analysis was undertaken on the basis of active ride control systems not being fitted, although the SLICE and SWATH craft were modelled with their fixed forward and aft fins whereas all other craft were assumed not to be fitted with fins.

The principal characteristics of the selected vessels are provided below for comparison:

PRINCIPAL CHARACTERISTICS OF CRAFT SELECTED FOR THE SEAKEEPING STUDY						
Hull ID	Type	LOA (m)	Disp (tonnes)	Payload (no liquids) (tonnes)	Design Speed (knots)	Brake Power at Design Speed (kw)
Hull 3	50m WPC	49	270	45	34	6128
Hull 5	45m CAT	45	185	29	43	8082
Hull 7	40m SWA	37	190	41	30	3885
S400	SLICE 400	34	225	32	30	5034
Hull 11	75m WPC	74	700	150	35	14491
S600	SLICE 600	65	1525	182	30	25500

The vessel hull lines were analysed to provide section details at 20 design stations between the forward and aft perpendiculars at the design displacement and at level trim. These were then input into the CATMO seakeeping programme along with a range of relevant design parameters as presented below.

ADDITIONAL RELEVANT DESIGN PARAMETERS FOR THE SEAKEEPING STUDY								
Hull ID	Type	Hull Sep (m)	Hull Sep Fwd (m)	Hull Sep Aft (m)	LCG (m)	VCG (m)	Rad P (m)	Rad R (m)
Hull 3	50m WPC	15	-	-	17.0	5.3	11.0	6.5
Hull 5	45m CAT	8.5	-	-	16.9	4.3	10.0	4.0
Hull 7	40m SWA	10	-	-	18.1	6.5	9.2	4.6
S400	SLICE 400	-	11.5	16	15.6	7.2	8.5	6.0
Hull 11	75m WPC	21.5	-	-	25.1	7.5	16.0	9.1
S600	SLICE 600	-	29.3	20.4	29.9	14	16.4	10.4

The above abbreviations have the following meanings:

- Hull Sep : Hull separation
- LCG : Longitudinal center of gravity
- VCG : Vertical center of gravity
- Rad P : Radius of gyration in Pitch
- Rad R : Radius of gyration in Roll

Details of the CATMO programme are presented in Annex C.

4.2. Seakeeping Data Output

For a given speed and heading the CATMO programme was set to provide a Response Amplitude Operator (RAO) output for a range of wave frequencies between 0.2 and 2.0 rad/s, for the following quantities:

- Heave : vertical motion at the centre of gravity position
- Pitch : angular motion about a transverse axis of rotation
- Roll : angular motion about a longitudinal axis of rotation
- Vert Acc : vertical acceleration at specified points on the vessel
- Rel motion : the relative motion between the ship and water surface at specified points on the vessel

These RAO values were then applied to a standard ITTC two-parameter sea spectrum, with a defined significant wave height and zero-crossing period, to determine the expected ship responses in an irregular sea.

The root mean square (rms or standard deviation) of the various responses are presented for each vessel at two speeds, five headings and in three seastates in Tables 4 to 9.

The positions assumed for the vertical acceleration and relative motion calculations were defined from the general arrangement drawings of each vessel as follows:

- Vacc1 : vertical acceleration at the bridge position
- Vacc2 : vertical acceleration at the extreme lateral seat position in the saloon on the main deck at the LCG position.
- Vacc3 : vertical acceleration at the LCG position on the main deck centreline
- Relmo1 : relative motion at the forward end, lower side of the wet deck
- Relmo2 : relative motion at the relevant waterjet inlet or propeller position

The relative motion values were then converted appropriately to probabilities of water contact on the wetdeck and probabilities of emergence of propellers or waterjet inlets as described in Ref 6 as follows:

$$P = \exp[-0.5*(amp/rms)^2]$$

where P is the probability that a given amplitude of motion, which has a root mean square value, rms , will exceed a given amplitude, amp . The term \exp is the exponential function, $e = 2.71828$. The code $*$ is a multiplication symbol and the code $^$ raises to the preceding number to the power of the following number. These probability values are also presented in Tables 4 to 9.

The seastates selected for this analysis were defined as follows:

- Seastate 3 : 0.875 m significant wave height, 4.5 sec zero crossing period
- Seastate 4 : 1.875 m significant wave height, 6.0 sec zero crossing period
- Seastate 5 : 3.25 m significant wave height, 8.5 sec zero crossing period
- Seastate 6 : 5.0 m significant wave height, 9.5 sec zero crossing period

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For this wave spectrum, the relationship between modal period and zero crossing period is:

$$\text{Modal Period} = 1.41 * \text{Zero Crossing Period}$$

For the SLICE 400 comparisons, seastates 3 to 5 were used and for the SLICE 600 comparison, seastates 4 to 6 were used. For all seastates, two ships speeds were assumed.

The low speed studied on all craft was 5 knots and the high speed was assumed to be the craft's design speed which ranged between 25 and 43 knots for the different vessels.

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FAST FERRY MOTION PREDICTION IN IRREGULAR SEAS								CRAFT - 50M WPC		
Motion Statistics - RMS Values								Probabilities		
	Heave	Pitch	Roll	Vacc1	Vacc2	Vacc3	Relmo1	Relmo2	Prob of Slam	Prob of Emerg
	(m)	(deg)	(deg)	(m/s ²)	(m/s ²)	(m/s ²)	(m)	(m)		
Condition : 33 knots in SS3										
Head	0.108	0.611	0.000	1.007	0.527	0.527	0.310	0.192	1.11E-12	5.58E-14
Bow	0.140	0.625	0.558	0.886	0.577	0.552	0.269	0.190	1.33E-16	2.92E-14
Beam	0.124	0.014	1.215	0.181	0.265	0.185	0.160	0.028	1.34E-45	0.00E+00
Qtr	0.095	0.451	0.449	0.035	0.028	0.015	0.123	0.167	1.18E-76	3.03E-18
Stern	0.085	0.688	0.000	0.204	0.078	0.078	0.210	0.113	8.96E-27	5.46E-39
Condition : 33 knots in SS4										
Head	0.411	1.817	0.000	2.358	1.409	1.409	0.663	0.394	2.42E-03	7.12E-04
Bow	0.428	1.500	1.297	1.828	1.272	1.238	0.485	0.315	1.31E-05	1.19E-05
Beam	0.351	0.019	2.137	0.300	0.406	0.305	0.221	0.038	3.02E-24	0.00E+00
Qtr	0.308	0.961	0.966	0.049	0.038	0.021	0.169	0.245	6.03E-41	7.25E-09
Stern	0.292	1.410	0.000	0.296	0.112	0.112	0.312	0.162	1.58E-12	2.42E-19
Condition : 33 knots in SS5										
Head	0.838	2.600	0.000	2.843	1.857	1.857	0.758	0.458	1.00E-02	4.69E-03
Bow	0.819	1.932	1.697	2.057	1.519	1.485	0.503	0.315	2.88E-05	1.17E-07
Beam	0.729	0.018	2.504	0.356	0.441	0.360	0.206	0.040	8.53E-28	0.00E+00
Qtr	0.681	1.306	1.319	0.049	0.039	0.028	0.154	0.232	3.66E-49	8.37E-10
Stern	0.687	1.739	0.000	0.275	0.106	0.106	0.296	0.153	7.75E-14	9.80E-22
Condition : 5 knots in SS3										
Head	0.102	0.896	0.000	0.415	0.186	0.186	0.253	0.129	1.13E-18	4.36E-30
Bow	0.112	0.639	0.564	0.301	0.179	0.156	0.147	0.110	6.94E-54	4.18E-41
Beam	0.127	0.025	1.237	0.198	0.282	0.207	0.163	0.027	5.82E-44	0.00E+00
Qtr	0.100	0.486	0.484	0.093	0.072	0.062	0.125	0.169	3.04E-74	7.82E-18
Stern	0.086	0.627	0.000	0.081	0.042	0.042	0.181	0.117	8.64E-36	2.03E-36
Condition : 5 knots in SS4										
Head	0.324	1.756	0.000	0.692	0.355	0.355	0.383	0.195	1.48E-08	1.42E-13
Bow	0.341	1.240	1.150	0.514	0.353	0.324	0.205	0.153	4.64E-28	1.34E-21
Beam	0.353	0.032	2.160	0.316	0.426	0.325	0.224	0.037	1.28E-23	0.0E+00
Qtr	0.320	1.039	1.046	0.195	0.162	0.149	0.173	0.256	4.16E-39	3.46E-08
Stern	0.297	1.386	0.000	0.173	0.113	0.113	0.277	0.169	1.07E-15	7.82E-18
Condition : 5 knots in SS5										
Head	0.708	2.195	0.000	0.741	0.448	0.448	0.372	0.190	5.00E-09	2.92E-14
Bow	0.723	1.549	1.503	0.570	0.440	0.416	0.189	0.143	6.95E-33	1.28E-24
Beam	0.730	0.029	2.520	0.367	0.456	0.374	0.209	0.040	5.04E-27	1.3E-30
Qtr	0.702	1.381	1.407	0.258	0.231	0.220	0.159	0.247	3.65E-46	9.81E-09
Stern	0.682	1.885	0.000	0.234	0.181	0.181	0.271	0.158	2.28E-16	2.68E-20

Table 4. 50M WPC Motion Prediction in Irregular Seas

Seaspeed Technology Limited

FAST FERRY MOTION PREDICTION IN IRREGULAR SEAS								CRAFT - 45M CAT		
Motion Statistics - RMS Values								Probabilities		
	Heave (m)	Pitch (deg)	Roll (deg)	Vacc1 (m/s ²)	Vacc2 (m/s ²)	Vacc3 (m/s ²)	Relmo1 (m)	Relmo2 (m)	Prob of Slam	Prob of Emerg
Condition : 38.5 knots in SS3										
Head	0.119	0.575	0.000	0.826	0.672	0.672	0.330	0.202	3.46E-07	3.71E-11
Bow	0.176	0.630	0.597	0.929	0.928	0.829	0.319	0.215	1.22E-07	6.20E-10
Beam	0.175	0.015	2.480	0.231	0.567	0.229	0.057	0.096	4.0E-221	3.38E-47
Qtr	0.118	0.649	0.694	0.117	0.073	0.072	0.234	0.132	1.42E-13	3.74E-25
Stern	0.105	0.766	0.000	0.250	0.163	0.163	0.332	0.111	4.14E-07	2.86E-35
Condition : 38.5 knots in SS4										
Head	0.464	1.637	0.000	2.080	1.880	1.880	0.725	0.421	4.59E-02	3.97E-03
Bow	0.509	1.442	1.580	1.965	2.049	1.820	0.598	0.378	1.08E-02	1.05E-03
Beam	0.425	0.023	3.810	0.387	0.790	0.385	0.074	0.133	5.8E-131	8.70E-25
Qtr	0.347	1.211	1.355	0.159	0.102	0.099	0.339	0.190	7.55E-07	1.62E-12
Stern	0.319	1.585	0.000	0.383	0.253	0.253	0.538	0.158	3.71E-03	8.94E-18
Condition : 38.5 knots in SS5										
Head	0.909	2.369	0.000	2.697	2.481	2.481	0.875	0.484	1.21E-01	1.52E-02
Bow	0.900	1.858	2.181	2.260	2.360	2.119	0.648	0.388	2.11E-02	1.49E-03
Beam	0.790	0.024	4.020	0.437	0.760	0.434	0.066	0.129	3.1E-162	2.66E-26
Qtr	0.721	1.487	1.717	0.145	0.094	0.091	0.318	0.179	1.10E-07	5.21E-14
Stern	0.701	1.988	0.000	0.364	0.242	0.242	0.537	0.148	3.63E-03	3.71E-20
Condition : 5 knots in SS3										
Head	0.112	0.896	0.000	0.305	0.198	0.198	0.372	0.129	8.24E-06	2.66E-26
Bow	0.140	0.846	0.985	0.358	0.342	0.227	0.312	0.078	5.92E-08	1.11E-70
Beam	0.177	0.017	3.023	0.241	0.736	0.238	0.050	0.136	1.0E-286	9.75E-24
Qtr	0.122	0.649	0.765	0.103	0.095	0.080	0.226	0.145	1.68E-14	5.72E-21
Stern	0.095	0.688	0.000	0.067	0.047	0.047	0.289	0.111	3.72E-09	4.39E-35
Condition : 5 knots in SS4										
Head	0.343	1.750	0.000	0.536	0.381	0.381	0.595	0.191	1.03E-02	2.15E-12
Bow	0.382	1.490	1.823	0.576	0.560	0.416	0.453	0.103	3.73E-04	1.30E-40
Beam	0.426	0.025	4.410	0.398	0.985	0.394	0.065	0.181	2.6E-169	1.02E-13
Qtr	0.356	1.250	1.530	0.206	0.196	0.175	0.335	0.212	5.38E-07	3.53E-10
Stern	0.316	1.470	0.000	0.151	0.123	0.123	0.472	0.161	6.95E-04	3.81E-17
Condition : 5 knots in SS5										
Head	0.731	2.190	0.000	0.606	0.475	0.475	0.597	0.186	1.06E-02	4.99E-13
Bow	0.761	1.745	2.186	0.617	0.607	0.492	0.431	0.096	1.61E-04	1.02E-46
Beam	0.791	0.025	4.480	0.443	0.917	0.441	0.058	0.168	5.2E-207	8.32E-16
Qtr	0.738	1.554	1.945	0.266	0.259	0.243	0.322	0.204	1.64E-07	5.93E-11
Stern	0.704	1.960	0.000	0.214	0.190	0.190	0.481	0.152	9.10E-04	3.79E-19

Table 5. 45M CAT Motion Prediction in Irregular Seas

Seaspeed Technology Limited

FAST FERRY MOTION PREDICTION IN IRREGULAR SEAS								CRAFT - 40M SWATH		
Motion Statistics - RMS Values								Probabilities		
	Heave	Pitch	Roll	Vacc1	Vacc2	Vacc3	Relmo1	Relmo2	Prob of Slam	Prob of Emerg
	(m)	(deg)	(deg)	(m/s ²)	(m/s ²)	(m/s ²)	(m)	(m)		
Condition : 30 knots in SS3										
Head	0.058	0.322	0.000	0.529	0.305	0.305	0.221	0.188	1.63E-28	1.50E-14
Bow	0.093	0.340	0.194	0.376	0.355	0.295	0.203	0.212	1.16E-33	1.35E-11
Beam	0.173	0.227	1.723	0.188	0.393	0.188	0.165	0.226	1.41E-50	2.72E-10
Qtr	0.124	0.632	1.604	0.050	0.036	0.036	0.192	0.135	1.53E-37	1.55E-27
Stem	0.138	0.813	0.000	0.146	0.109	0.109	0.322	0.108	8.14E-14	1.29E-42
Condition : 30 knots in SS4										
Head	0.357	0.875	0.000	0.990	0.841	0.841	0.502	0.397	4.12E-06	7.94E-04
Bow	0.432	0.742	0.712	0.831	0.932	0.821	0.498	0.435	3.37E-06	2.62E-03
Beam	0.454	0.428	4.219	0.369	0.723	0.358	0.266	0.435	6.59E-20	2.62E-03
Qtr	0.344	1.226	3.320	0.067	0.048	0.042	0.268	0.239	1.27E-19	2.80E-09
Stem	0.367	1.590	0.000	0.217	0.158	0.158	0.512	0.150	6.65E-06	1.93E-22
Condition : 30 knots in SS5										
Head	0.987	1.370	0.000	1.438	1.393	1.393	0.890	0.500	1.93E-02	1.11E-02
Bow	0.990	1.071	2.068	1.208	1.390	1.211	0.786	0.536	6.36E-03	1.99E-07
Beam	0.845	0.491	6.350	0.447	0.827	0.431	0.280	0.557	4.89E-18	2.66E-01
Qtr	0.710	1.580	4.451	0.067	0.052	0.047	0.254	0.300	9.20E-22	3.73E-06
Stem	0.725	1.969	0.000	0.204	0.147	0.147	0.500	0.139	3.73E-06	5.16E-26
Condition : 5 knots in SS3										
Head	0.261	0.888	0.000	0.425	0.381	0.381	0.520	0.214	9.57E-06	2.14E-11
Bow	0.259	0.769	0.868	0.394	0.442	0.359	0.454	0.235	2.60E-07	1.42E-09
Beam	0.197	0.645	2.560	0.235	0.469	0.216	0.282	0.321	8.59E-18	1.81E-05
Qtr	0.155	1.348	2.745	0.236	0.281	0.114	0.291	0.418	9.40E-17	1.60E-03
Stem	0.129	1.287	0.000	0.154	0.072	0.072	0.371	0.196	1.38E-10	1.91E-13
Condition : 5 knots in SS4										
Head	0.668	2.380	0.000	0.978	0.791	0.791	1.180	0.357	1.06E-01	1.47E-04
Bow	0.636	1.890	3.616	0.846	0.938	0.706	0.948	0.440	3.09E-02	2.99E-03
Beam	0.493	1.080	7.480	0.456	0.947	0.405	0.463	0.701	4.67E-07	1.01E-01
Qtr	0.406	2.350	6.350	0.386	0.552	0.220	0.475	0.786	9.66E-07	1.62E-01
Stem	0.367	2.500	0.000	0.279	0.155	0.155	0.607	0.309	2.07E-04	7.64E-05
Condition : 5 knots in SS5										
Head	1.039	3.280	0.000	1.140	0.900	0.900	1.370	0.384	1.89E-01	4.86E-04
Bow	0.997	2.470	6.460	0.964	1.120	0.792	1.050	0.574	5.87E-02	3.29E-02
Beam	0.871	1.097	11.050	0.527	1.190	0.470	0.166	0.934	5.61E-50	2.75E-01
Qtr	0.790	2.660	8.150	0.420	0.628	0.280	0.493	0.912	2.61E-06	2.59E-01
Stem	0.755	3.060	0.000	0.326	0.218	0.218	0.635	0.320	4.31E-04	1.68E-05

Table 6. 40M SWATH Motion Prediction in Irregular Seas

Seaspeed Technology Limited

FAST FERRY MOTION PREDICTION IN IRREGULAR SEAS								CRAFT - SLICE 400		
Motion Statistics - RMS Values								Probabilities		
	Heave	Pitch	Roll	Vacc1	Vacc2	Vacc3	Relmo1	Relmo2	Prob of	Prob of
	(m)	(deg)	(deg)	(m/s ²)	(m/s ²)	(m/s ²)	(m)	(m)	Slam	Emerg
Condition : 30 knots in SS3										
Head	0.049	0.367	0.000	0.734	0.511	0.511	0.169	0.187	1.03E-42	5.59E-22
Bow	0.061	0.267	0.227	0.342	0.339	0.246	0.167	0.173	1.00E-43	1.47E-25
Beam	0.113	0.096	0.707	0.113	0.170	0.109	0.153	0.151	5.92E-52	2.54E-33
Qtr	0.119	0.573	1.196	0.047	0.048	0.030	0.153	0.191	5.92E-52	4.25E-21
Stem	0.182	0.844	0.000	0.181	0.144	0.144	0.269	0.159	2.68E-17	4.01E-30
Condition : 30 knots in SS4										
Head	0.225	0.822	0.000	1.119	0.829	0.829	0.365	0.378	9.97E-10	6.29E-06
Bow	0.276	0.625	0.537	0.662	0.673	0.561	0.365	0.372	9.97E-10	4.26E-06
Beam	0.373	0.159	1.554	0.256	0.351	0.247	0.251	0.297	9.24E-20	3.76E-09
Qtr	0.302	1.206	2.930	0.081	0.070	0.043	0.279	0.294	3.93E-16	2.52E-09
Stem	0.433	1.880	0.000	0.255	0.201	0.201	0.495	0.290	1.27E-05	1.46E-09
Condition : 30 knots in SS5										
Head	0.803	1.330	0.000	1.311	1.100	1.100	0.678	0.619	2.46E-03	1.15E-02
Bow	0.857	1.045	0.941	0.929	0.956	0.856	0.618	0.616	7.25E-04	1.10E-02
Beam	0.804	0.176	2.459	0.352	0.464	0.342	0.274	0.401	1.18E-16	2.39E-05
Qtr	0.641	1.713	4.240	0.085	0.074	0.048	0.372	0.283	2.16E-09	5.25E-10
Stem	0.720	2.580	0.000	0.247	0.186	0.186	0.598	0.390	4.43E-04	1.30E-05
Condition : 5 knots in SS3										
Head	0.092	0.419	0.000	0.154	0.111	0.111	0.259	0.210	1.33E-18	1.35E-17
Bow	0.111	0.334	0.203	0.138	0.131	0.110	0.249	0.229	4.55E-20	6.73E-15
Beam	0.152	0.074	0.514	0.131	0.171	0.127	0.207	0.249	1.03E-28	1.03E-12
Qtr	0.132	0.920	0.508	0.067	0.113	0.081	0.207	0.182	1.03E-28	3.66E-23
Stem	0.109	1.580	0.000	0.102	0.062	0.062	0.261	0.228	2.49E-18	5.05E-15
Condition : 5 knots in SS4										
Head	0.461	1.690	0.000	0.468	0.353	0.353	0.754	0.474	7.77E-03	4.92E-04
Bow	0.478	1.320	0.792	0.431	0.407	0.349	0.653	0.555	1.54E-03	3.87E-03
Beam	0.490	0.179	1.707	0.328	0.430	0.321	0.382	0.556	6.05E-09	3.94E-03
Qtr	0.401	2.233	1.671	0.163	0.276	0.192	0.413	0.344	9.32E-08	5.24E-07
Stem	0.346	3.440	0.000	0.193	0.139	0.139	0.533	0.345	6.01E-05	5.70E-07
Condition : 5 knots in SS5										
Head	0.988	3.320	0.000	0.723	0.556	0.556	1.137	0.618	1.18E-01	1.13E-02
Bow	0.979	2.450	2.270	0.642	0.626	0.525	0.914	0.786	3.67E-02	6.27E-02
Beam	0.925	0.235	4.137	0.440	0.601	0.429	0.421	0.800	1.71E-07	6.90E-02
Qtr	0.811	3.040	3.618	0.244	0.396	0.268	0.501	0.502	1.67E-05	1.12E-03
Stem	0.758	4.420	0.000	0.249	0.209	0.209	0.648	0.648	1.39E-03	1.70E-02

Table 7. SLICE 400 Motion Prediction in Irregular Seas

Seaspeed Technology Limited

FAST FERRY MOTION PREDICTION IN IRREGULAR SEAS								CRAFT - 75M WPC		
Motion Statistics - RMS Values								Probabilities		
	Heave	Pitch	Roll	Vacc1	Vacc2	Vacc3	Relmo1	Relmo2	Prob of	Prob of
	(m)	(deg)	(deg)	(m/s ²)	(m/s ²)	(m/s ²)	(m)	(m)	Slam	Emerg
Condition : 35 knots in SS4										
Head	0.330	1.353	0.000	2.260	0.939	0.939	0.737	0.409	1.22E-03	1.89E-06
Bow	0.359	1.128	0.977	1.761	0.952	0.882	0.569	0.369	1.29E-05	9.27E-08
Beam	0.318	0.018	1.788	0.327	0.479	0.334	0.324	0.120	8.32E-16	3.15E-67
Qtr	0.281	0.642	0.646	0.052	0.038	0.023	0.247	0.320	1.13E-26	4.45E-10
Stern	0.232	0.957	0.000	0.213	0.099	0.099	0.394	0.236	6.35E-11	6.40E-18
Condition : 35 knots in SS5										
Head	0.784	2.204	0.000	3.020	1.470	1.470	0.935	0.526	1.55E-02	3.46E-04
Bow	0.776	1.605	1.425	2.110	1.270	1.190	0.621	0.384	7.85E-05	3.20E-07
Beam	0.698	0.017	2.230	0.363	0.502	0.369	0.305	0.110	9.62E-18	7.21E-80
Qtr	0.654	0.999	1.016	0.050	0.038	0.026	0.234	0.319	1.23E-29	3.89E-10
Stern	0.641	1.327	0.000	0.206	0.092	0.092	0.407	0.233	2.78E-10	2.29E-18
Condition : 35 knots in SS6										
Head	1.220	3.040	0.000	3.977	2.005	2.005	1.220	0.693	8.64E-02	1.01E-02
Bow	1.205	2.180	1.959	2.740	1.690	1.602	0.794	0.485	3.08E-03	8.49E-05
Beam	1.102	0.021	2.997	0.482	0.651	0.488	0.382	0.100	1.42E-11	1.73E-91
Qtr	1.040	1.419	1.445	0.065	0.051	0.039	0.291	0.402	2.02E-19	1.19E-06
Stern	1.034	1.820	0.000	0.258	0.114	0.114	0.514	0.292	1.02E-06	5.87E-12
Condition : 5 knots in SS4										
Head	0.254	1.170	0.000	0.611	0.239	0.239	0.455	0.251	2.26E-08	6.31E-16
Bow	0.282	0.870	0.830	0.445	0.282	0.225	0.271	0.195	2.79E-22	6.55E-26
Beam	0.326	0.035	1.811	0.373	0.518	0.386	0.335	0.100	7.84E-15	1.73E-96
Qtr	0.264	0.763	0.757	0.191	0.132	0.111	0.260	0.345	3.83E-24	9.00E-09
Stern	0.232	0.988	0.000	0.180	0.081	0.081	0.386	0.231	2.37E-11	1.13E-18
Condition : 5 knots in SS5										
Head	0.646	1.720	0.000	0.714	0.344	0.344	0.487	0.262	2.12E-07	1.12E-14
Bow	0.674	1.240	1.225	0.538	0.379	0.333	0.267	0.191	6.23E-23	5.63E-27
Beam	0.701	0.032	2.240	0.396	0.532	0.407	0.314	0.101	8.80E-17	1.33E-94
Qtr	0.654	1.147	1.158	0.264	0.206	0.187	0.253	0.364	1.86E-25	5.92E-08
Stern	0.621	1.540	0.000	0.254	0.151	0.151	0.416	0.233	7.12E-10	2.29E-18
Condition : 5 knots in SS6										
Head	1.041	2.380	0.000	0.935	0.477	0.477	0.622	0.334	8.10E-05	2.60E-09
Bow	1.070	1.720	1.700	0.712	0.516	0.462	0.336	0.239	9.51E-15	1.72E-17
Beam	1.100	0.040	3.010	0.520	0.685	0.532	0.393	0.102	5.63E-11	9.05E-91
Qtr	1.040	1.600	1.620	0.362	0.291	0.268	0.317	0.464	1.77E-16	3.57E-05
Stern	1.007	2.168	0.000	0.350	0.221	0.221	0.531	0.294	2.43E-06	8.34E-12

Table 8. 75M WPC Motion Prediction in Irregular Seas

Seaspeed Technology Limited

FAST FERRY MOTION PREDICTION IN IRREGULAR SEAS								CRAFT - SLICE 600		
Motion Statistics - RMS Values								Probabilities		
	Heave (m)	Pitch (deg)	Roll (deg)	Vacc1 (m/s ²)	Vacc2 (m/s ²)	Vacc3 (m/s ²)	Relmo1 (m)	Relmo2 (m)	Prob of Slam	Prob of Emerg
Condition : 30 knots in SS4										
Head	0.106	0.442	0.000	0.768	0.449	0.449	0.512	0.427	8.76E-26	4.96E-17
Bow	0.136	0.332	0.301	0.380	0.428	0.262	0.407	0.410	2.22E-40	2.07E-18
Beam	0.236	0.139	0.809	0.127	0.244	0.135	0.403	0.342	3.59E-41	3.84E-26
Qtr	0.182	0.832	2.150	0.034	0.035	0.019	0.307	0.335	2.02E-70	3.24E-27
Stern	0.269	0.977	0.000	0.115	0.074	0.074	0.766	0.335	6.38E-12	3.24E-27
Condition : 30 knots in SS5										
Head	0.473	0.833	0.000	0.878	0.583	0.583	0.775	0.651	1.16E-11	9.67E-08
Bow	0.557	0.632	0.556	0.529	0.550	0.453	0.655	0.645	4.89E-16	7.15E-08
Beam	0.669	0.191	1.370	0.216	0.361	0.232	0.477	0.531	1.35E-29	2.86E-11
Qtr	0.476	1.404	3.125	0.039	0.049	0.026	0.534	0.423	9.98E-24	2.43E-17
Stern	0.574	1.710	0.000	0.107	0.068	0.068	0.961	0.452	7.71E-08	2.81E-15
Condition : 30 knots in SS6										
Head	0.863	1.238	0.000	1.177	0.829	0.829	1.130	0.948	7.17E-06	4.92E-04
Bow	0.981	0.934	0.838	0.753	0.781	0.669	0.971	0.949	1.08E-07	5.00E-04
Beam	1.090	0.265	2.025	0.314	0.505	0.337	0.636	0.764	5.76E-17	8.07E-06
Qtr	0.790	2.016	4.298	0.056	0.074	0.041	0.766	0.577	6.38E-12	1.18E-09
Stern	0.901	2.520	0.000	0.133	0.085	0.085	1.310	0.642	1.49E-04	6.13E-08
Condition : 5 knots in SS4										
Head	0.167	0.413	0.000	0.165	0.110	0.110	0.627	0.469	1.96E-17	2.98E-14
Bow	0.202	0.318	0.230	0.129	0.134	0.109	0.528	0.494	2.74E-24	6.36E-13
Beam	0.277	0.199	0.528	0.115	0.193	0.134	0.443	0.520	3.38E-34	1.01E-11
Qtr	0.206	0.837	0.407	0.054	0.141	0.100	0.462	0.411	1.68E-31	2.52E-18
Stern	0.194	1.308	0.000	0.093	0.073	0.073	0.523	0.416	9.67E-25	6.64E-18
Condition : 5 knots in SS5										
Head	0.851	1.116	0.000	0.386	0.303	0.303	1.411	0.809	5.02E-04	2.87E-05
Bow	0.866	0.793	0.683	0.341	0.347	0.300	1.120	0.951	5.80E-06	5.16E-04
Beam	0.842	0.464	1.332	0.241	0.380	0.276	0.635	0.966	5.12E-17	6.52E-04
Qtr	0.695	1.957	1.128	0.130	0.265	0.189	0.896	0.633	6.58E-09	3.81E-08
Stern	0.584	2.799	0.000	0.167	0.136	0.136	1.120	0.499	5.80E-06	1.15E-12
Condition : 5 knots in SS6										
Head	1.437	1.839	0.000	0.600	0.474	0.474	2.180	1.170	4.15E-02	6.74E-03
Bow	1.438	1.288	1.167	0.528	0.537	0.460	1.715	1.413	5.84E-03	3.24E-02
Beam	1.350	0.693	2.188	0.360	0.558	0.405	0.888	1.422	4.68E-09	3.39E-02
Qtr	1.120	2.950	1.840	0.203	0.387	0.275	1.323	0.926	1.77E-04	3.41E-04
Stern	0.977	4.160	0.000	0.248	0.203	0.203	1.670	0.662	4.41E-03	1.65E-07

Table 9. SLICE 600 Motion Prediction in Irregular Seas

4.3. Seakeeping Performance Results

Whilst the root mean square (rms or standard deviation) values for all the vessel motions considered are presented for each craft in Tables 4 to 9, a graphical presentation of the angular motions (pitch and roll) is also provided in Annex A.

To enable an assessment of this data, it is useful to consider suitable criteria with which to compare the results.

Some accepted operational criteria for a range of ship types are presented in Ref 7 from which the following have been extracted. It should be noted that these threshold criteria are relevant to experience gained at sea in a range of merchant and naval craft and do not specifically address fast ferries. However they are considered to be relevant to this sector.

Maximum rms pitch motion	: approx 1.5 to 2.5 degrees
Maximum rms roll motion	: approx 2.5 to 4 degrees
Vert Acc rms (cargo craft)	: 1.5 to 2.5 m/s ² anywhere on vessel
Probability of a slam	: approx 0.01 to 0.05
Probability of propulsor emergence	: approx 0.01 to 0.2

In making comparisons with these threshold values, it should be remembered that the seakeeping analysis undertaken in this study assumes long-crested waves (ie. without using a energy spreading function). Since these criteria have been derived from practical experience, they relate to at-sea performance which is normally associated with short crested seas (ie. with wave energy spread across a range of relative headings). Thus they should be used only as a guide.

In terms of pitch, none of the craft would be limited by this criteria within the seastates studied.

In terms of roll, only the 40M SWATH would be limited by this criteria in the highest seastate studied.

In terms of vertical acceleration for cargo carrying (relevant to the 75M WPC and SLICE 600 only), the WPC is likely to be limited in head and bow seas in seastates 5 and 6. Based on operational experience of the Incat 74 metre WPC, this conclusion appears to be realistic.

In terms of slamming, the 45M CAT would be limited in head seas in seastate 4 and the 40M SWATH and 50M WPC in seastate 5. Again this appears to be a realistic conclusion. Surprisingly the SLICE 400 does not appear to be limited even in seastate 5. The 75M WPC would be limited in head seas in seastate 5 and 6 whilst the SLICE 600 again appears not to suffer from the same problem.

In terms of propeller emergence or waterjet inlet emergence, the 45M CAT, 40M SWATH and SLICE 400 appear to be limited in head seas in seastate 5. Additionally the 40M SWATH and SLICE 400 appear to be suffer similarly in beam seas in seastate 5 at low speeds, although at such low speeds the emergence problem would be unlikely to represent a limiting condition. At the higher speeds, propeller or waterjet racing associated with air ingestion, is often the cause of engine tripping due to overspeed.

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In terms of passenger comfort within a transport environment, a specific international standard exists; ISO 2631/3 (Ref 8). This requires the results of a third octave analysis of the motion response of the vessel to be compared with threshold curves of vertical acceleration.

Such an analysis has been undertaken for the head sea case for each vessel at both high and low transit speeds and the results are presented in Annex B.

The threshold lines for 0.5 hour and 2 hours represent a level of tolerance where it is considered that approximately 10% of the passengers will experience seasickness once exposed to this level of vertical acceleration for the specified length of time (ie 0.5 or 2 hours).

For operation at the low speed of 5 knots, the ISO criteria are not significantly exceeded by any of the designs although the small waterplane area designs lose some of their advantage in these conditions. This is likely to be due to the fact that their hull forms have been tuned for the higher speeds during the design process and, at low speed, they are operating in an off-design condition.

For the service speed case the SLICE craft are the only designs that do not exceed the criteria in any of the seastates considered. All other non-small waterplane area craft exceed the ISO thresholds in seastate 4 and above.

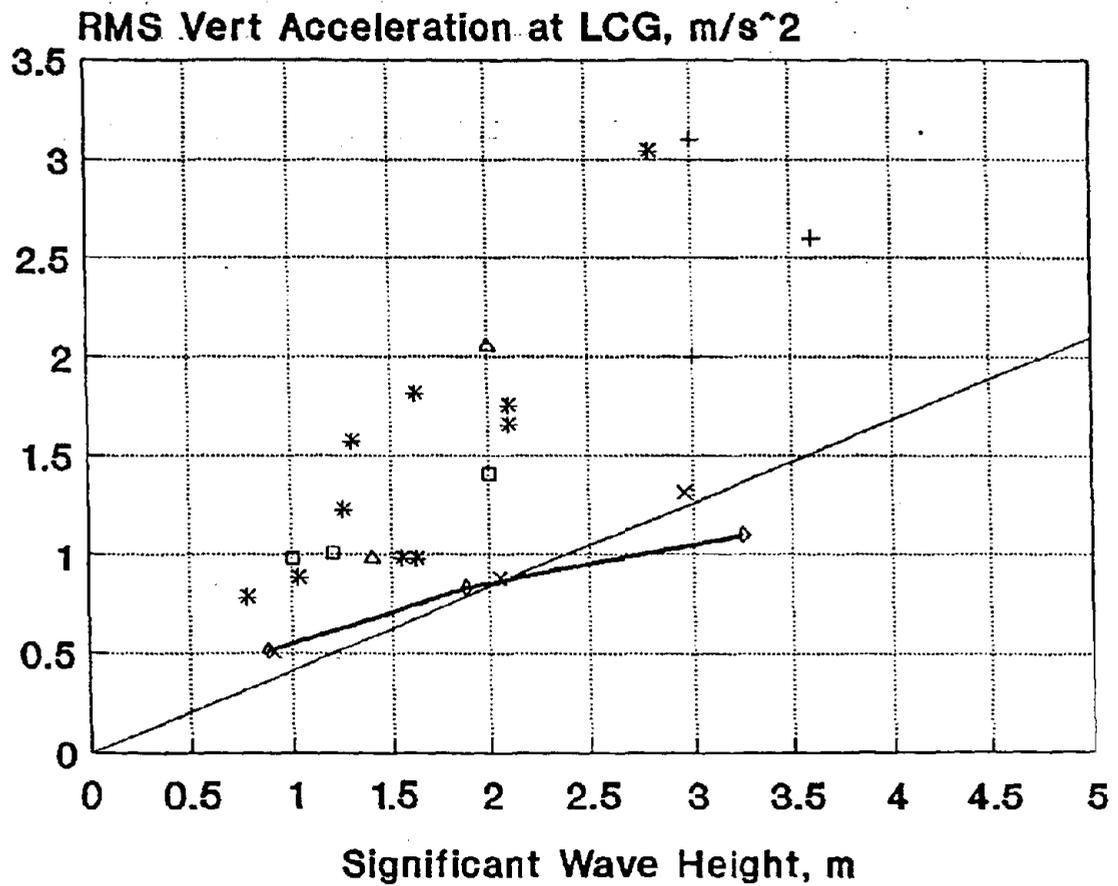
It should be remembered that the analysis assumes that none of the craft are assisted by active ride control systems. With the use of such a system the vertical acceleration performance can be improved significantly in the lower seastates and certainly the 50M WPC and 75M WPC could be expected to operate successfully in seastate 4 with ride control systems. Of course the use of such a system on the SLICE and SWATH craft would also improve their performance considerably.

As an additional comparison, the predicted vertical acceleration response at the LCG of the SLICE 400 has been compared with the results of a range of full scale trials measurements in Figure 2. It is clear from the results that small waterplane area craft have a significant advantage over most other high speed craft. As a guide, a limit line representing the best achieved results has been added and it can be seen that the performance of the SLICE is impressive although not a great deal better than some other SWATH craft.

It should be noted here that the responses of most high speed craft are sensitive to the wave period and the above analysis only considers one period per wave height. In order to provide some insight into the sensitivity of the vessel motion to wave period, an analysis was undertaken for the SLICE 400 and 50m WPC for significant wave heights associated with seastates 3, 4 and 5, covering zero crossing periods between 3 and 12 seconds.

The results are presented in Figure 3 and give a good indication of the relevant importance of significant wave height and zero crossing period. It can be seen that for the higher seastates, the effect on vertical acceleration of a two second difference in wave period can be equivalent to that of a 0.5 metre difference in significant wave height.

Comparison of SLICE 400 performance with trials results of existing fast ferries - 25 to 35 knots, 250/450 pax



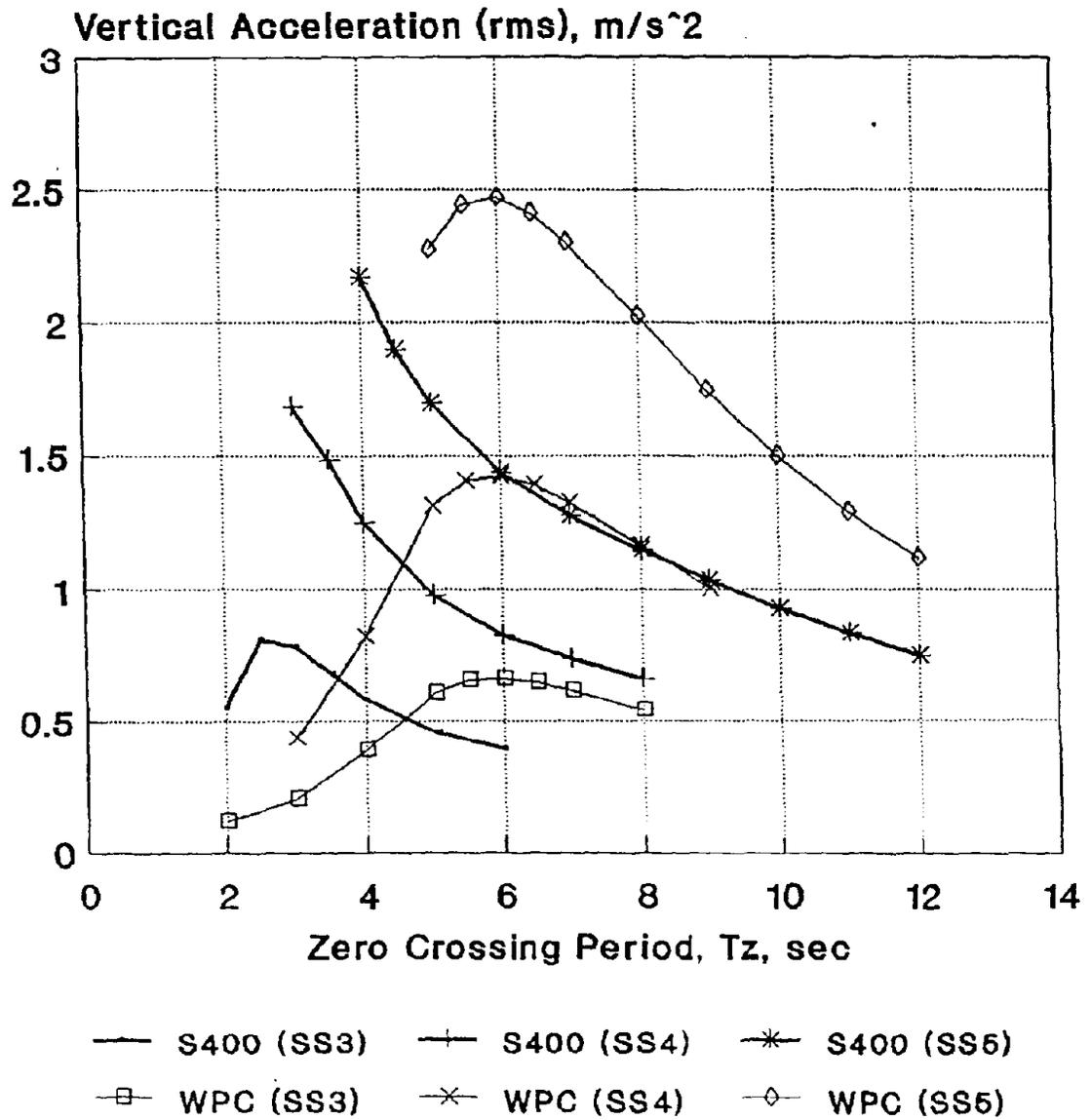
Head Sea Condition

* CAT	+ MONO	Δ HYD	□ SES
x SWATH	◊ S400	— Best Existing Limit	

(Note - All data for vessels without
active ride control systems)

Figure 2. Comparison of SLICE 400 Performance with Fast Ferry Trial Results

Ship Motion Sensitivity to Wave Period SLICE 400 and 50M WPC Comparison of Vertical Acceleration at LCG Position



(SLICE 400 @ 30 kts, 50M WPC @ 33 kts)

Figure 3. Analysis of Motion Sensitivity to Wave Period

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5. CONCLUSIONS

The study provides a range of model test and full scale powering and seakeeping data for high speed craft along with predicted results, on which to base a realistic performance assessment of the SLICE 400 and SLICE 600 designs.

The principal characteristics of eleven modern fast ferry designs are presented in the report, all with comparable speeds and payload capacities to the SLICE designs.

Firstly it is clear that the overall weights of the SLICE designs are higher (per tonne of payload) than their competitors. In the case of the SLICE 400 the displacement per tonne of payload is approximately 30% greater than the mean of comparable craft, and in the case of the SLICE 600, almost 75% greater than that of the equivalent HSC considered.

This goes some way to explaining the difference in powering characteristics where the SLICE 400 has a net power requirement of about 50% greater than its competitors and the SLICE 600, almost double the power requirement for the same speed and payload.

It should be noted that the powering comparisons were made in calm water conditions and it is likely that the SLICE and other SWATH designs would show improved performance if their powering characteristics in rough water were compared.

The draft of the SLICE 400 is approximately 50% greater than the equivalent SWATH craft at 4.57 metre against the SWATH mean of 3 metres. Clearly the catamarans have significantly less draft at about 1.5 metres.

The draft of the SLICE 600 is similarly about 3 times the draft of an equivalent catamaran although there were no equivalent SWATH craft in the study with which to compare this SLICE variant.

The seakeeping performance of the two SLICE craft and four selected craft of the eleven fast ferry examples, was derived using the prediction software CATMO (the details of which are described in an Annex to this report with verification examples). Based on a strip theory approach, but run in the time domain, this software provided the predicted response characteristics of the craft in three seastates (seastates 3, 4 and 5 for the SLICE 400 and seastates 4, 5 and 6 for the SLICE 600), at two speeds (5 knots and the relevant design speed for each design) and at five headings (0 to 180 degrees at 45 degree intervals). The results were not only compared with a range of full scale trial data but also with a number of practical performance criteria in an attempt to evaluate the benefits of the SLICE concept.

It is clear that the seakeeping performance of the SLICE is a significant improvement over that of typical catamarans and monohulls in virtually all conditions studied, although the performance of the SWATH craft was also impressive.

In particular the passenger comfort assessment using the ISO 2631/3 criteria indicated that the motion on board the SLICE 400 and 600 would be acceptable in all seastates considered which was by no means the case for the other HSC studied.

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Although the study assumed that ride control systems were not fitted, it is clear that the performance of all craft would benefit from such an addition, possibly improving the small waterplane area craft more than the others.

In conclusion it is considered that the SLICE offers a trade off between seakeeping and powering to a more extreme extent than SWATH craft, providing an impressive seakeeping capability but with a resulting powering performance likely to render the concept unattractive except in very particular cases where the improved motion or wash characteristics (noted from an associated report, Ref 9) were crucial.

However, it is thought that the attractiveness of the concept could be improved considerably with modification of the hull design to take modern propulsion systems and to reduce the structural weight and wetted area, without significantly compromising the seakeeping performance. The draft would appear to be an issue for the larger vessels although this is not expected to be an insurmountable problem, particularly for the smaller craft.

REFERENCES

1. Jane's High Speed Marine Transportation 1999/2000.
2. 400 Passenger Slice Ferry, Technical Data Package, Lockheed Marine Systems, April 1995.
3. SLICE 600 Passenger Vehicle Ferry, Technical Data Package, Lockheed Marine Systems, April 1995.
4. NPL High Speed Series, D.Bailey, National Maritime Institute, RINA 1976.
5. Effect of Pitch and Blade Width on Propeller Performance, GAWN, INA 1953.
6. Seakeeping - Ship Behaviour in Rough Weather, ARJM Lloyd, 1998.
7. Seakeeping Performance Assessment of Ships, NSTM, Stockholm, 1986.
8. ISO Standard 2631/3 - Evaluation of human exposure to whole-body vibration.
9. Wake Wash Measurement Trials - MV SLICE, Fox Associates, April 1999.

ANNEX A - SEAKEEPING RESULTS - ANGULAR MOTION COMPARISONS

Pitch Angle Comparison (Operational Speeds)

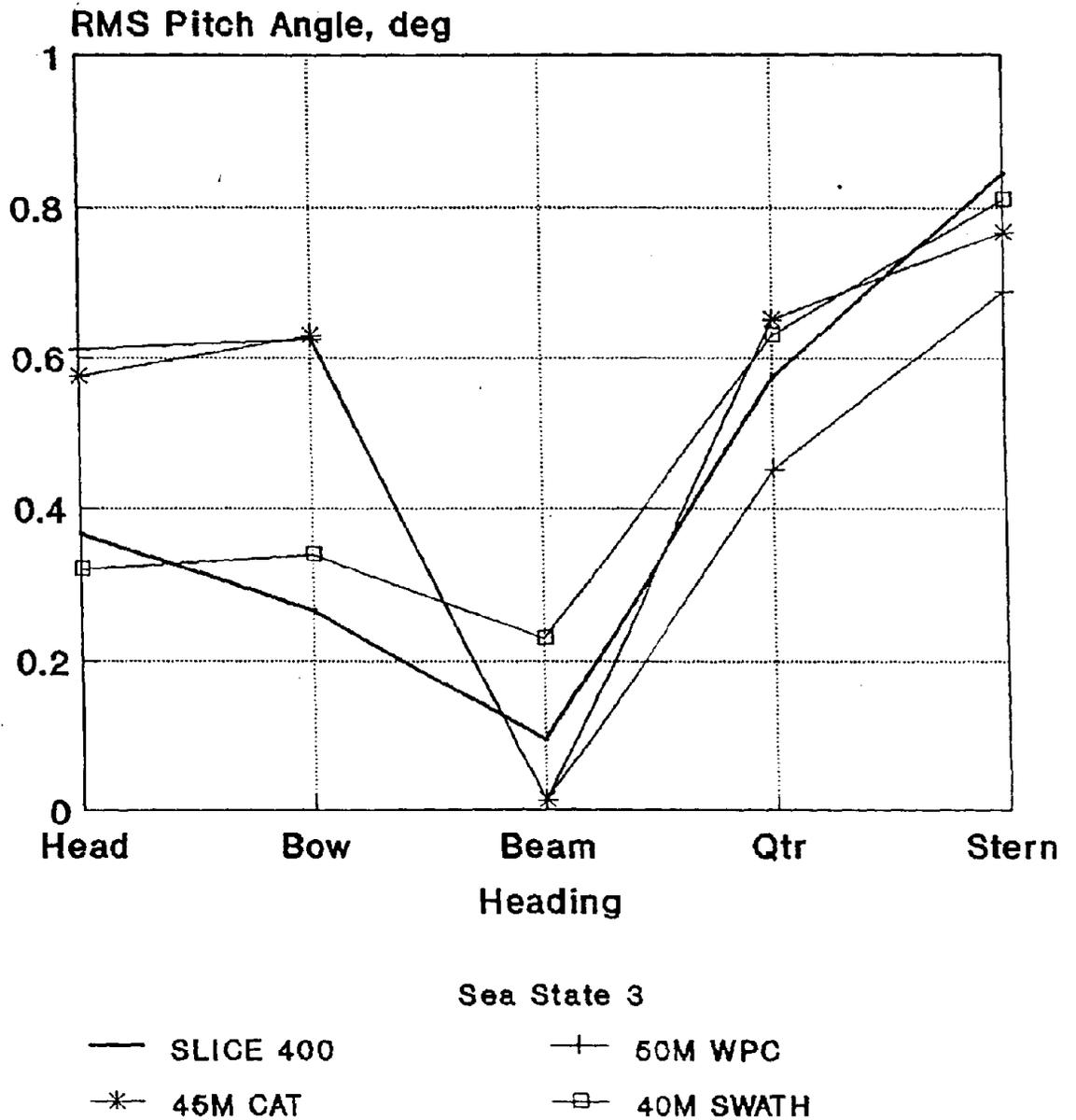


Figure A.1. SLICE 400 Pitch Angle Comparison in SS3

Pitch Angle Comparison (Operational Speeds)

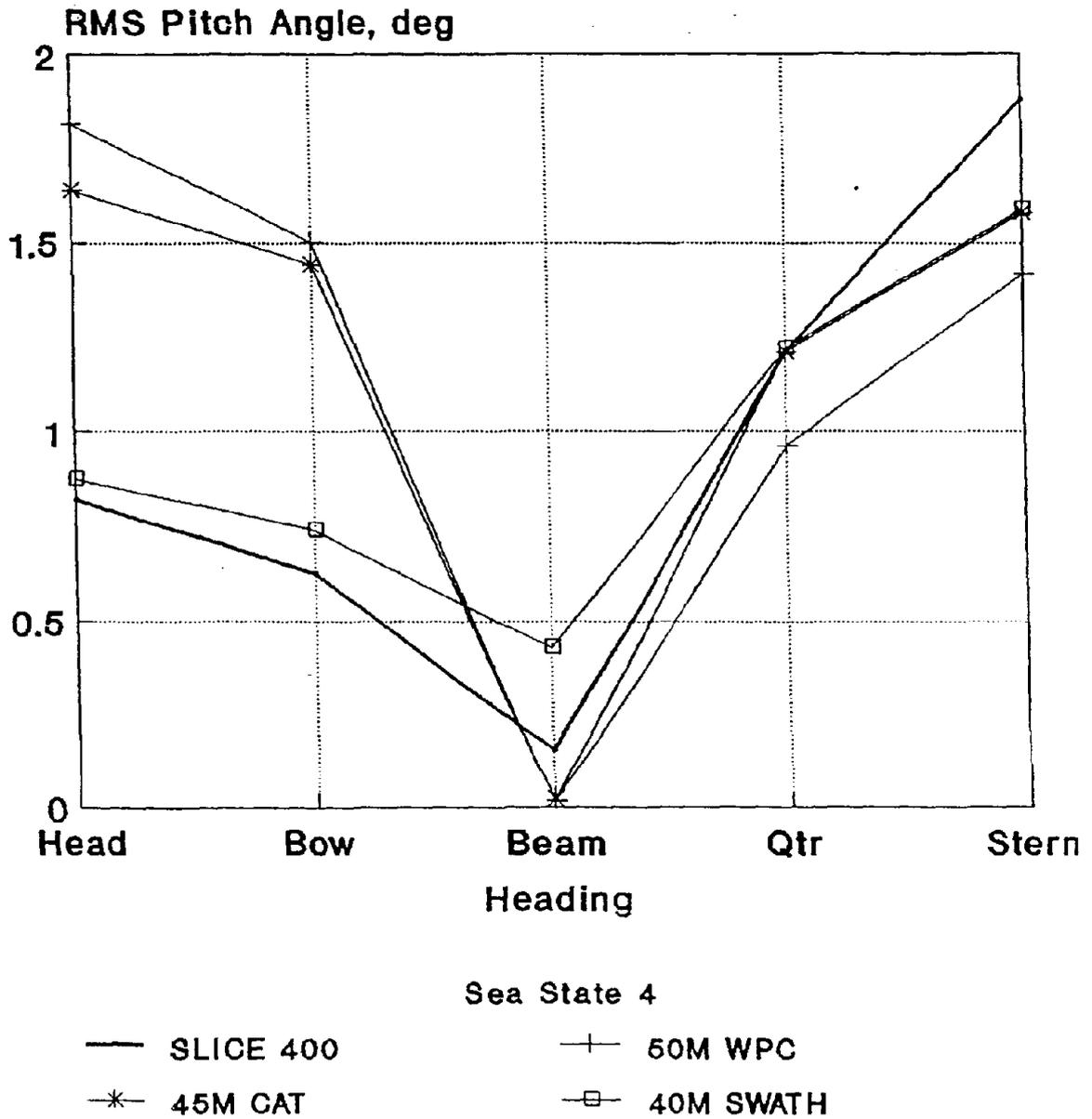


Figure A.2. SLICE 400 Pitch Angle Comparison in SS4

Pitch Angle Comparison (Operational Speeds)

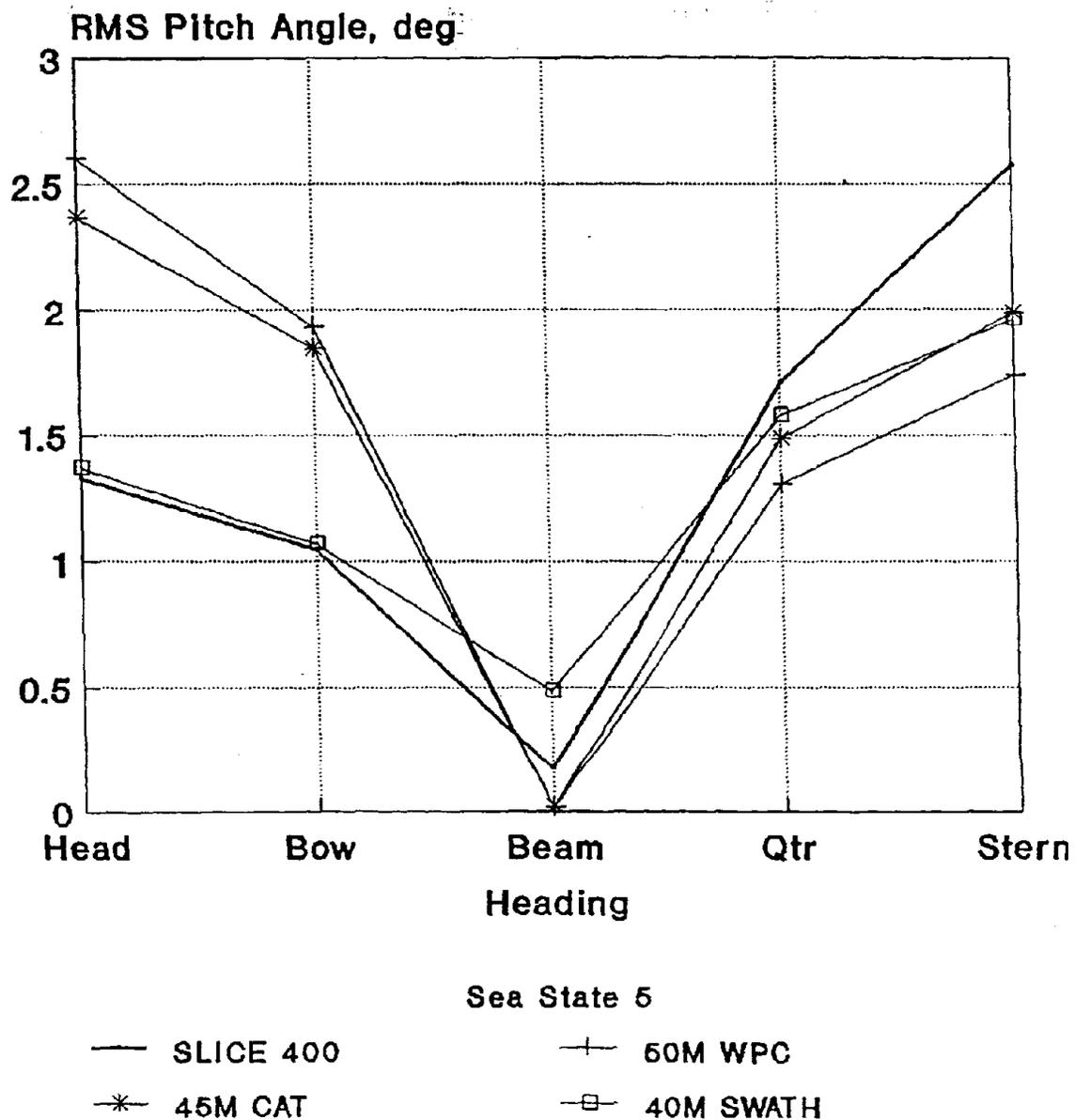
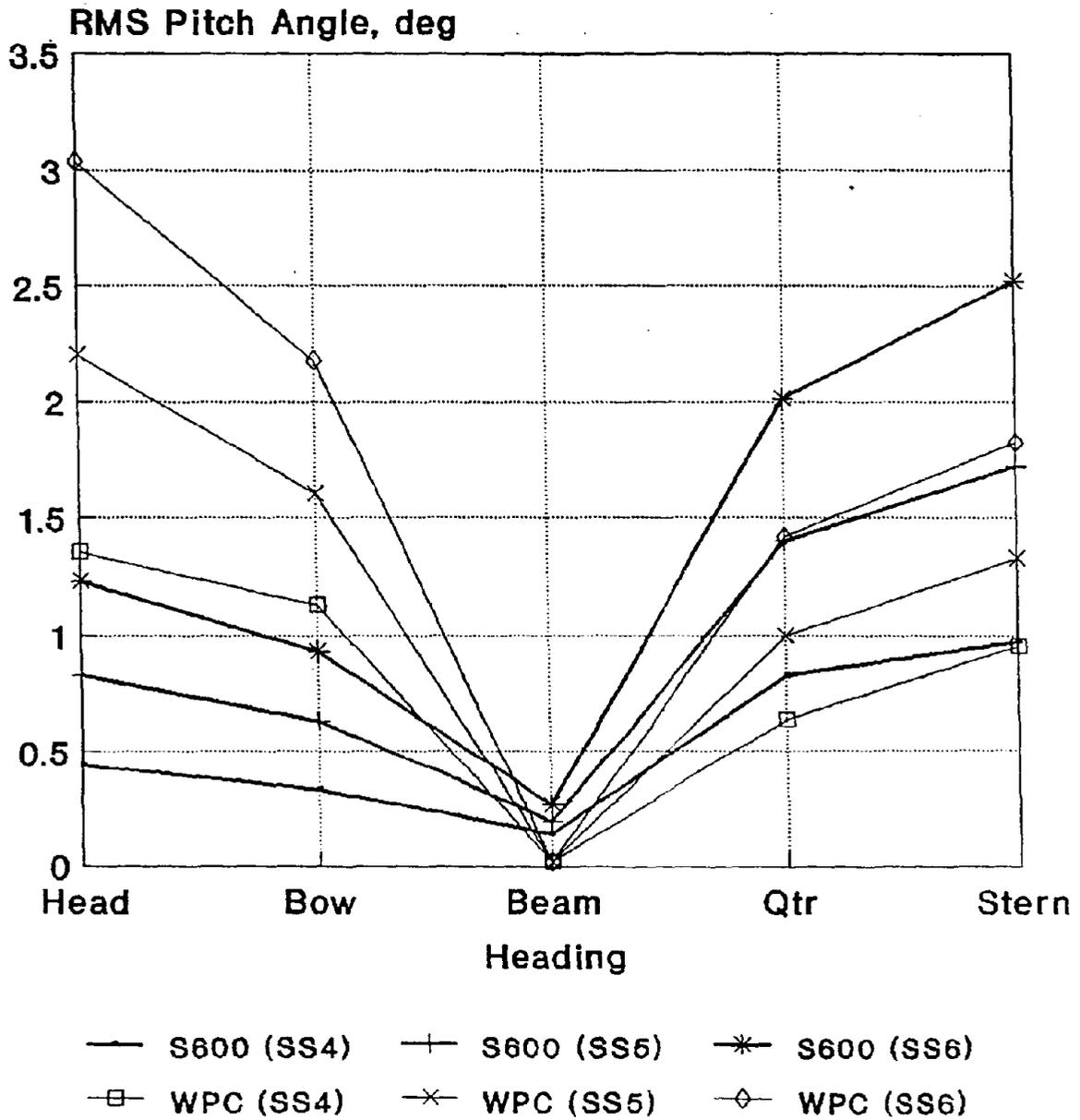


Figure A.3. SLICE 400 Pitch Angle Comparison in SS5

SLICE 600 vs 75M WPC Pitch Angle vs Heading and Sea State



(SLICE 600 @ 30kts, 75M WPC @ 35kts)

Figure A.4. SLICE 600 Pitch Angle Comparison

Roll Angle Comparison (Operational Speeds)

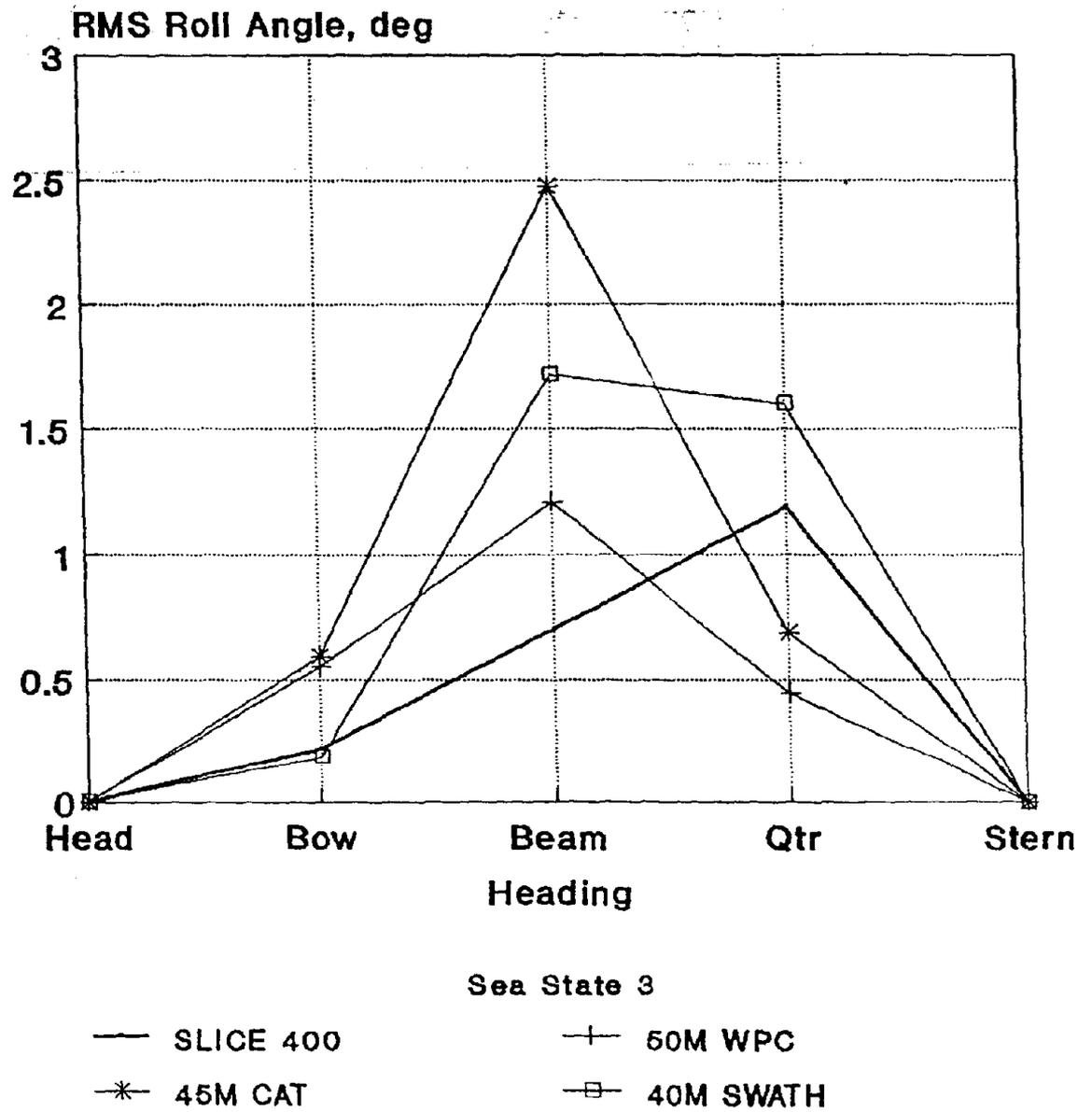


Figure A.5. SLICE 400 Roll Angle Comparison in SS3

Roll Angle Comparison (Operational Speeds)

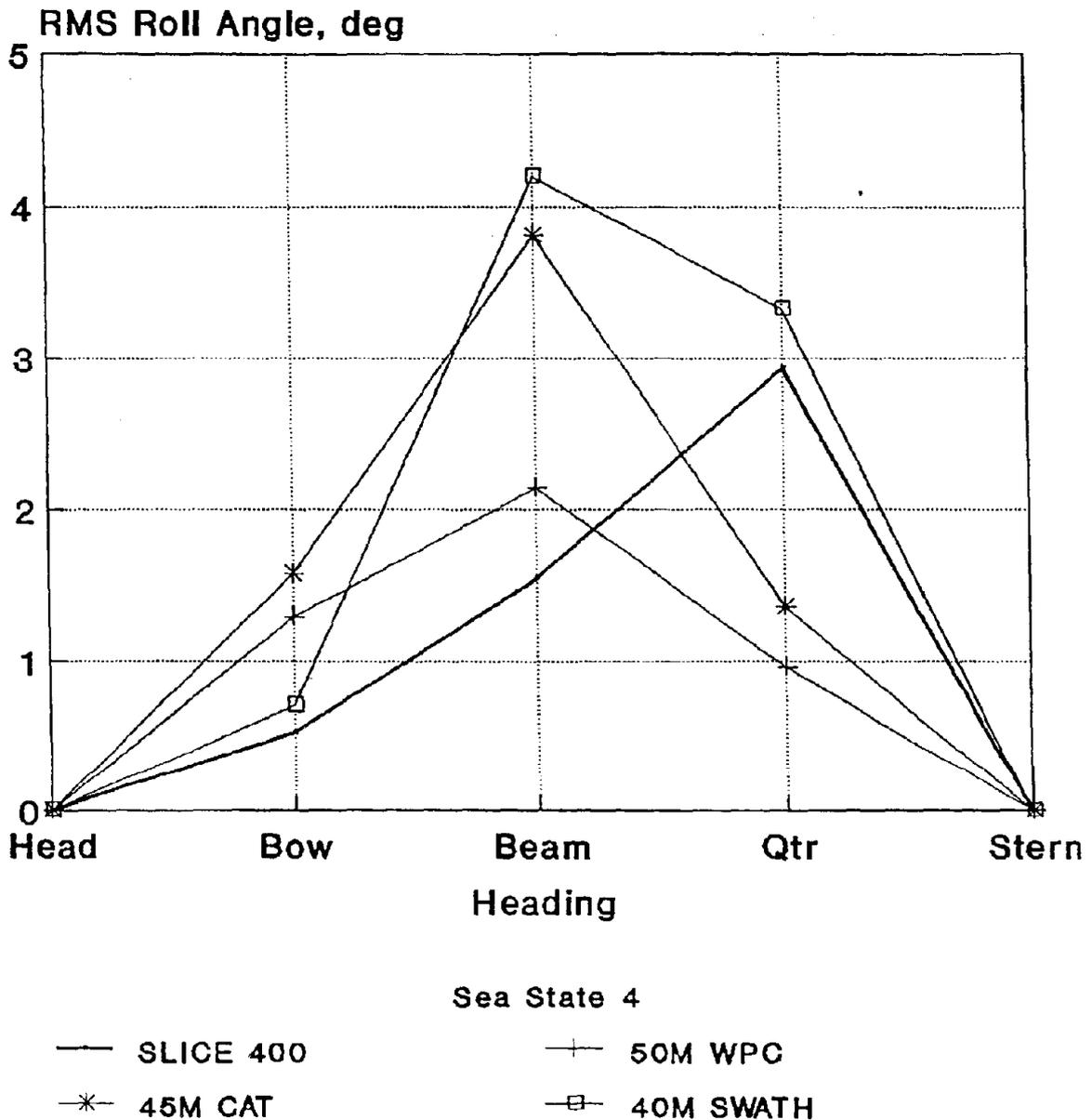


Figure A.6. SLICE 400 Roll Angle Comparison in SS4

Roll Angle Comparison (Operational Speeds)

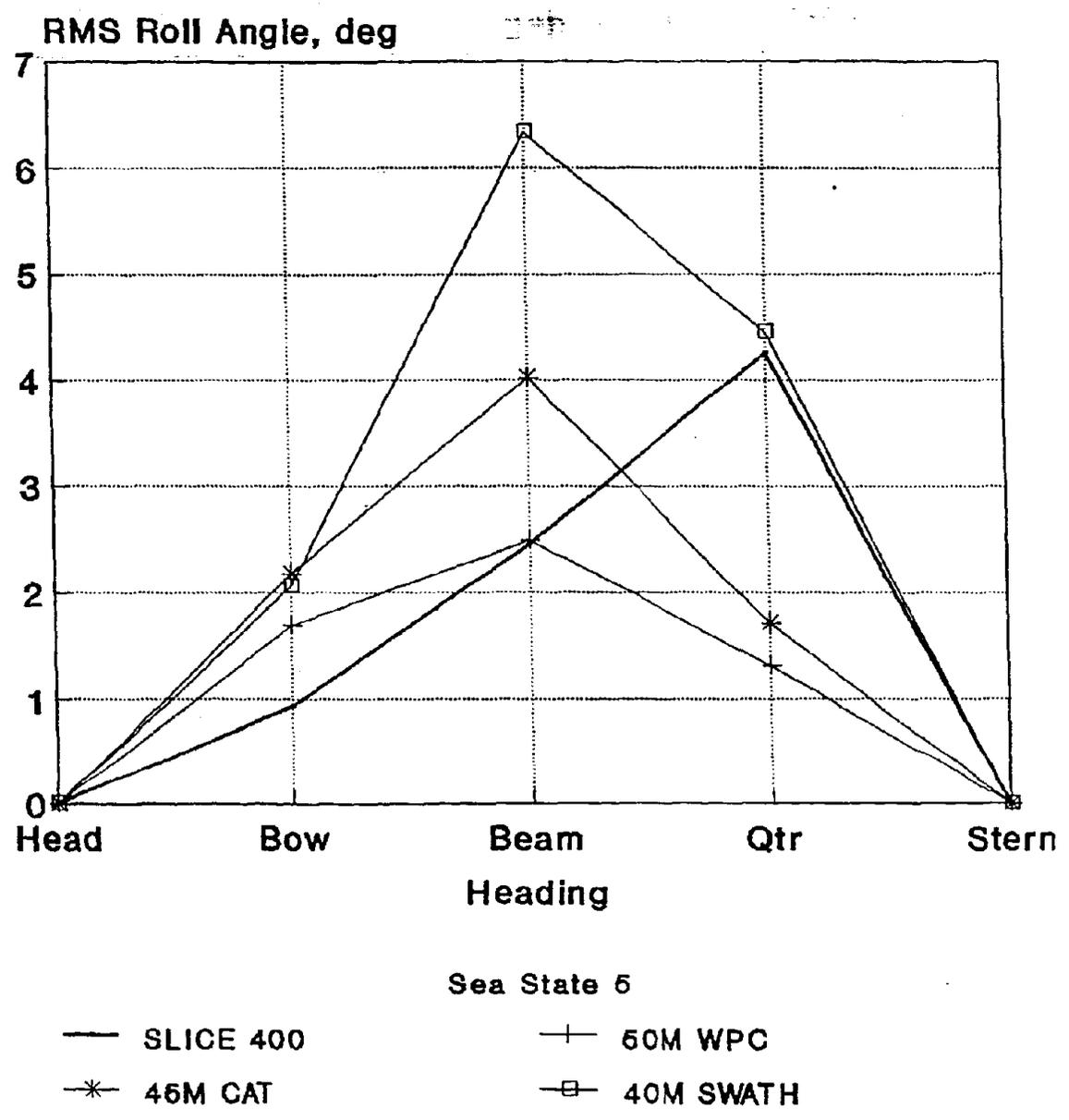
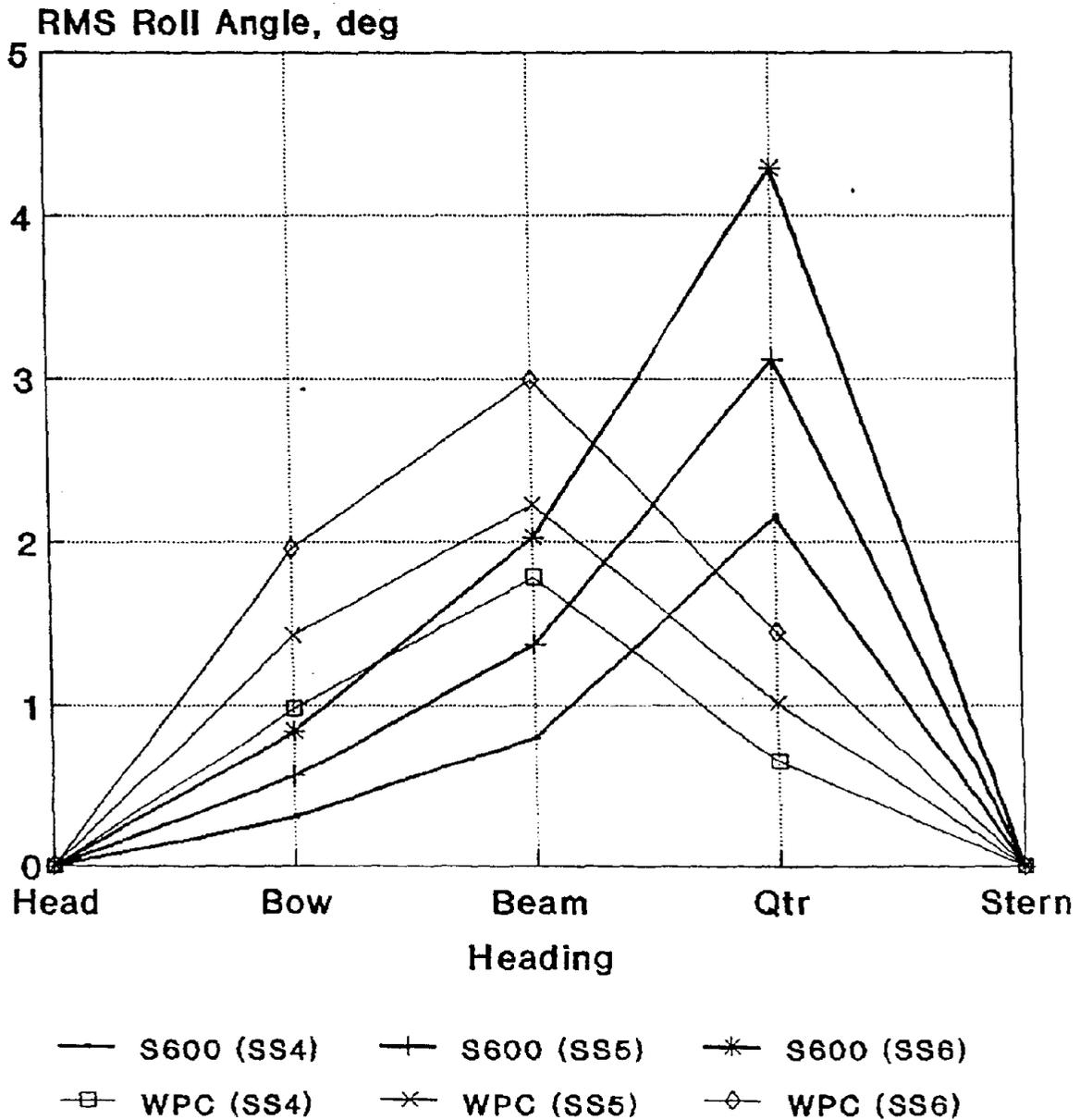


Figure A.7. SLICE 400 Roll Angle Comparison in SS5

SLICE 600 vs 75M WPC Roll Angle vs Heading and Sea State



(SLICE 600 @ 30kts, 75M WPC @ 35kts)

Figure A.8. SLICE 600 Roll Angle Comparison

ANNEX B - SEAKEEPING RESULTS - ISO 2631/3 COMPARISONS

ISO 2631 Chart Comparison (Operational Speeds in Head Sea) Vertical Accelerations at the LCG

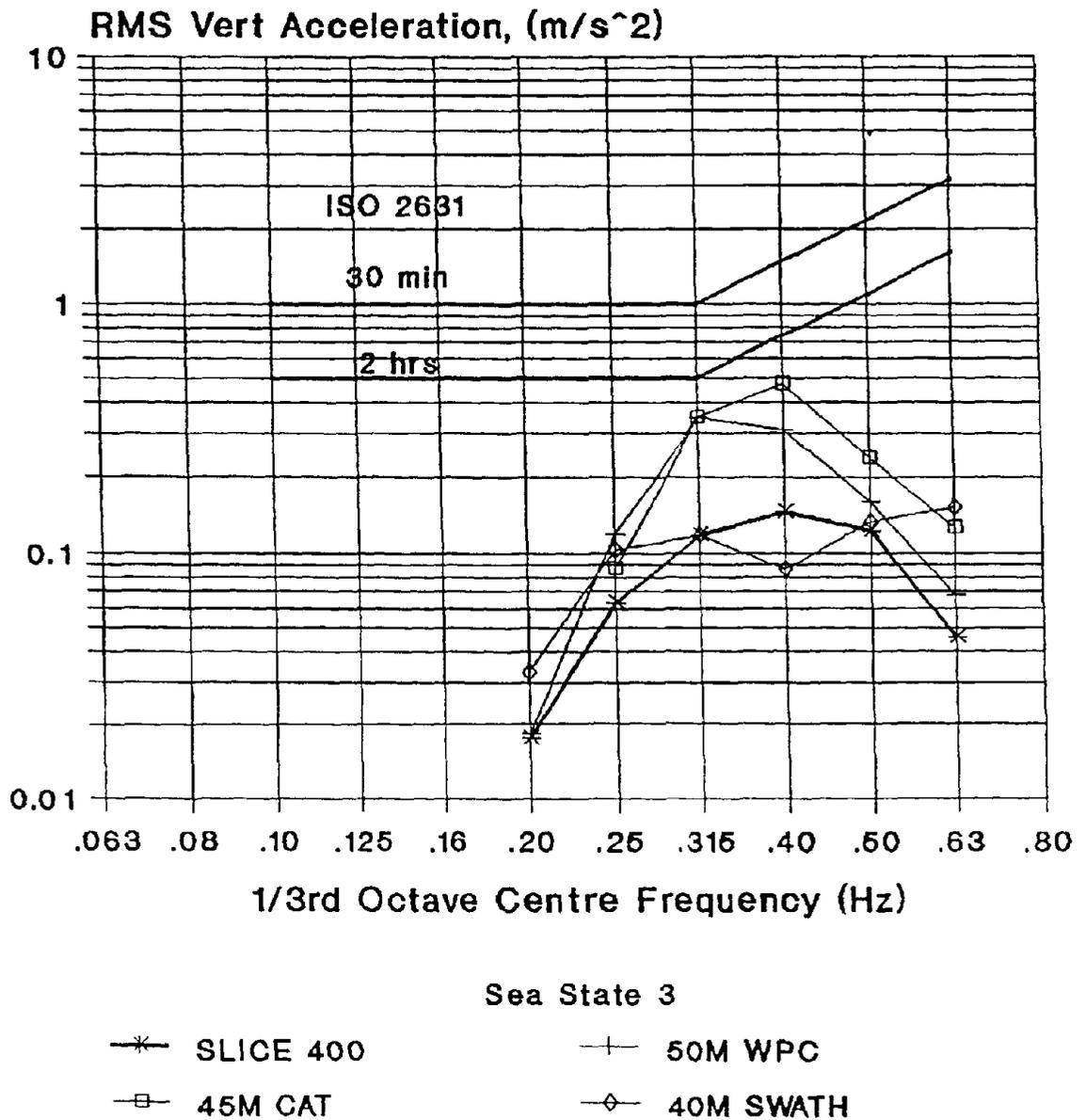


Figure B.1. SLICE 400 ISO 2631/3 Comparison in SS3 at Operational Speeds

ISO 2631 Chart Comparison (Operational Speeds in Head Sea) Vertical Accelerations at the LCG

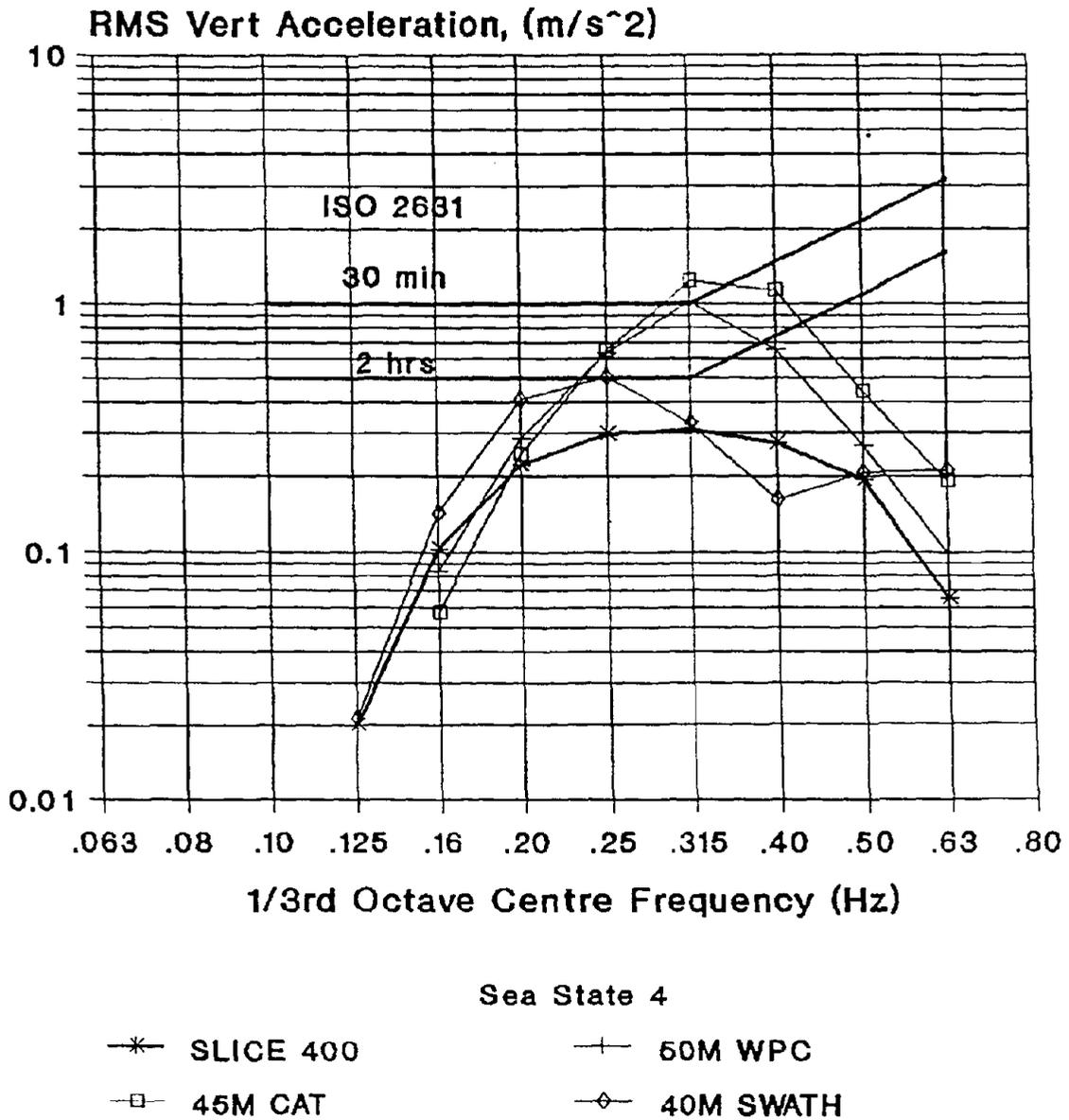
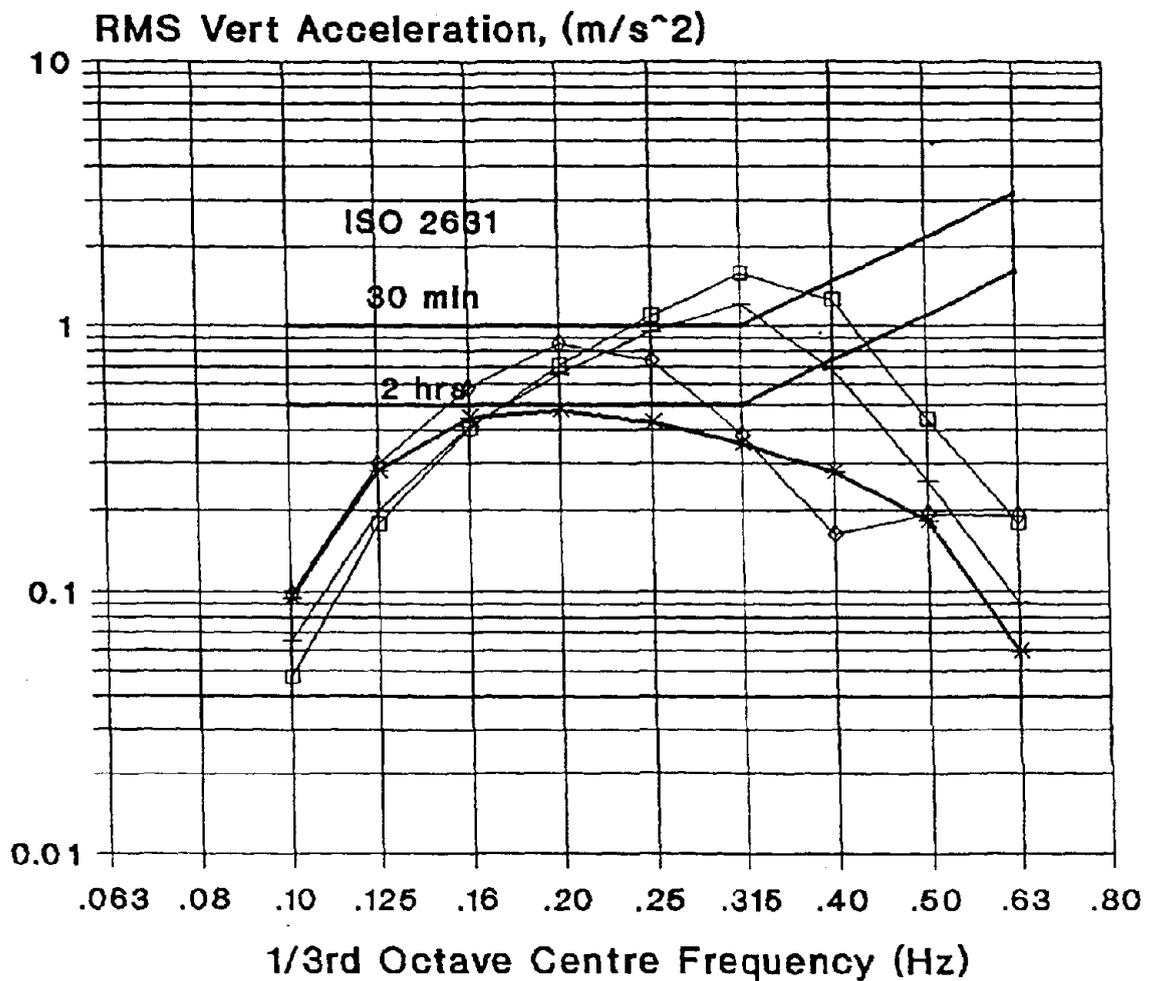


Figure B.2. SLICE 400 ISO 2631/3 Comparison in SS4 at Operational Speeds

ISO 2631 Chart Comparison (Operational Speeds in Head Sea) Vertical Accelerations at the LCG



Sea State 5

* SLICE 400

+ 50M WPC

□ 45M CAT

◇ 40M SWATH

Figure B.3. SLICE 400 Pitch Angle Comparison in SS5 at Operational Speeds

ISO 2631 Chart Comparison - SLICE 600 vs 75M WPC at operational speed in Head Sea Vertical Accelerations at the LCG

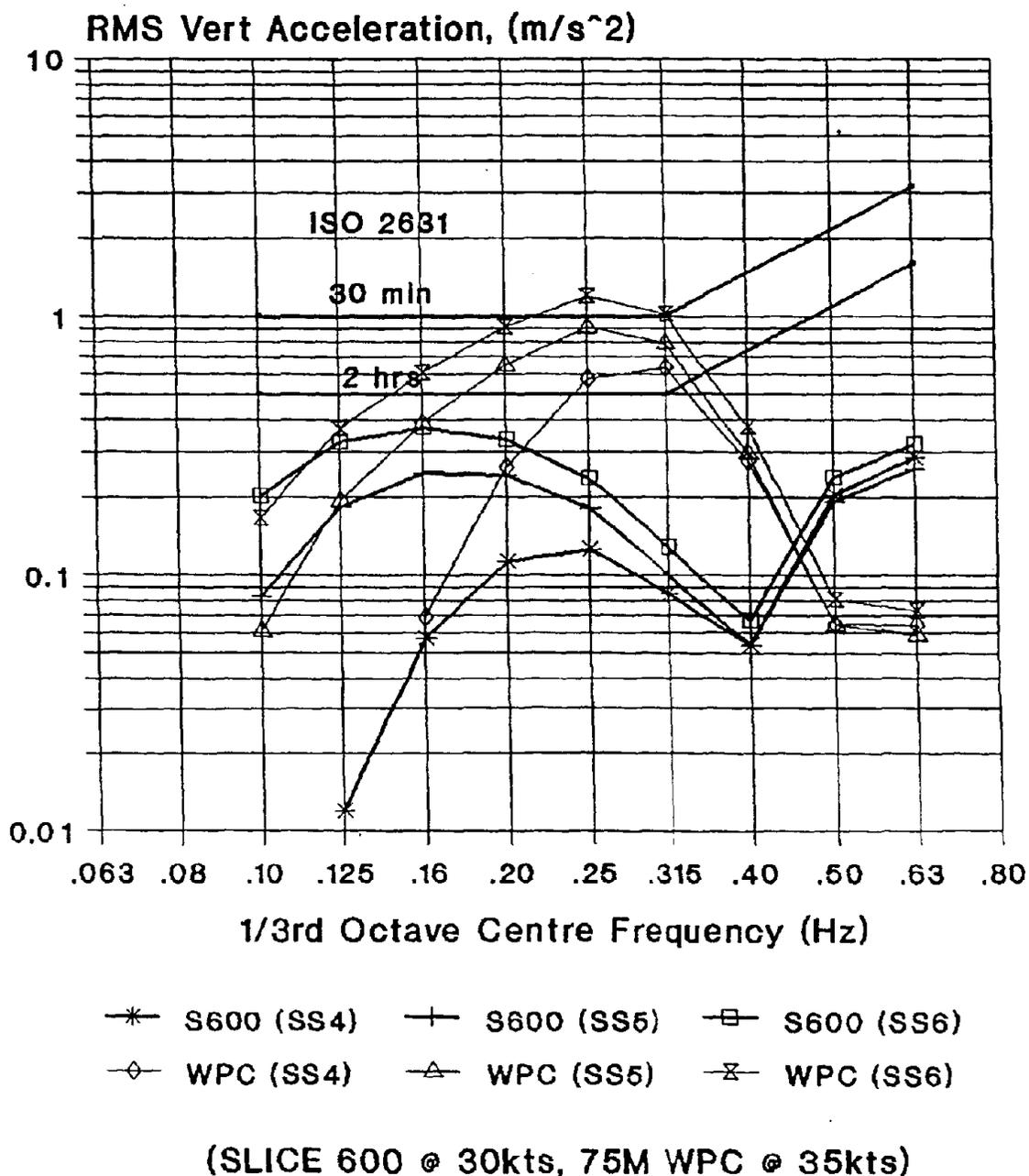


Figure B.4. SLICE 600 ISO 2631/3 Comparison at Operational Speeds

ISO 2631 Chart Comparison (5 knots in Head Sea) Vertical Accelerations at the LCG

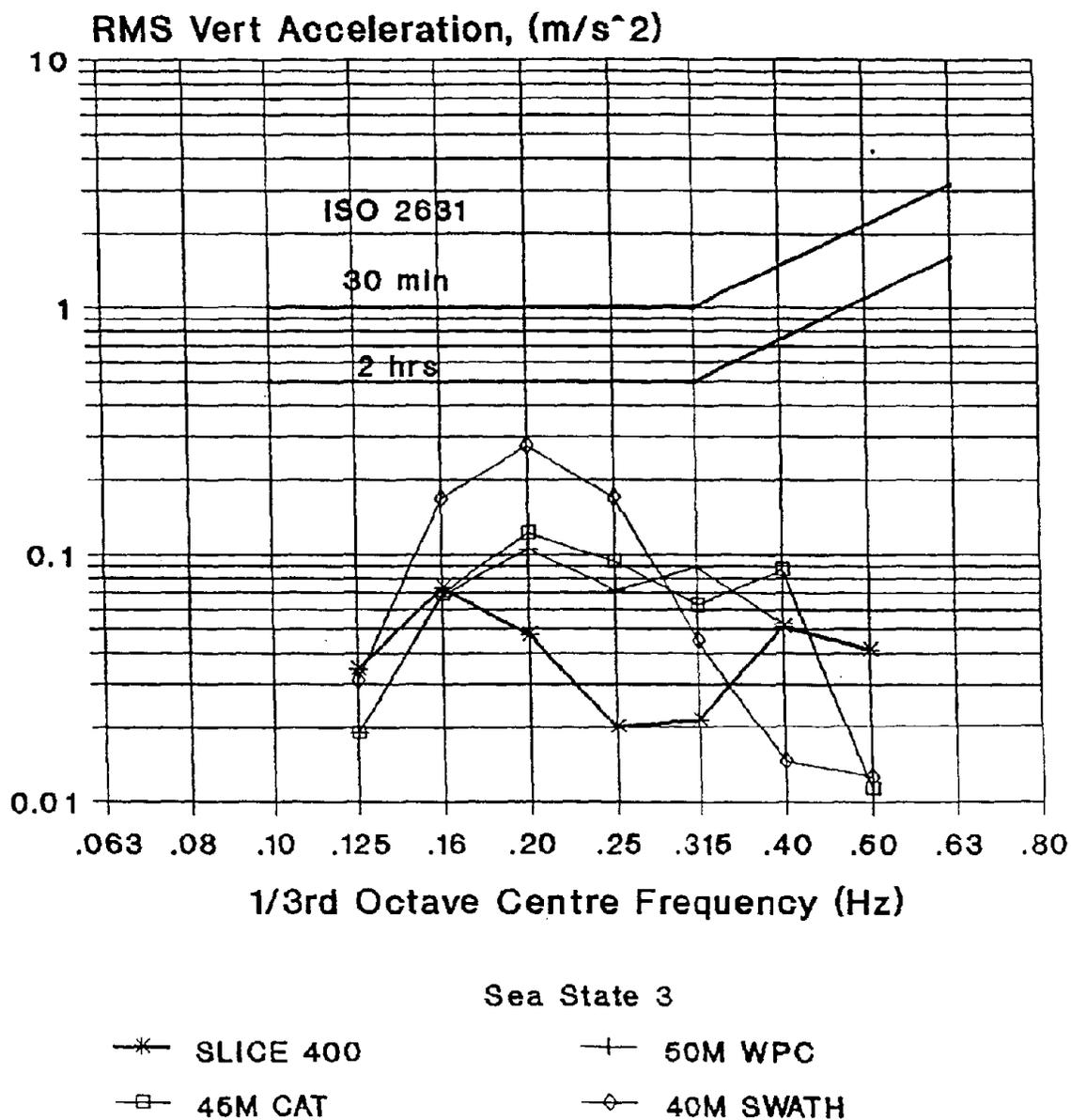


Figure B.5. SLICE 400 ISO 2631/3 Comparison in SS3 at 5 knots

ISO 2631 Chart Comparison (5 knots in Head Sea) Vertical Accelerations at the LCG

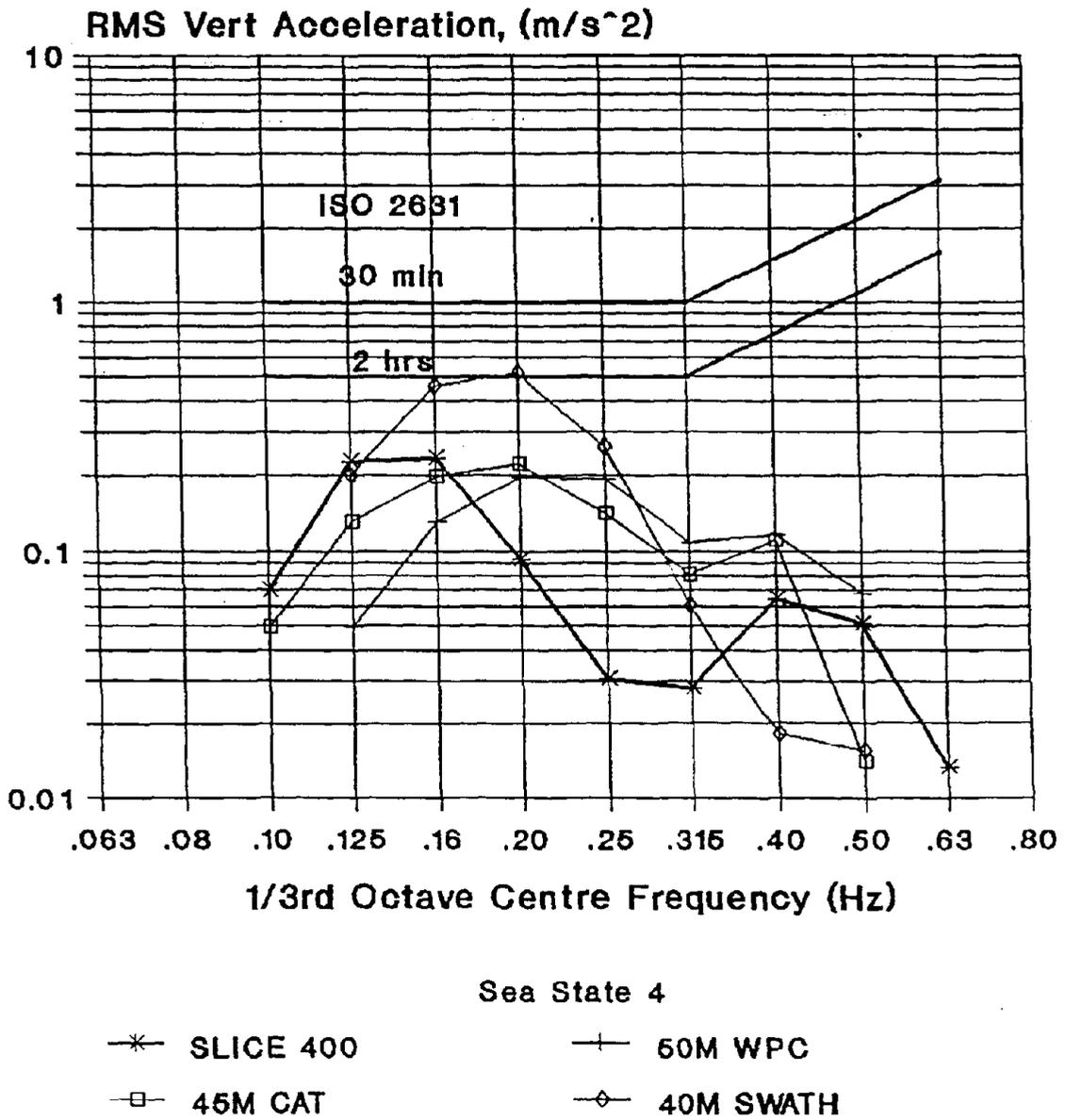


Figure B.6. SLICE 400 ISO 2631/3 Comparison in SS4 at 5 knots

ISO 2631 Chart Comparison (5 knots in Head Sea) Vertical Accelerations at the LCG

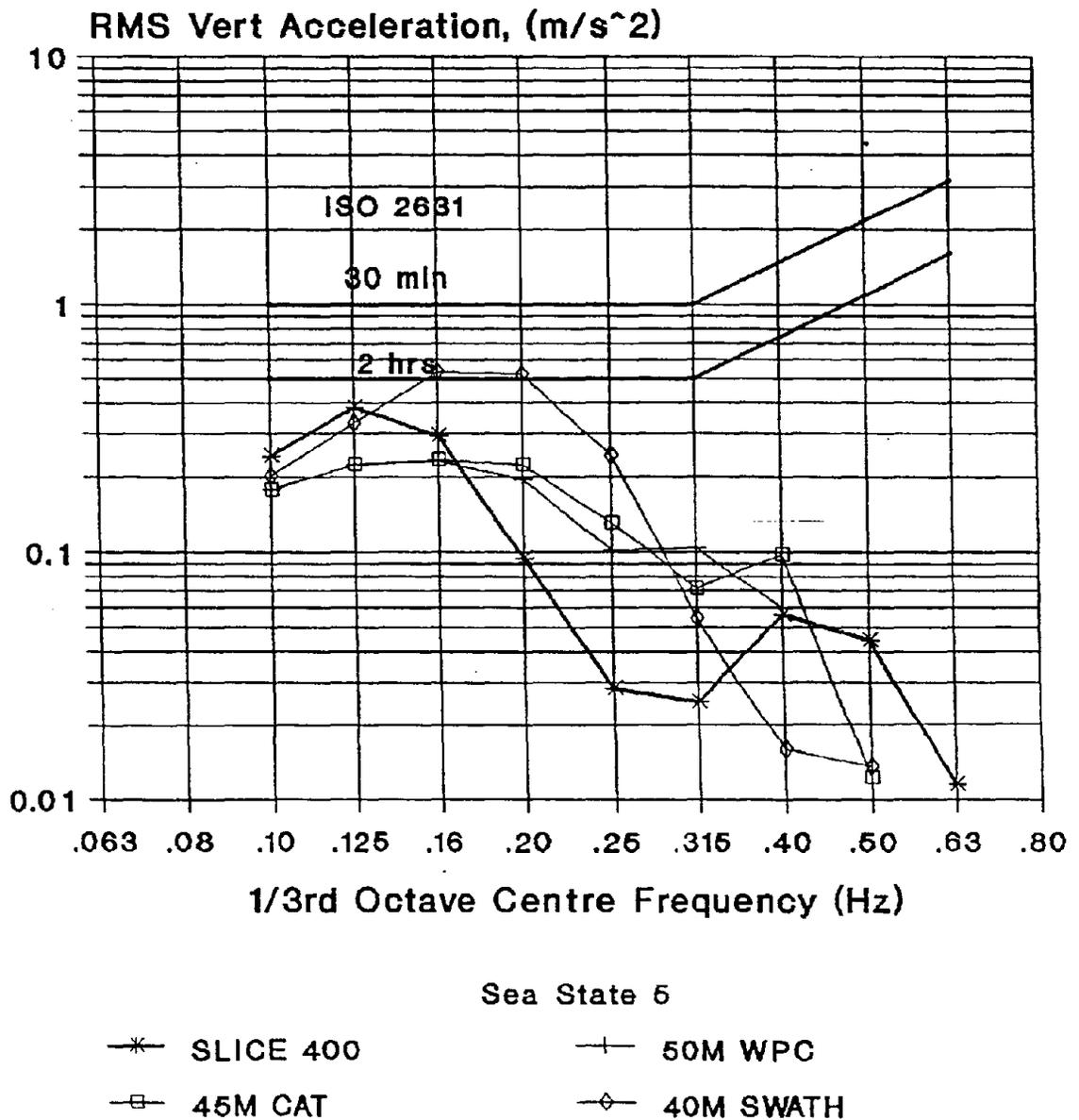
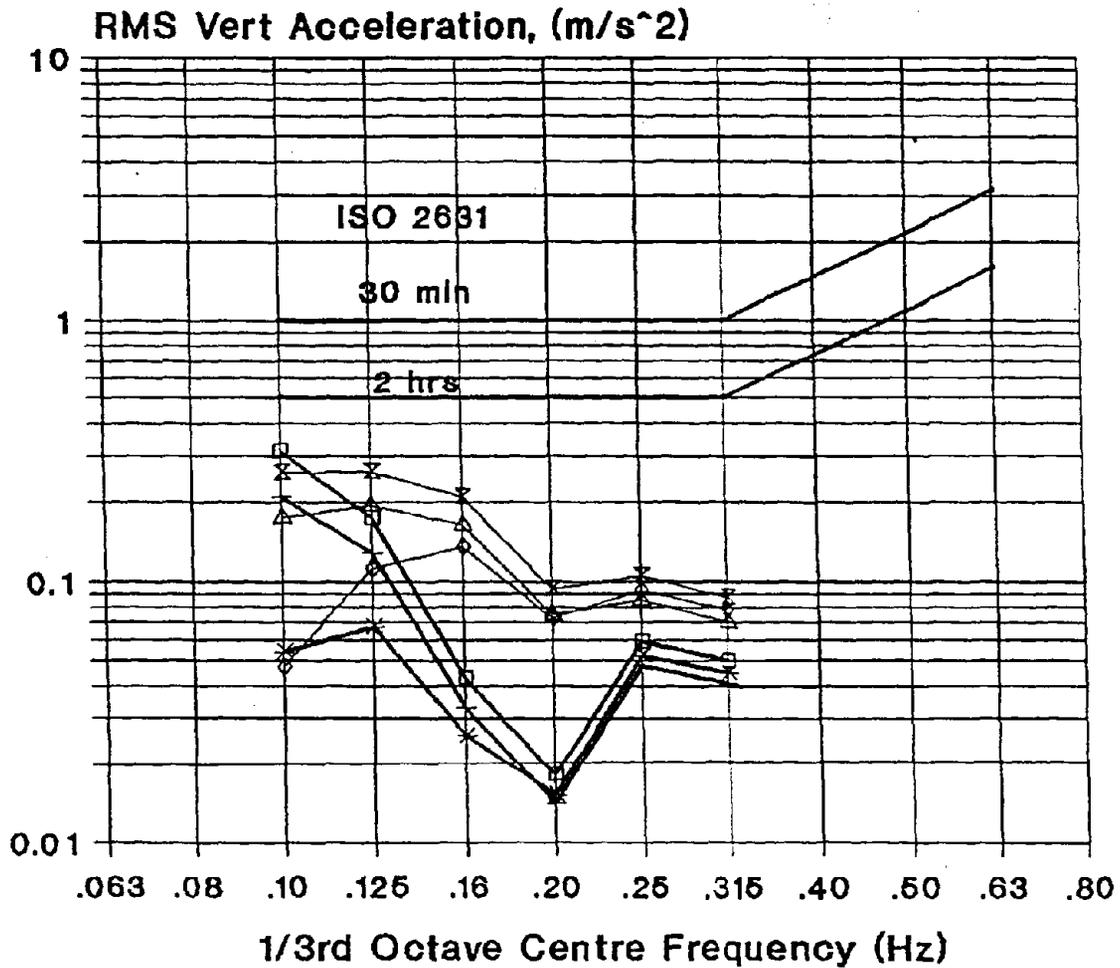


Figure B.7. SLICE 400 ISO 2631/3 Comparison in SS5 at 5 knots

ISO 2631 Chart Comparison - SLICE 600 vs 75M WPC at 5 knots in Head Seas Vertical Accelerations at the LCG



Sea State		
* S600 (SS4)	+ S600 (SS5)	□ S600 (SS6)
◇ WPC (SS4)	△ WPC (SS5)	⊗ WPC (SS6)

Figure B.8. SLICE 600 ISO 2631/3 Comparison at 5 knots

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ANNEX C - SEAKEEPING PROGRAMME VERIFICATION DATA

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C.1. PROGRAMME DESCRIPTION

The CATMO programme has been developed by Seaspeed Technology Limited for the prediction of multihull vessel motion in waves and the associated development of ride control systems.

The programme was originally developed for the design of active fin control systems and to enable rapid development of new multihull form concepts. It is based on a strip theory approach but is run in the time domain in order to facilitate the design of control system algorithms. This also allows for the future development of the programme to study non-linear motion characteristics, particularly where buoyant cross structures are required to be considered (a feature of many multihull vessels).

For the SLICE study analysis, the programme considers the vessel as a series of 40 transverse, two dimensional, sections (20 sections per hull of a catamaran and 10 sections per hull of a SLICE). The section information is derived from the ship's lines plan and the hydrodynamic coefficients from a database of experimental and theoretical results. The sections are considered to make up a rigid body with a specified centre of gravity, displacement and rotational inertias.

Interaction between the two hulls has not been accounted for in the analysis and surge, yaw and sway have also been neglected.

Recent applications of this software include motion and wetness predictions for fast multihull ferries and offshore supply craft, including Swath, WPC and catamaran forms, development of small fast catamarans for the UK Defence Research Agency, the development of new medium speed Swath passenger vessels recently constructed for the UK Ministry of Defence, and for the study of fast monohull patrol craft performance.

C.2. PROGRAMME VERIFICATION

In order to provide representative verification data for this project, the motion characteristics for a 40m (waterline length) catamaran for which both model and full scale data was available, were calculated using CATMO.

The regular head wave comparison between the CATMO response amplitude operator output and the model test results are compared in Figure C.1.

Using an ITTC two parameter spectrum analysed for the significant wave height and zero crossing period measured on trials, and applying a \cos^2 spreading function, the expected motion characteristics in short crested seas were calculated using CATMO. The results, in terms of vertical accelerations at the LCG and in the fwd and aft saloons are compared in Figures C.2 to C.4.

Finally, an ISO 2631/3 analysis of the CATMO generated vertical acceleration results at the LCG were compared with those from the trials and these are compared in Figure C.5.

These comparisons provide a good demonstration of the expected accuracy of the CATMO programme output for this SLICE comparative sea performance study.

Program Verification - 40m LWL Catamaran
Model Tests vs CATMO predictions
Vert Acc LCG: Speed 35 knots

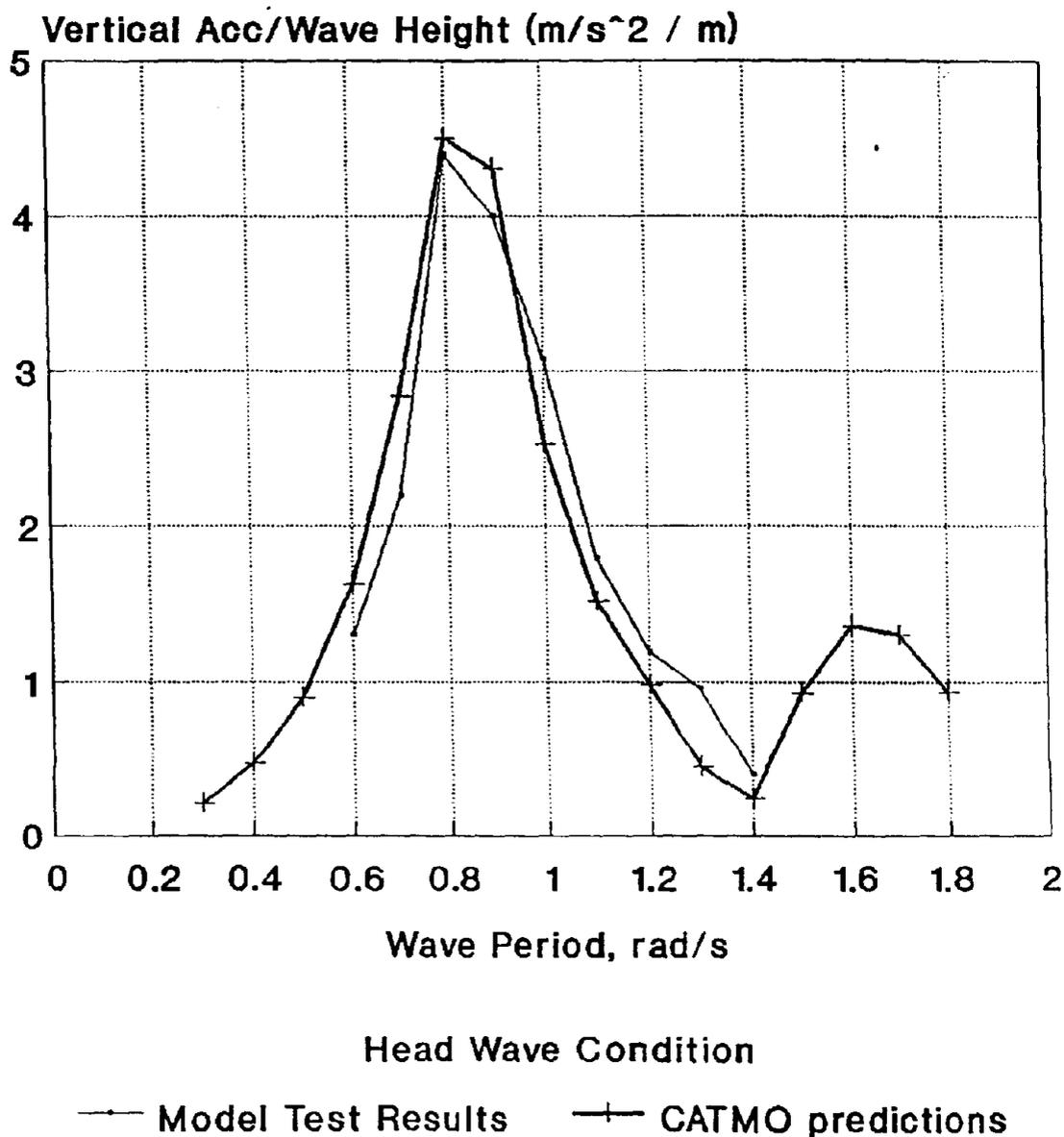
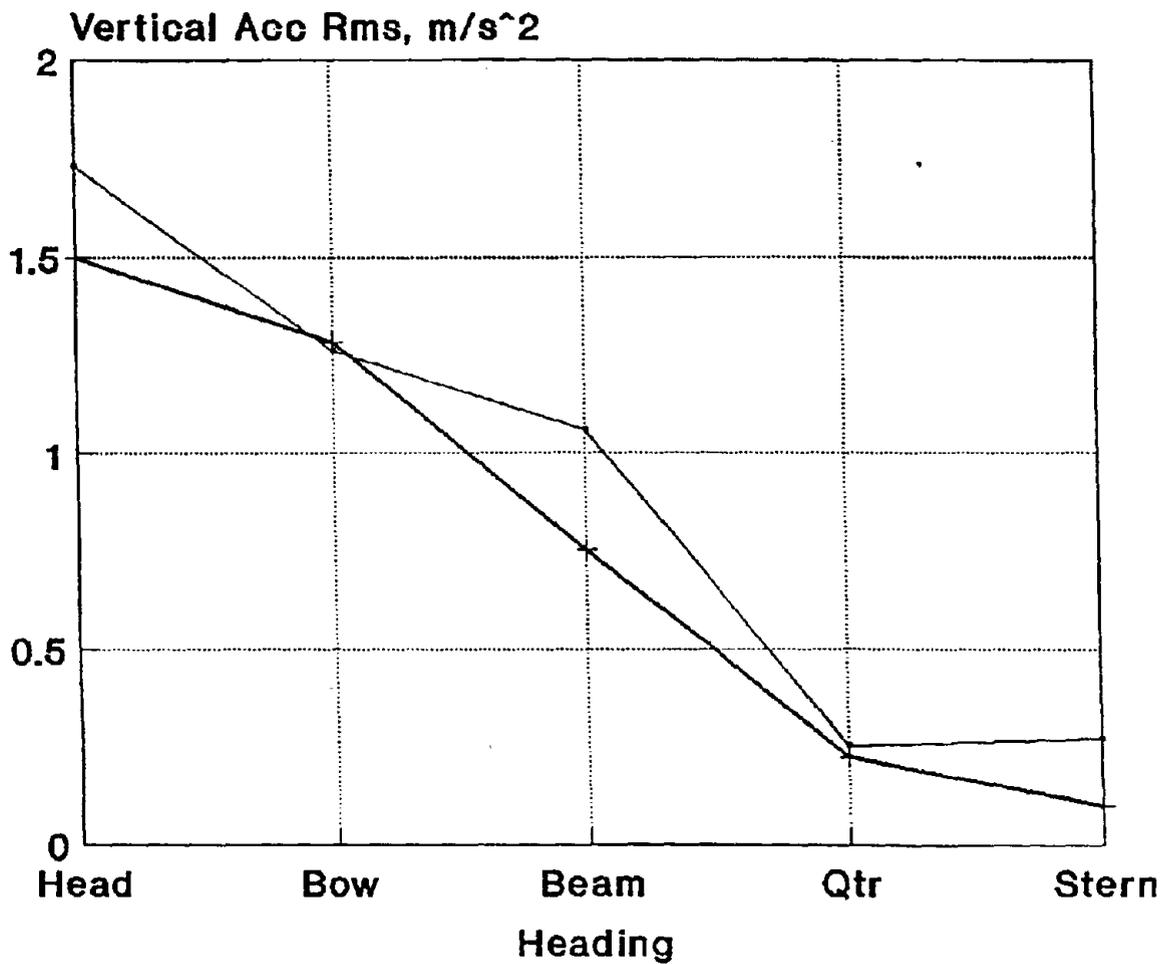


Figure C.1. Vertical Acceleration (LCG) RAO's - comparison of CATMO output with model test results

Program Verification - 40m LWL Catamaran Sea Trials Results vs CATMO predictions Vert Acc LCG: Speed 33 knots



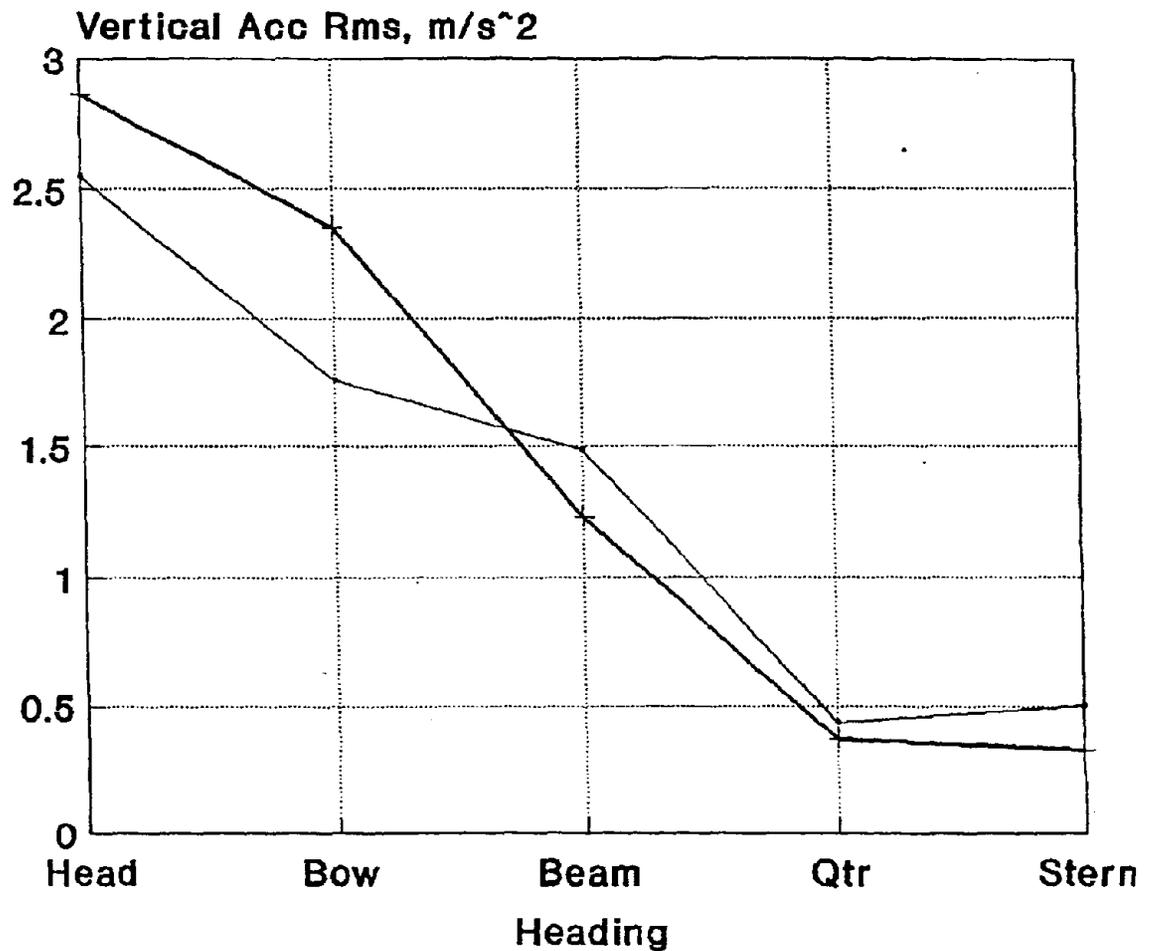
Hsig=2.1m, Tz=5.6s

— Trials Results + CATMO predictions

(Note: Predictions assume ITTC two parameter spectrum and cos² spreading)

Figure C.2. Vertical Acceleration (LCG) rms values - comparison of CATMO output with full scale trial results.

**Program Verification - 40m LWL Catamaran
Sea Trials Results vs CATMO predictions
Vert Acc Fwd: Speed 33 knots**



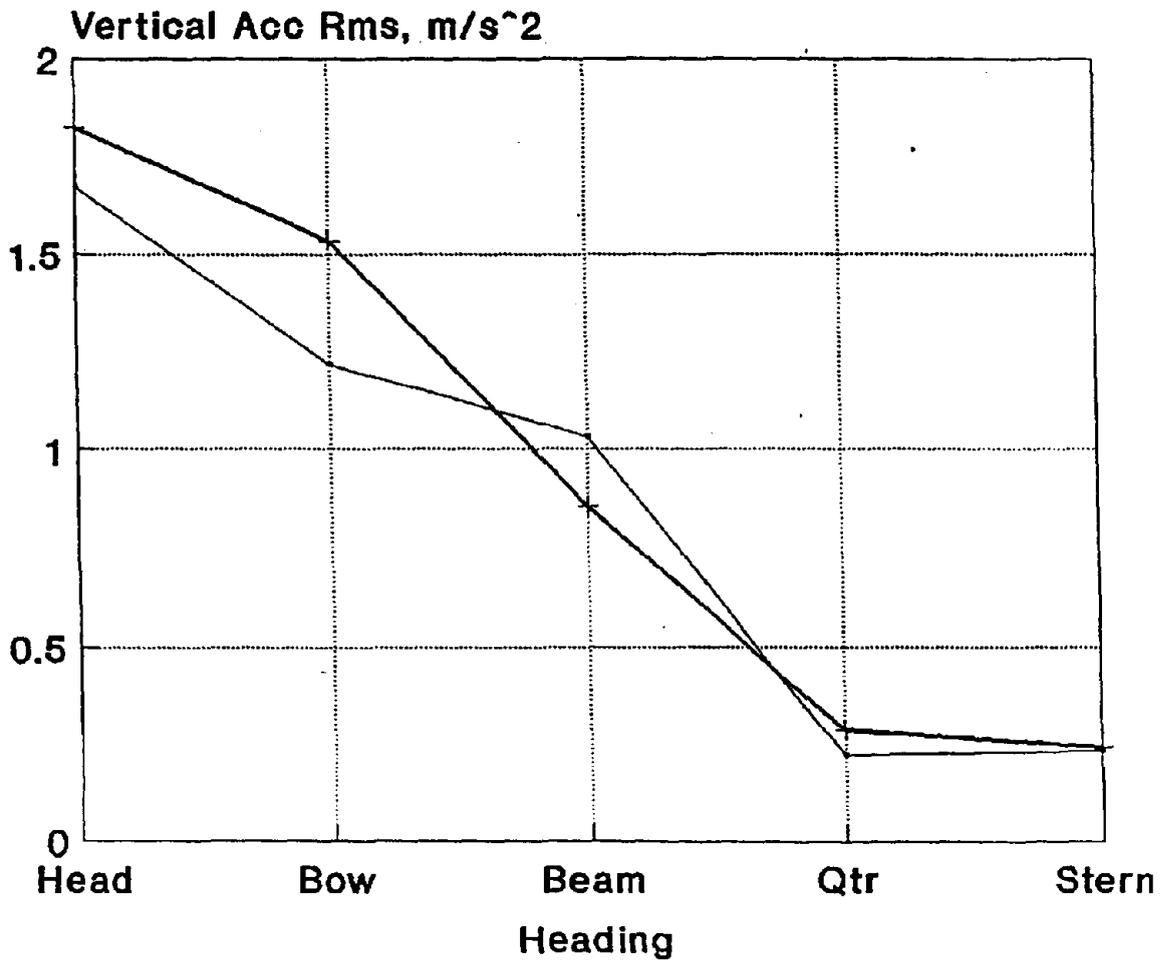
Hsig=2.1m, Tz=5.6s

—+— Trials Results —x— CATMO predictions

(Note: Predictions assume ITTC two parameter spectrum and cos² spreading)

Figure C.3. Vertical Acceleration (Fwd) rms values - comparison of CATMO output with full scale trial results.

Program Verification - 40m LWL Gatamarn Sea Trials Results vs CATMO predictions Vert Acc Aft: Speed 33 knots



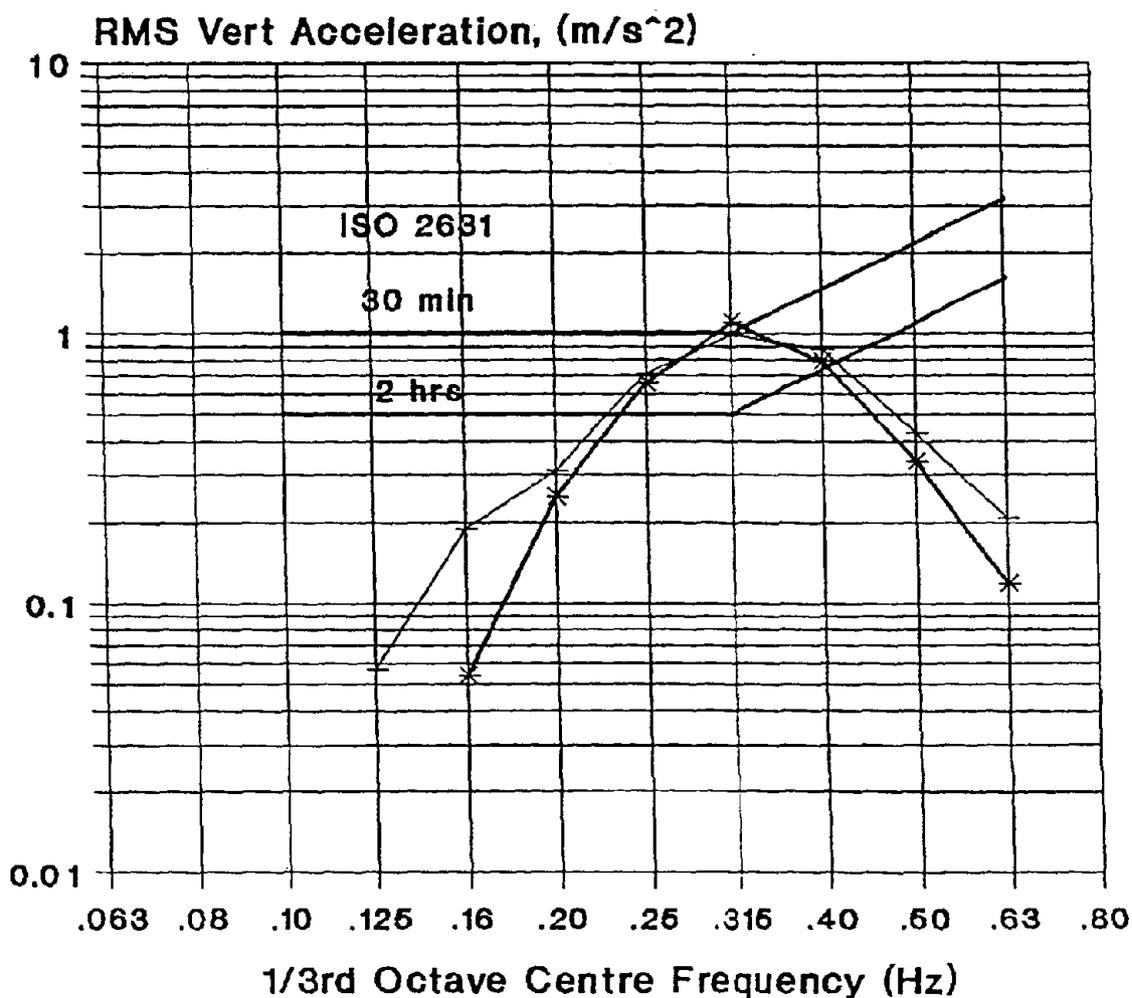
Hsig=2.1m, Tz=5.6s

— Trials Results —+— CATMO predictions

(Note: Predictions assume ITTC two parameter spectrum and cos² spreading)

Figure C.4. Vertical Acceleration (Aft) rms values - comparison of CATMO output with full scale trial results.

**Program Verification - 40m LWL Catamaran
Sea Trials Results vs CATMO Predictions
Vert Acc @ LCG: Speed 33 knots: Head Sea**



Hsig=2.1m, Tz=5.6s

*- CATMO Predictions + Trials Results

(Note: Predictions assume ITTC two parameter spectrum)

Figure C.5. Vertical Acceleration (LCG) third octave analysis - comparison of CATMO output with full scale trials results using ISO 2631/3 criteria.

