Optimizing Your Ferry System:
Choosing the Right Vessel for the Right Route

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Transportation planning is vital to selecting the right vessel and operating scenario for a ferry route or for optimizing a ferry transportation system. An effective transportation planning model should take into consideration vessel acquisition, operating costs and traffic demand. Choosing the right measures of success can help ensure predictions meet expectations. The accuracy of a vessel cost analysis can be increased by incorporating knowledge of naval architecture, wave climatology, regulatory issues, seakeeping, and marine labor practices. Traffic demand analysis can be honed with an understanding of fare elasticity and service elasticity. Optimizing an entire system requires another level of planning to reduce the number of unique vessel designs and find optimum route structures to meet demand.

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Introduction

Transportation planning is vital to making the best choices when considering new or improved ferry service. Questions typically addressed by marine transportation planning studies include those of vessel design, such as the number, size, speed and type of vessels, and those regarding the service to be offered, such as frequency, vessel commonality and the choice of existing or new vessels.

This paper presents a high-fidelity approach to vessel and cost modeling, in which system alternatives are formulated in terms of unique route and vessel combinations, and solutions are evaluated and ranked by various measures, as the operator's needs dictate. This approach can easily be paired with service and/or fare elasticity models to generate quality answers to the important questions facing operators contemplating new or improved ferry service.

Measures of Success

The following measures are commonly used to rank the suitability of alternatives in light of the traffic demand and service costs:

- Maximum net revenue
- Minimum operating cost
- Maximum ridership

Maximum net revenue is imperative for commercial operators. For public operators, the net revenue may be negative on vital links with low demand. In this case, the same goal may be expressed in terms of minimum operating subsidy.

Minimum operating cost is commonly used as a substitute for maximum net revenue, but it is only a reliable guide if gross revenue can be regarded as a constant. If different ways of delivering the service are under consideration, this is not a good assumption. For example, if vessel speed is a variable, then ridership is likely to vary for each service alternative. This is termed *service elasticity*. Ridership and net revenue can also vary as a consequence of *fare elasticity*.

Maximum ridership is another common measure. When it is used as a proxy for maximizing net revenue, it is presumed that capital and operating costs are constant. This assumption omits possibilities for savings on the cost side. Maximizing ridership is also encountered as a proxy for some other public goal, such as reducing freeway congestion and vehicle emissions.

Rational Cost Modeling

No matter what goal is chosen, superior solutions are best identified through the combined application of a good vessel cost model and a good traffic demand model. Unfortunately it is common for marine transportation studies to focus on one aspect or the other, but not both.

Vessel Analysis

Glosten uses models based on parametric designs, in which vessels are described by a set of key parameters, such as length, breadth, weight and propulsion power. The parameters define the design sufficiently to perform comparative economic evaluation and to make preliminary judgments regarding a vessel’s ability to meet design requirements, such as seakeeping and dock interface specifications. Power and fuel consumption cost models are therefore based on sound naval architectural principles that allow us to consider not only vessel types, for instance monohull or catamaran, but also variables that characterize hull form, such as the length to beam ratio. Careful calibrations for weight are also included, ensuring realistic designs and increasing the accuracy of acquisition cost estimates.

The Glosten Associates (Glosten) has developed these models of weight, speed and power, and fuel consumption for a wide variety of vessels, including monohulls and catamarans optimized to operate at speeds ranging from those modest speeds of a slow displacement hull to the high speeds characteristic of vessels designed to the high-speed craft code.

In a route optimization analysis, Glosten also models the wind and wave environment along each segment of the route. In each month of the operating year, we determine the statistics of added resistance due to wind and waves. These additional forces, in turn, contribute to the determination of the installed power necessary to maintain schedule. They also make possible the estimation of the associated increases in power, fuel consumption and cost.

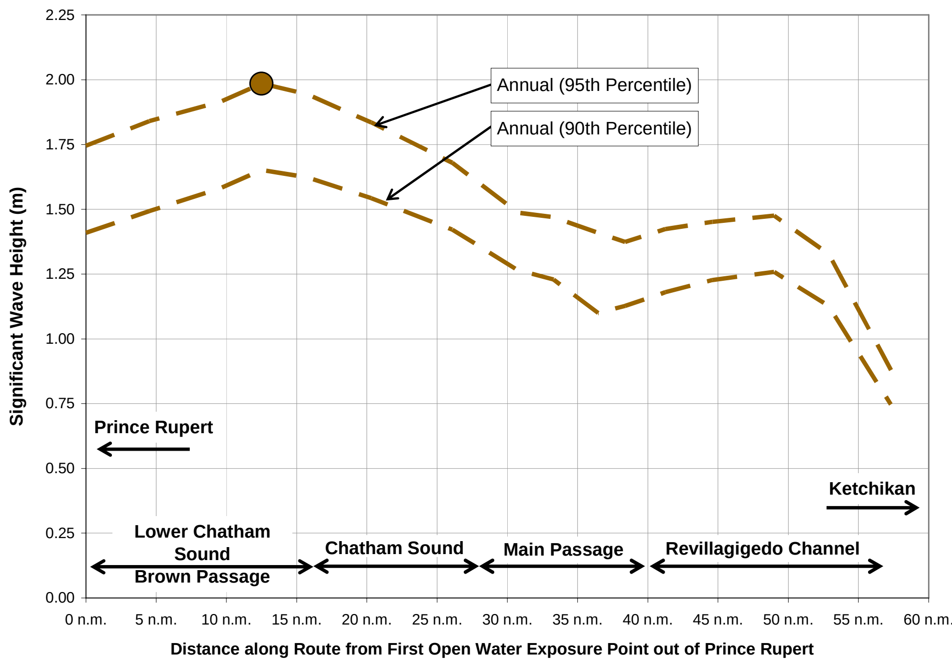


Figure 1: Significant wave heights along the Southern Gateway route

A feature rather unique to our analysis models is consideration of route operability, including passenger comfort and seasickness. Vessels that fail these criteria may be excluded from further consideration.

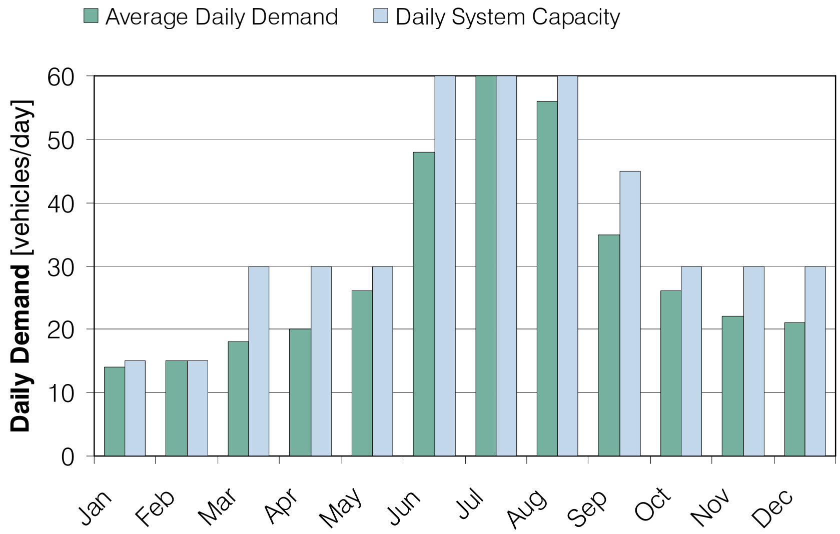
Traffic Demand Analysis

Each route is characterized by a base traffic demand. Predictable variation in the traffic demand over time is captured by a profile. These profiles are resolved over whatever cycle may be appropriate to the service. In Glosten's work for the Alaska Marine Highway System, the base traffic demand is characterized by month over the annual cycle. In an urban commuter setting it would be appropriate to characterize the base demand over the hours of the day and the day of the week.

It is here that this high-fidelity cost model can be coupled with a fare and/or service elasticity of demand model, permitting meaningful evaluation and ranking by total ridership and net revenue measures.

Route 4: Annual Operating Profile

No. of Vessels on Route	2	vessels	No. Crew	4	
Max. No. of Round Trips	2	daily RT/vessel	Vessel Capacity	15	vehicles
Max. Day Length	6	hr	Transit Time	4.58	hr/day



Annual Operations Summary

Transit Time	In-port Time	Paid Crew Time	Days in Service	Days in Lay-up
hr/year	hr/year	hr/year	vessel-days	vessel-days
2028	1868	3896	487	243

Figure 2: Example of seasonal variation of demand and capacity

Parametric design solutions are represented by vessel and service characteristics that satisfy the peak traffic demand profile. Solutions are ranked by objective measures such as acquisition, operating and life cycle costs, total ridership, gross and net operating revenues, and service quality indices. Solutions that offer excess capacity, for instance during the off-season when traffic demand lags, are at a disadvantage. Options for adjusting capacity to meet variations in demand, for example by adjusting the number of daily round trips, or laying up vessels in the off-season, are evaluated to see if they result in an improvement in the objective measures and ranking of the solution.

Crew Cost Analysis

Other elements of the parametric model have been developed to address crew labor and institutional costs. These model elements can be informed and customized to represent existing conditions, when known, or they can be drawn from Glosten's library of models. For example, existing conditions might be represented by union agreements and institutional factors including such things as Coast Guard regulations and overhead. Other cost elements can include such things as off-season layup costs and costs associated with non-sailing days.

Evaluation and Ranking Process

Glosten's parametric approach permits the rapid and systematic evaluation and ranking of hundreds of operating scenarios and vessel designs that satisfy the basic service demands for the route or routes considered.

Single Route Solutions

For a single route alternative, the approach to the design and economic analysis includes five key steps:

1. Postulate operating scenarios
2. Develop parametric vessel designs for each operating scenario
3. Check each vessel design for validity and compliance with design requirements
4. Evaluate the economics of each valid vessel design
5. Rank solutions by their economic performance

Figure 3, taken from a recent design study for the Alaska Marine Highway System, examines different service scenarios and new vessel designs for service between Ketchikan, Alaska and Prince Rupert, British Columbia. The figure traces the fate of the set of unique combinations of operating scenarios and parametric designs.

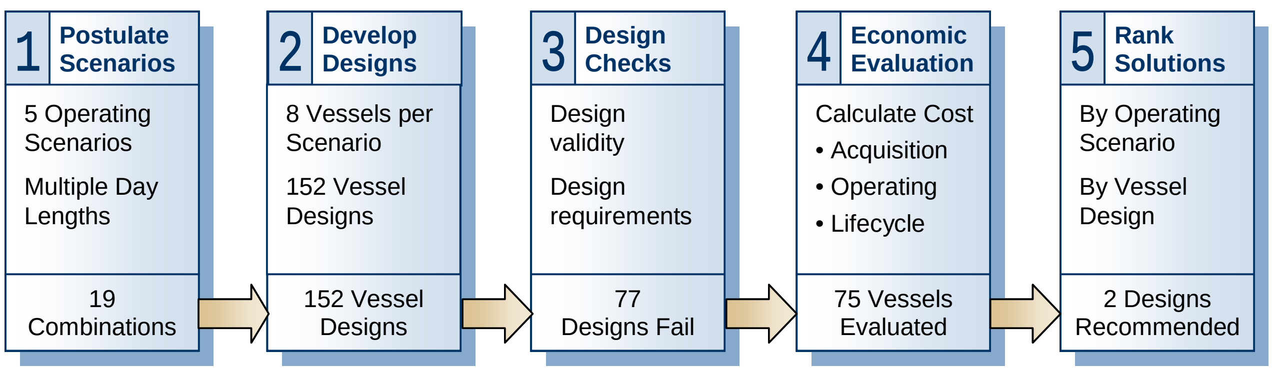


Figure 3: Example of evaluation and ranking process

A total of 152 parametric vessel designs were generated, each matched to serve the traffic demand in one of five operational scenarios and subject to different service day lengths chosen to explore break points in maritime labor agreements. Of these 152 design solutions about half failed some design validity check, such as speed range, speed-to-length ratio or dimensional proportions. For example, a 5-knot boat and a 60-knot boat were discarded as unrealistic. The remaining 75 solutions were subjected to economic evaluation as indicated by Step 4, and these solutions were then ranked in Step 5. In this example two designs were recommended for further study and evaluation.

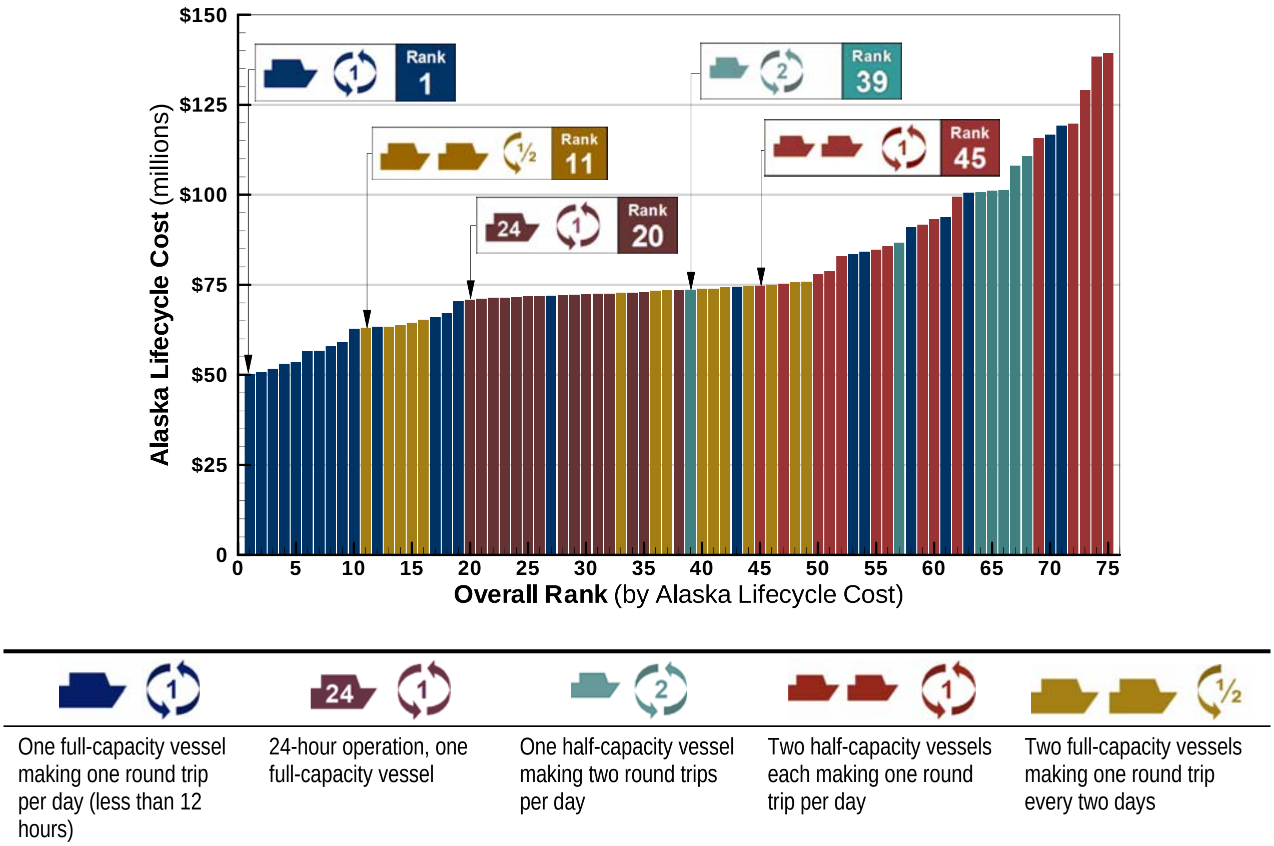


Figure 4: Parametric design Alaska lifecycle cost rankings

Figure 4 shows the ranking of the various solutions in this example. In this case, the rankings are according to a measure designated as the Alaska life cycle cost that represents the net present value of the cost to the State of Alaska of acquiring and operating each vessel for twenty years. The solutions are coded by color and icons to represent the five different operating scenarios considered. In this example the operating scenario of one dayboat, making one round trip in less than 12 hours each day is the best solution, and captures the top ten rankings in the global solution set.

System-wide Solutions

This approach to marine transportation analysis also lends itself to system-wide optimization where the system consists of route alternatives to serve the same core mission and/or where the system consists of a network of routes.

In the case of route alternatives to serve the same core mission, the objective economic measures for each route alternative can be determined for each route, and the results of the global solution set can be ranked to ascertain the route, service scenario and parametric vessel design that is best.

In the case of networks of routes, we can search across the highest-ranking solutions for each route for common vessel designs that maximize system-wide net revenue. System-wide optimum solutions may not be the top-ranked solution for some routes, but will be high ranking solutions that achieve the desired goal for the objective economic measure while achieving the desirable goal of minimizing the number of unique vessel designs in the system.

Project Examples

Service and Fare Elasticity of Demand

The Juneau Access Marine Alternatives Study was performed to examine marine transportation alternatives to a proposed new East Lynn Canal Highway (65 miles of new road). The study examined conventional monohull ferries, high-speed catamarans and high-speed monohulls. Ten port/service combinations were considered. Solutions were developed for capacities of 100, 250, 500, 750 and 1000 vehicles per day. System performance, acquisition cost, operational cost and life cycle costs were developed for each solution examined. A total of 780 marine alternatives were developed (628 conventional monohull solutions and 152 high-speed solutions). Solutions were ranked at each traffic volume level by several measures, including lowest life cycle cost, lowest acquisition cost and lowest operating cost. Operational variables considered included length of service day, number of vessels in the system and number of round trips per vessel per day.

Subconsultant Northern Economics, Inc. developed a service and fare demand elasticity model for these marine alternatives that evaluated the effect on traffic demand of service convenience (as measured by number of daily departures and travel time) and tariffs. Using this demand elasticity model, Northern Economics estimated tariffs and traffic volumes that would recover 60% of the operating costs (i.e., 40% operating subsidy).

Figure 5 is a scatter plot showing the "break-even" points for a wide array of parametric vessel designs. Conventional options offer the lowest tariffs for moderate demand (demand ≈200% of current demand) while high-speed options offer the lowest tariffs at very high demand levels (demand >400% of current).

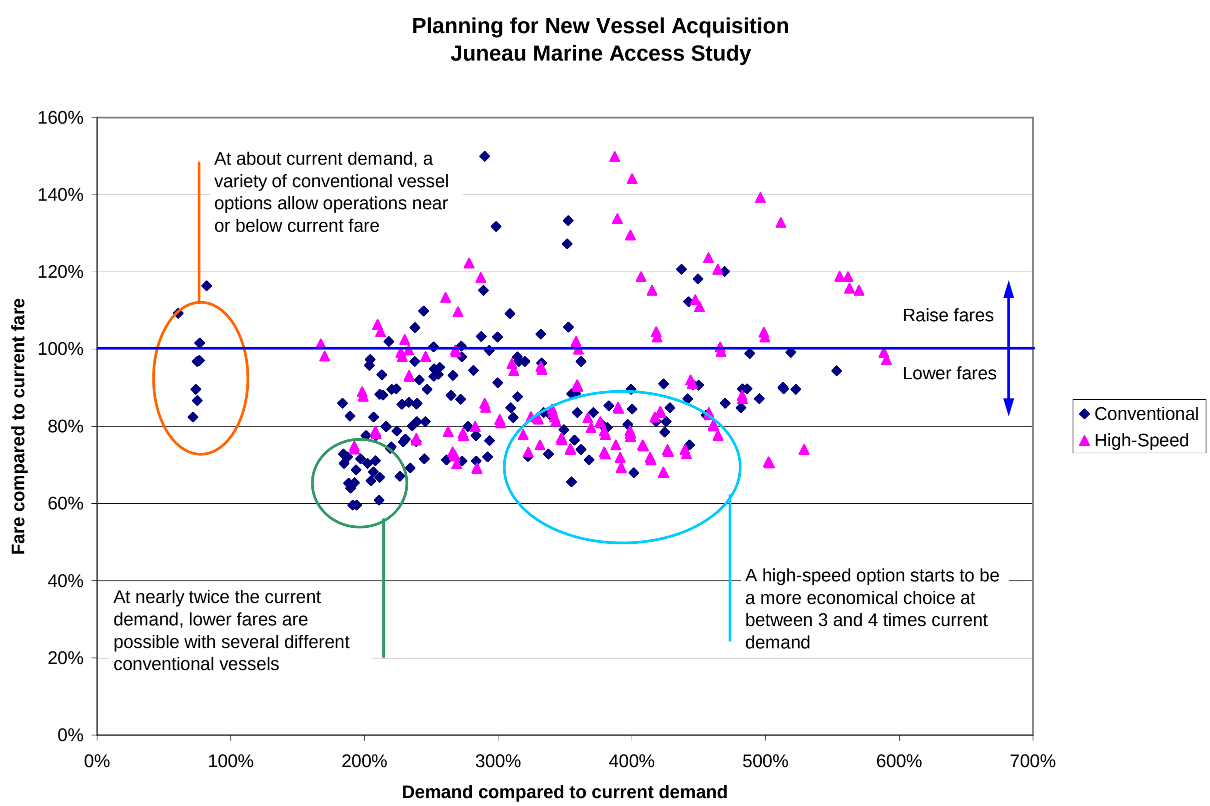


Figure 5: Optimal solutions as a function of traffic demand and tariff

System-wide Optimization and Vessel Commonality

Pursuant to the 2000 Southeast Alaska Transportation Plan (SATP), Glosten carried out a Vessel Suitability Study (VSS). We assisted the Alaska Marine Highway System in developing plans for a completely new ferry system to serve 14 ports in Southeast Alaska and interface with three other local ferry systems. The analysis included development of 82 alternative route systems, as well as vessel operating profiles, acquisition and operating cost estimates, and feasibility-level designs for hundreds of candidate vessels to meet the projected traffic demand in the year 2020.

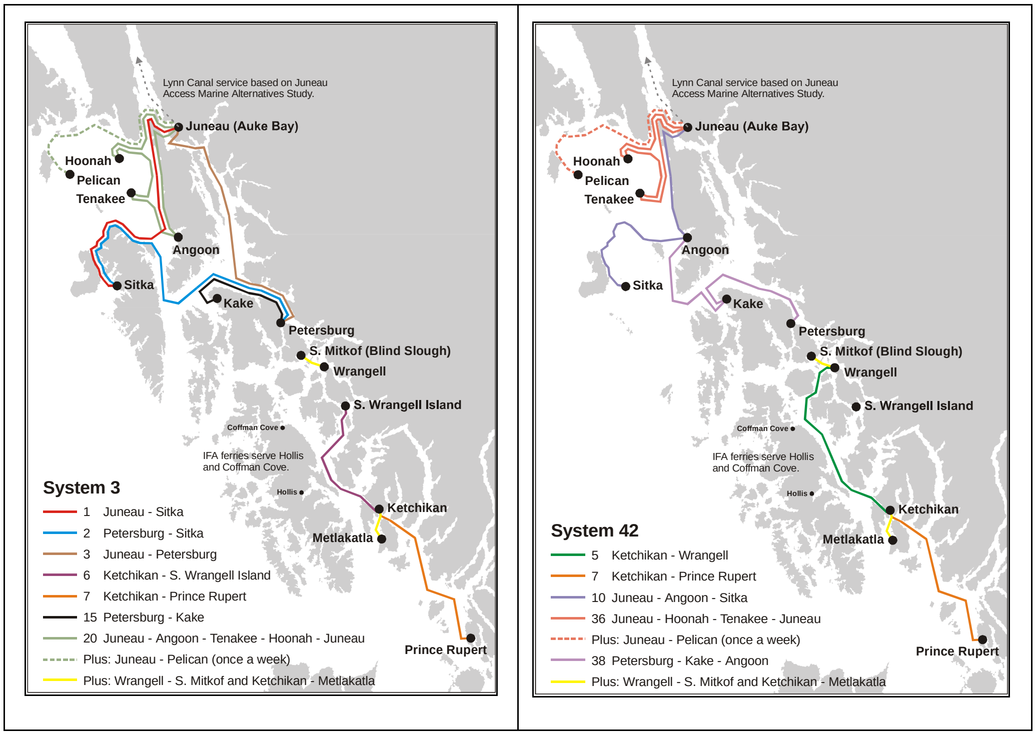


Figure 6: Two sample route systems evaluated for Alaska Marine Highway System

One of the VSS activities was to determine the optimum and ranked near-optimum vessel and service solutions for each SATP regional and local service route. These route-optimized solutions became starting points and building blocks for subsequent consideration of the entire SATP route system and vessel commonality.

We studied 20 representative systems for "system commonality," in an attempt to minimize the number of unique vessel designs while maintaining low operating costs. Approximately 120 good solution sets emerged from this study, comprising from two to six rationally-selected vessel designs with low operating cost and associated route system. Minimizing the number of unique vessel designs offers a number of advantages, which include:

- Limiting the amount of time and resources dedicated to acquiring multiple, unique designs.
- Acquisition cost savings associated with multiple-vessel procurement.
- The ability of crew members to operate and maintain a number of vessels in the system without additional training.
- Allowance for a smaller inventory of equipment and spare parts.
- The flexibility to move common vessels to different routes in the system, if another vessel is out of service.

The vessel commonality analysis reduced the number of unique suitable vessel designs to 24, of which two to six are combined to serve a system. Of these 24, six are conventional monohulls, eleven are high-speed monohulls and seven are high-speed catamarans.

Intermediate Speed Vessels

The speed range between a length Froude number of 0.3 and 0.5 is particularly problematic due to the strong wave making in this speed range[1]. In earlier studies we left a gap in the vessel design space between the conventional displacement solutions operating at Froude numbers below 0.3 and the high speed solutions operating at Froude numbers above 0.5. Figure 7 shows the gap covered by new intermediate-speed-range vessels.

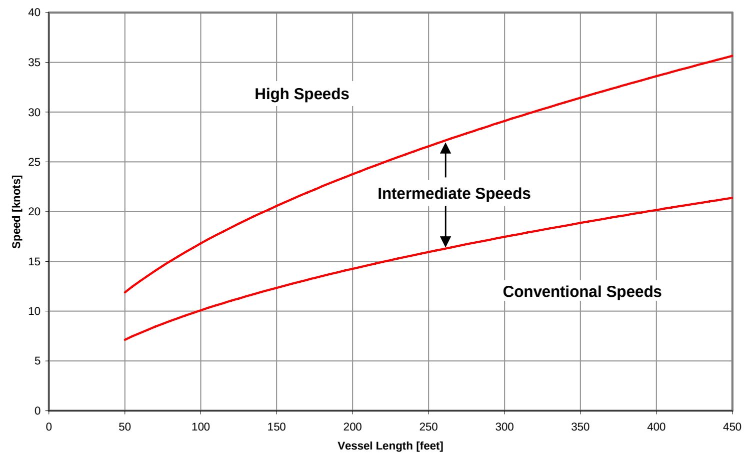


Figure 7: Ratio of speed to vessel length by vessel class

This intermediate speed range was of particular interest for the Alaska Marine Highway System's Southern Gateway design study for a vessel to operate between Ketchikan, Alaska and Prince Rupert, British Columbia because the distance between ports led towards dayboats operating in the intermediate speed range. To meet this challenge we developed parametric naval architectural models for resistance and propulsion of monohulls and catamarans operating at these intermediate speeds. Having bridged that modeling gap, the optimal solutions for that route were found to be monohulls operating at speeds between 21 and 23 knots.

Passenger-Only Models

Many of our studies have focused on combination vehicle and passenger ferries. However, our work for the San Francisco Bay Area Water Transit Authority (WTA) provided an opportunity to develop parametric models for passenger only vessels. Features and issues that are important to the modeling of passenger-only service in dense urban settings include diurnal demand cycles and the need for detailed passenger time and motion models for loading and discharge during quick turnarounds on short routes.

Closing Thoughts

Multi-destination marine transportation systems are complex. Successful design and analysis demands an array of skills spanning several disciplines. Glosten's knowledge of ship design and procurement, coastal structures, wave climatology, ship motions and operability, and marine safety and regulatory issues is critical to our ability to serve clients effectively in this field.

[1] For example, at 100 foot length this corresponds to speeds between 10 knots and 17 knots. At 300 foot length this corresponds to speeds between 18 knots and 28 knots.