# Design, Economics and Politics: The Viability of Urban Ferry Systems

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**Abstract:**

*Urban ferry systems have traditionally been favored by environmental advocacy organizations and progressive land use and transportation planners.*

*However, recent proposals have encountered unanticipated opposition based on perceived problems in these areas. As a result, modern trends in speeds, propulsion systems and layout of both vessels and terminals may change significantly with the next generation of ferries.*

*Using the San Francisco Water Transit Authority as a case history in progress, the author examines how newly recognized concepts of public transit efficiency, emissions, land use and system integration play key roles in the political viability of new ferry service, and how these considerations ultimately reflect back on the vessels themselves by imposing new sets of design constraints.*

*Some short-term solutions are proposed, and long-term predictions for the shape of the mid-21st Century urban ferry are presented.*

## Part I

### Rational Design for an Irrational World

Why use a ferry to span a body of water that is already crisscrossed by bridges and tunnels? Water is sticky and air is thin. Wheels on steel rails or smooth concrete produce negligible resistance compared to the frictional and wave-making effects of a hull in water. And land vehicles enjoy essentially 100% propulsive efficiency between driveline and useful thrust.

Public land vehicles also benefit from an economy of scale: A single operator can drive a train that moves well over a thousand commuters, or a bendy bus or multi-car streetcar holding a hundred or more passengers.

Land-based transit can serve multiple terminals within the high-density centers of business, commercial and residential districts.

Ferry advocates will counter with operational advantages unique to ferries – e.g. the absence of required massive infrastructure investment (no roads or rails needed), the flexibility of routing topology (no requirement to follow the historic routes of existing roads or rails as demand patterns change over time) and the infinite scalability (no issues with exceeding the capacity of the roads or rails).

(We ignore, for the time being, potential land-side problems with terminal capacity, siting and access.)

But where the ground transportation infrastructure already exists, the success of urban ferries represents a profound failure of shoreside planning and politics.

A single commuter lane typically carries 2,000 people per hour. Change to HOV status, and this increases to 24,000 people per hour (http://www.transcoalition.org/reports/revt/6.0.html). Yet this remains a politically unfeasible solution for increasing capacity along the Bay Bridge commute corridor.

Rail transit operates at only about half the theoretical maximum throughput, limited (in the case of BART) by imprecise train detection and control systems, a century-old "block" system for train separation, and inadequate parking at suburban stations.

The point here is that the rational approach to increasing mobility around the Bay Area -- and most other urban centers that already have bridges and tunnels across their waterways -- is to make more intelligent use of these bridges and tunnels.

But we design for the world as it is, and not for world as it should be.

This irrational world is not limited to poor use of physical resources; the political and cultural climate within which a ferry proposal must be sold is every bit as perverse.

On the other hand, ferries enjoy one correspondingly irrational advantage over other transit modes: People like boat rides. There is an attraction to the water that is deeply rooted in the human psyche. Our task is to leverage the power of this attraction against the physical and social barriers that have been erected against water-borne transportation.

The big secret is that the pay-off is not cleaner air, reduced congestion, greater mobility or shorter commute times. The real justification for the urban ferry is quality of life.

Unfortunately, this has to remain a secret if urban ferry proposals are to succeed. We still need to justify them in terms of air quality, congestion relief, mobility and economics, regardless of how artificial and contrived some of these criteria have become.

***San Francisco Bay and the Bay Area Council.***

The two major bridges, Golden Gate Bridge and the San Francisco Bay Bridge, were completed in the 1930s. The Richmond-San Rafael Bridge opened in the 50s, completing the central bay circuit. The BART transbay tube came on line in 1973.

After 25 years of population growth without any significant new transbay capacity, congestion was becoming recognized as a serious obstacle to efficient commerce.

Ferries appeared to be an attractive option. The Bay Area Council, a private business-oriented advocacy and planning organization, initiated the "Blue Ribbon Task Force" in 1997. This was a 52-member group established by the Legislature to study feasibility and create a basic plan for high-speed ferry service on the Bay. The result was released in1999 as the Bay Area Water Transit Action Plan.[1]

The plan proposed a 75-vessel regional system with 28 terminals carrying up to 20 million passengers per year, eventually growing to 125 ferries, 30 routes and 30 to 40 terminals. The task force also called for the creation of the Water Transit Authority, which was accomplished by the passage of Senator Perata's SB 428.[2]

From an environmental perspective, the 1999 plan was an easy target. Ships are extremely energy efficient when they are large and slow. Small and fast are just the opposite. The proposed network of relatively small high-speed ferries, using conventional diesel power, was inherently wasteful and did little or nothing for air quality.

All of the plan's environmental considerations were directed at secondary effects – wake, dredging, bird habitat, waterfront parking and access road congestion. Meanwhile the marine diesel prime movers were essentially uncontrolled for emissions.

Although marginally tighter standards for marine diesels were being implemented, Bluewater Network,[3] a San Francisco based environmental advocacy organization, found an easy target in the 1999 plan. Comparing the emissions of unregulated marine diesels to land-based bus and train systems, it was easy to show that the proposed ferry system would do nothing positive for air quality.[4]

The San Francisco Bay Water Transit Authority began its life in September of 2000 with a $12 million grant from the state. Their task was to implementing some version of the 1999 plan, and WTA also found itself on the receiving end of environmentally motivated criticism.

While it may be true that Bluewater Network was not playing fair by comparing highly emission-controlled land vehicle engines to essentially unregulated marine systems,[5] [6] [7] the basic attack was successful. Ferry advocates found themselves seriously at odds with the environmental community. From a January 2001 article in the Bay Guardian:

> *" Stinking ships - If the transit authority gets its way, 120 new ferries will be spewing diesel into the bay."* [8]

The initial charges made by Bluewater still have traction.

And from a 2004 newspaper article appearing just before the Regional Measure 2 transportation referendum:

> *"Studies show ferries operating now on the Bay produce four to 10 times more air pollution per passenger than cars or buses, said Teri Shore, spokeswoman for the Bluewater Network."*[9]

***The details were wrong***

One of the problems with the WTA enabling legislation was that by specifying the purpose of WTA - to reduce highway congestion and improve air quality - it predetermined the main result of the analysis they were charged with performing.

The initial plan also made some assumptions about land use patterns around terminal locations. The plan assumed that a mixed use commercial/business/residential center would be developed around each terminal location, making the high-speed network a viable mode for commuting, shopping and general mobility. But in some locations, this concept collided head-on with local preferences.

For example, the Eastshore State Park acquisition, driven by a local park advocacy group and the local Sierra Club, dedicated most of the available shoreline in Berkeley and Albany to open space. This position statement from the Sierra Club is representative:

> *"...the Sierra Club opposes commuter ferry service in or adjacent to a park. Consequently, the Sierra Club opposes any idea of a commuter ferry in or adjacent to the proposed East Bay State Seashore. I wish to make it very clear to the Water Transit Authority that the Sierra Club will fight any effort to establish a commuter ferry service along the East Bay shoreline adjacent to the new Eastshore State Park/Seashore especially at Gilman Street or at the Berkeley Pier as was discussed."* [10]

Sierra Club opposition continues. Consider this public statement by John Holtzclaw of the SF Bay chapter:

> *"We just don't think ferries are the most effective, especially if there are going to be huge parking lots surrounding them, which will just encourage more people to drive."*

By Sierra Club logic, a car sitting in a local parking lot all day pollutes more than a car crossing the bridge in traffic.

Other assumptions made by the 1999 plan read well but presented broad and vulnerable targets. It was blithely assumed that 50% of ferry riders would access the ferry by some mode other than private auto.[11] Later analysis by WTA demonstrated that 80% of ferry passengers would arrive by car.

The Water Transit Authority also made some serious errors in its early attempts to show that subsidy levels would not be oppressively high. During the initial public presentations to local Waterfront Commissions and other interest groups, it was argued that because the farebox recovery ratio was comparable to other modes, the public cost to subsidize the ferry routes was not excessive. Of course everyone immediately wanted to know the actual projected dollar amount of the estimated subsidy for each ride. Who cares about the ratio? For public policy purposes, the actual amount of subsidy per ride is what counts. Those numbers did not look nearly as favorable.

Considering WTA's legislative mandate, they really had no choice. WTA was formed to reduce congestion and improve air quality by establishing a network of ferry routes, according to the enabling legislation. The vital questions - can a ferry system reduce highway congestion and improve air quality - had already been answered by the State legislature!

The more intelligent critics could always point to the probability that any new transportation system, however clean, would be additive to the pollution load on the regional air mass. Taking cars off the bridge might have a temporary benefit, but no extra capacity on a route like the Bay Bridge goes unfilled for long. The best WTA could hope to demonstrate was a relative improvement in air quality and congestion compared to other scenarios. That is, things would get worse, but maybe not as bad and not as fast if the ferry were not there to help.

***Opposition from unlikely quarters***

Even the San Francisco Bay Yacht Racing Association was not comfortable with the 1999 ferry proposal. This is a group with more than theoretical interest in water travel, with members drawn from a demographic likely to be best served by a ferry system, with existing travel destinations likely to be close to the terminals. Yet the YRA board reacted negatively, concerned that 125 high speed boats over 30-40 routes would severely limit their access to the Bay for recreational uses.

***Partial Course Correction***

In July 2003, the Water Transit Authority adopted the San Francisco Bay Area Water Transit Implementation and Operations Plan.[12] This plan backed off considerably on the number of new routes and the speeds of the new boats, considering only 15 routes to be viable and dropping speeds to 25 knots for many of them.

***Regional Measure 2***

Despite all the shortcomings of the Bay Area Council plan and WTA's initial association with it, people still like ferries. On March 2, 2004, Regional Measure 2 passed by a comfortable margin.

Measure 2 calls for a one dollar increase in local Caltrans bridge tolls, from which a significant portion ($84 million through 2009) will be earmarked for developing new ferry routes, expanding old ones, and continuing the funding for WTA.[13]

***Irrational Regulations***

Transportation planners and park advocates are not the only source of headaches for ferry proponents. Our government plays a major role in the design of ferries, in the form of tonnage regulations.

The trouble started in 1865, when U.S. tonnage regulations began to diverge from European practice. The importance of an extensive network of wide navigable rivers in the U.S. during its period of rapid industrialization produced a type of fairly large river boat with nearly all usable space above the main deck. Successful lobbying by steamboat operators resulted in tonnage exemptions for nearly all the volume above the main deck.

It worked fine for steamboats on the Mississippi and Missouri rivers. But for modern ferries, this is a problem. Current U.S. tonnage regulations are extremely type-forming, encouraging designs that are short and high. Because they are high, they also tend to be wide for stability. Because framing depth can be deducted from measured volume, large modern ferries often carry extra structure in deep frames for no purpose other than keeping the tonnage number low. Non-functional "tonnage ports" must be added to above deck spaces to make them nominally "open" and eligible for exemption, and these also add weight and waste space.

Vessels built to optimize U.S. tonnage rules are inefficient and uncomfortable. Long slender hulls measure poorly, so U.S. ferries tend to be short and fat, with extra framing and other unnecessary features.

Most of the world has standardized on an international or "convention" tonnage system that is far simpler and not nearly as type-forming, without the complicated exemptions of U.S. practice.

Medium speed ferries of the type applicable to Berkeley, Treasure Island and South San Francisco routes will benefit from this change - designers will be free to use far more fuel-efficient hull forms and save significant unnecessary structural weight.

But U.S. ferry operators are still required, for all practical purposes, to stay below 100 gross tons under the old U.S. system in order to avoid the expensive crewing and lifesaving requirements of larger ships. These requirements are fairly onerous, because after 140 years of evolving loopholes, it is assumed that any vessel exceeding 100 gross tons is quite large. Under the more rational international system, vessels pass the 100 ton mark at only about 80 feet long. Yet the 730-passenger Spaulding monohulls on the Larkspur route measure less than 100 tons under the U.S. system. They would probably be 400 ton vessels under the international system. The Coast Guard is in the process of setting new regulatory break points that are consistent with international practice, but this is a very complex project, since tonnage numbers are involved in a wide range of regulations, so achieving stability, consistency and fairness including a transition from the existing situation is not a trivial problem. Though no-one wants to be the last agency to build, buy or operate ferries under the old rules, there is another alternative: A surprising number of vessels, mainly historic craft, but at least one ferry, have been granted various forms of relief, often through special acts of Congress. It may be worth pursuing this in that such relief would not give an unfair competitive advantage for new operators, since they are new public agencies anyway and would ultimately result in a savings to taxpayers.

***Ferries for the World as it Is***

How, then, can a ferry system be configured to fit within this raft of constraints?

Fortunately, this is a problem that has solutions. Not all of the various constraints work against each other, and some of the suggested solutions are complementary.

A conceptual design solution for an urban ferry service, and for the vessel itself, is proposed here.

## Part II

### 14 Steps to a Politically Viable Ferry Service

***1) Show that the Route is Viable***

This is particularly easy in the case of the Berkeley/Albany to San Francisco route, as it was selected as one of the first tier new routes by both the Bay Area Council and WTA.

There is historical validation as well, considering that there was regular commercial ferry service from the Berkeley Pier to San Francisco from the late 19th Century right up until 1956, a full two decades after the Bay Bridge was opened.

The Berkeley waterfront has the advantages of relatively short distance to San Francisco, but also a reasonable separation from the approaches to the Bay Bridge, and the BART tunnel. Separation, especially where it does not increase route distance or move terminals away from population or destination centers, improves the ferry's ability to compete against wheeled alternatives.

Of several candidate Berkeley/Albany terminal locations, the Berkeley Marina offers the most extensive existing infrastructure:

- Deep water, requiring minimal dredging.
- Existing bus service over the AC Transit #9 route, a relatively short local route that is coordinated with the ferry schedule.
- Existing parking (within certain limits).
- Existing four-lane road access.
- Existing compatible land uses in the form commercial, recreational and maritime facilities already in place as part of the Berkeley Marina complex.

Other Berkeley or Albany locations that have been considered (north and south sides of the Golden Gate Fields race track, and the foot of Gilman Street) offer shoreside advantages in the form of a much larger parking resource (albeit on land not currently under public ownership) and possibly better road access, especially in the case of a Buchanan Street site.

In a rational world these locations would make perfect sense for a large-scale ferry terminal supporting a schedule comparable to the Larkspur-San Francisco route. But the political reality renders these locations non-viable, mainly because of the required dredging, perceived effect on seasonal bird habitat in and adjacent to Eastshore State Park waters, and the public activism for unbroken open space already invested by Sierra Club and Eastshore State Park advocates.

These groups are at least taking a more-or-less neutral position on the Berkeley Marina or Berkeley Pier location.

Still, the damage has been done as far as the startup date of a Berkeley ferry is concerned. The South San Francisco route, which was only recommended for study rather than first-tier implementation in the initial WTA plan, is now first in line thanks to support from San Mateo county and a much less contentious political climate. Service connecting the Oakland Estuary, Oyster Point and the SF Ferry Terminal could begin as early as 2008.

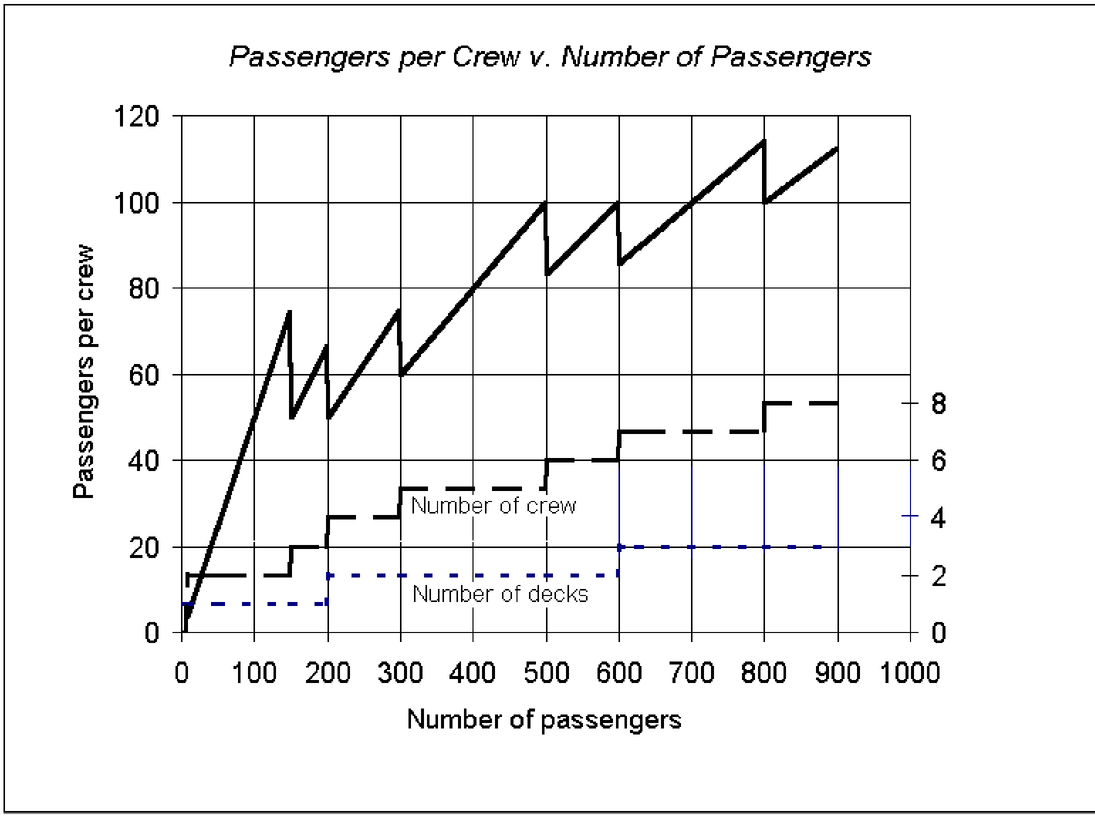

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**Figure 1**

***2) Design for Operational Economy***

The WTA and other transit authorities have put a great deal of resources into new technologies to reduce engine emissions, increase efficiency and suppress wake. But for a reasonably short route such as Berkeley to San Francisco, there are mature technologies that accomplish exactly the same thing.

The distance of 5.6 nautical miles is traversed in 20 minutes at only 16.8 knots.

The most efficient hull shape for this speed depends on the vessel size: Small craft work best in planing mode, larger vessels are better optimized as long slender displacement hulls. Within a large band of intermediate size ranges, hulls slender enough to optimize resistance while carrying the required weight and volume will need some from of roll stability augmentation - or, more likely, given current trends, a multihull configuration of some kind.

What is the most efficient size? Big ships are always more fuel-efficient than small ones, but a ferry is a product of regulatory forces and market realities

Figure 1 shows the minimum required number of crew as a function of the number of passengers and number of decks, (making a reasonable assumption on the relationship between number of seats and number of decks).

The solid line plots the number of required crew per passenger as a function of number of passengers. Economic performance of any transit system is strongly dependent on maximizing this parameter.

In addition, there are many other capital expenditures that come into play as soon as the number of passenger exceeds 149, especially with respect to fire resistance and other safety features which become more "ship-like" rather than "boat-like" when the 149 passenger threshold is crossed.

Positions of these peaks and valleys may vary depending on deck layout and local Coast Guard discretion, but 149 passengers is an industry standard size for medium-small ferries, driven entirely by these regulations.

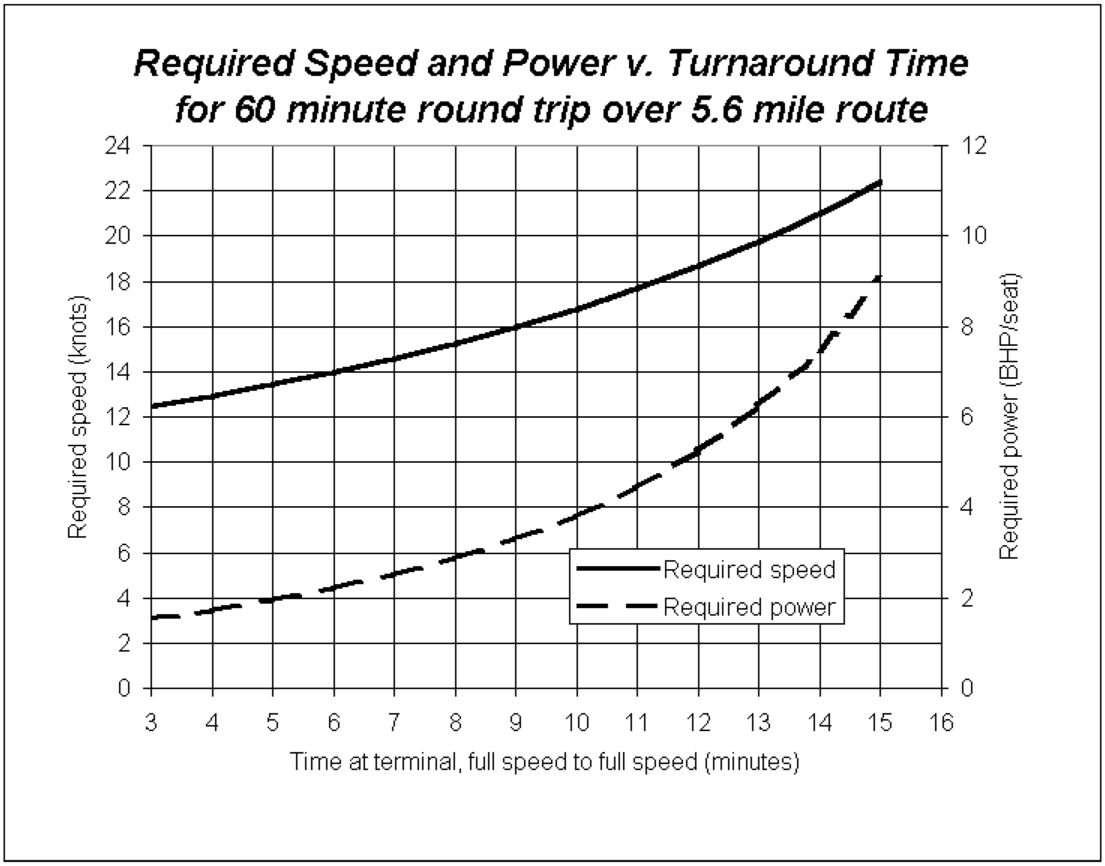



**Figure 2**

(Because we already have some foreknowledge of outside constraints - i.e. parking and limited demand - we can bypass the full design spiral and settle on this capacity number early in the process)

***3) Select the Right Speed***

The important concept for the non-naval architect transportation planner to grasp is that propulsion power is roughly proportional to speed cubed. That is, if speed doubles, required power multiplies by a factor of eight. This is a direct consequence of the nature of frictional resistance, which is roughly proportional to speed squared. Power equals resistance times speed, so when speed doubles, resistance increases by a factor of four and power by four times two, hence a factor of eight.

All costs associated with engines - first cost, maintenance and operation - scale roughly with power. (Although fuel consumption and emissions, on a per mile basis, scale more closely to speed squared, not cubed, because per-mile effects are all divided by speed.)

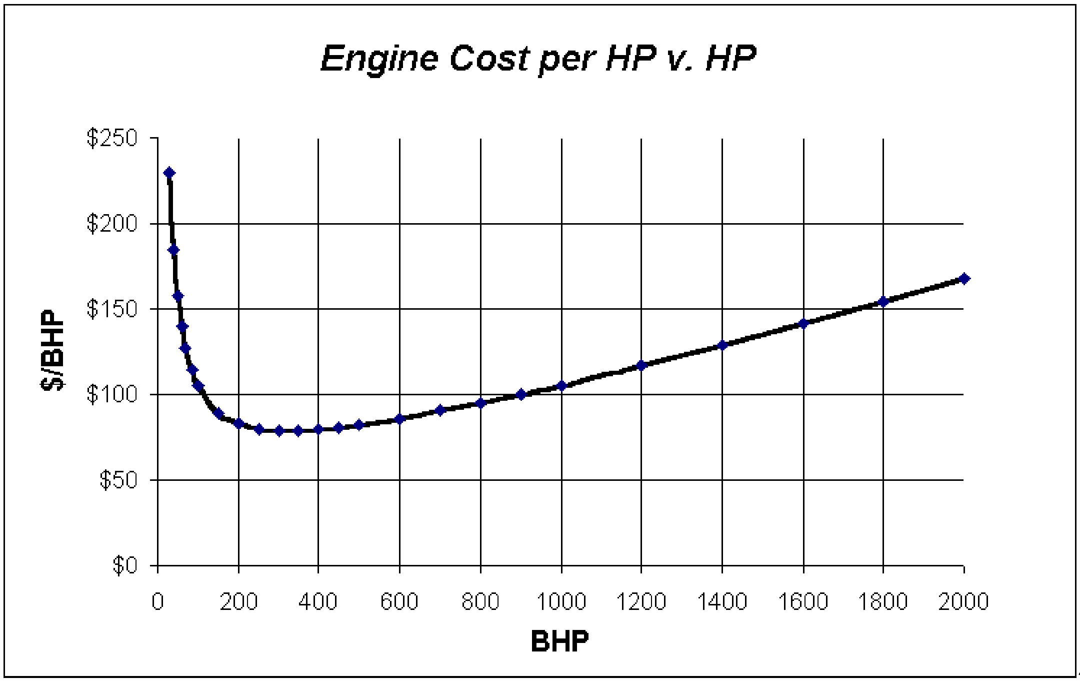
Therefore the "right" speed is generally the minimum speed that offers acceptable service.

For the relatively short 5.6 mile route from Berkeley to San Francisco, there is little incentive to reduce transit time to much less than 20 minutes. ("They need at least twenty minutes to buy a latté and open up their laptops.")

A 20 minute transit facilitates single-vessel operation on a simple-to-remember hourly schedule, or two vessels on 30-minute headway.

Figure 2 shows the relationship between turn-around time at each end of the route (defined here as full speed approach to full speed after departure) and required service speed to meet the 60-minute schedule. Assuming ten-minute turn-around, a service speed of only 17 knots is required.

In practice, vessel and terminal design optimized for quick turn-around will reduce the speed requirement further. But to allow for headwinds and adverse tide, a service speed of 18 knots is specified.




4)

**Figure 3**

***Configure for Economical Operation***

The 149-passenger size and 18 knot speed makes the vessel much too big for efficient planing, and will require roll control to be comfortable if there is only one long slender hull for minimum resistance.

The options for multihull configuration are catamaran, trimaran and proa. Trimaran and proa both have the considerable advantage of potentially reducing total wetted surface while increasing hull length. This reduces both viscous and wave-making drag over the catamaran.

Trimarans and proas also have the potential advantage of using only one engine and drive system instead of two, for a potential economy of scale.

However, real-world examples have tended to negate this advantage due to drag on the amas (outriggers). Traditional human-powered outrigger vessel types have dealt with this shortcoming by minimizing the displacement of the ama, and relying on human factors to avoid capsize.

It is interesting to note that as vessels become larger, the relative negative effects of the stabilizing ama become smaller. This is because heeling forces are generally a function of wind area times height, and scale up by size cubed. Righting moment, on the other hand, scales by displacement times beam, or size to the fourth power. So as a trimaran or proa configuration scales up, the relative size of the amas can be reduced and the resistance penalty becomes a less significant negative factor.

In the present study, the proa configuration may have been slightly favorable for total resistance, but powerplant considerations drove the design back to the more conventional catamaran.

Figure 3 shows the approximate relationship between engine size and cost per horsepower. The power requirement for this hypothetical design is 700 HP total. It can be seen that there is no cost advantage to a single large engine instead of two smaller ones, and in fact there is a significant savings by splitting the propulsion system. The more conventional arrangement has the advantage of faster maneuvering at the terminal, and also avoids potential problems due to lack of redundant motive power and terminal design to accommodate an asymmetrical deck layout.

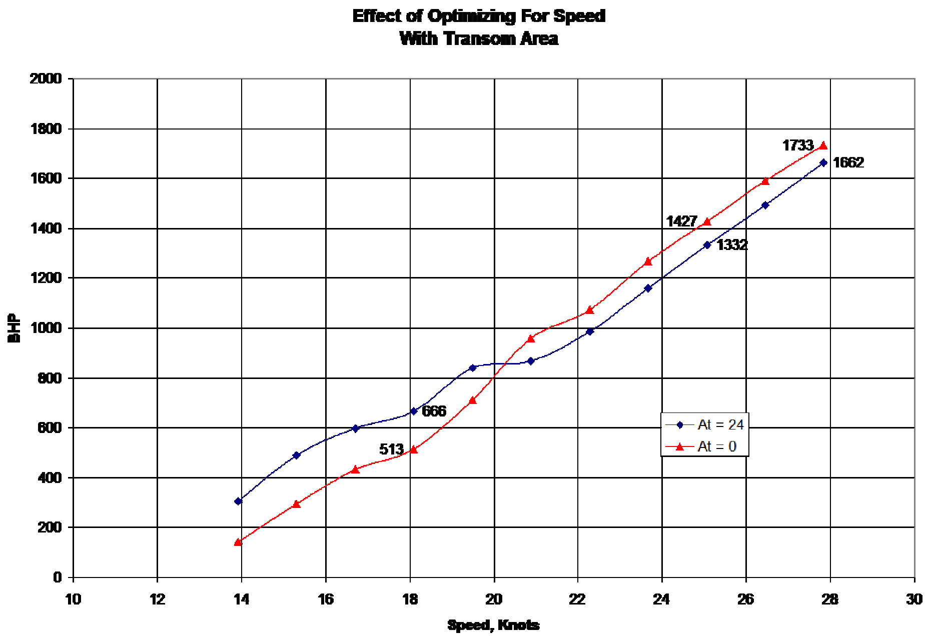



Figure 4

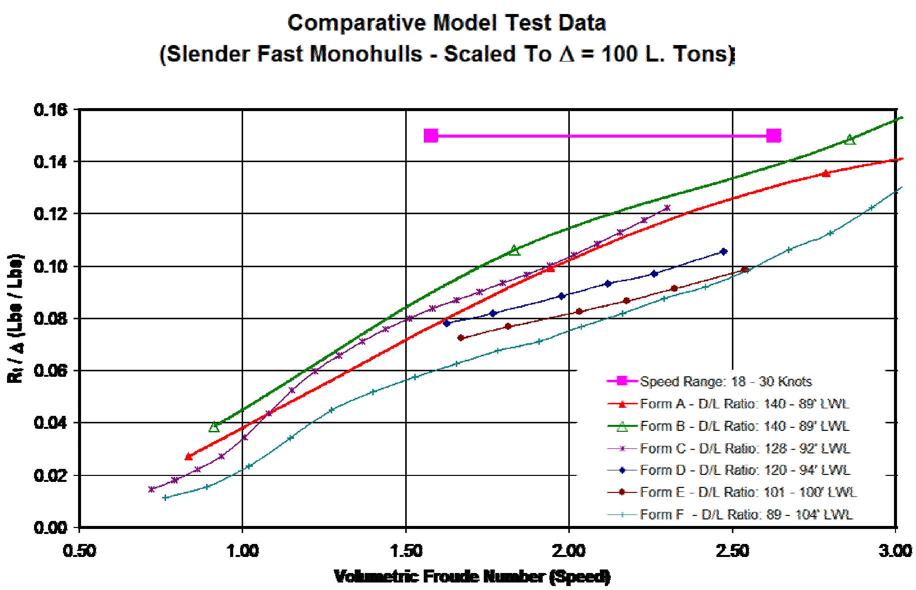



Figure 5

Good design is also important. This includes selecting the appropriate requirements for the hull and selecting a good hull. Figure 4 shows the importance of design for the appropriate speed. In this case only one geometric parameter, transom area ratio, is varied, and is optimized for either 18 or 25 knots. The performance loss at the non-optimum speed in each case is substantial – you can't assume the best fast boat is the best slower boat. Figure 5 is the result of a series of hull forms normalized to 100 tons and shows substantial differences in resistance. These forms are monohulls, but are representative of forms commonly used for the hulls of catamarans, so though the exact numbers may be different, the variation between hull forms is similar.

### *5) Design for Very Fast Turn-Around*

The dashed line in figure 2 shows the substantial reduction in required power for every minute saved at the terminal, assuming the 60-minute schedule is a constant. This is reflected in reduced first cost, increased fuel economy and reduced emissions.

In order to interface with a terminal designed for very fast boarding, the design should feature very wide side decks to accommodate multiple gangways. Loading and unloading of bicycles, wheelchairs and pets should not slow down the embarkation/disembarkation process at all.

Historically, the method of ticketing and payment control has been a dilemma: Should passengers pass through a control point before boarding and then wait in a confined area for the boat to arrive? Or should the control point be at the gangway, allowing passengers more freedom while waiting but slowing down the boarding process? Or should tickets be checked while underway? All three methods are in use, and all have drawbacks, but it can be predicted with reasonable certainty that remotely-read electronic tickets will soon tip the balance in favor of the gangway as the control point.

### *6) Minimize Terminal Delays*

Passengers generally don't care how fast the ferry travels. But they do care how long it takes to get from home to work. It has been shown that when departure times are variable, commuters will generally try to arrive two standard deviations ahead of the mean departure time.

This variability in departure time, however, has to include all variables that affect the trip from front door to ferry gangway. For most passengers, this includes the variability in the length of time required to find a parking spot and to walk back to the terminal from this spot. This variability has just as great an impact on trip time as variable arrival and departure times of the ferry itself.

Running the ferry exactly on schedule is therefore only part of the operational goal. In order to provide fast door-to-destination service, it is important to eliminate as many variables as possible from both the shoreside delays and the ferry departure time.

This implies more than "just adequate" parking. There needs to be enough parking so that the variability in finding a parking spot is minimized - meaning very little chance of encountering a problem finding a space right away.

If parking scarcity is used as a method of discouraging cars in favor of other modes, then variability is very high, trip time increases dramatically, and the viability of the entire service is seriously diminished.

### *7) Include Everyone*

*Bicycles - Scooters - Dogs - Disabled - Small Craft.*

Public hearings are not accurate surveys of public opinion. Nor are they objective expressions of the democratic process. But in the absence of a scientific survey or a fair election, the self-selected voices at public hearings are often taken as the best available substitutes for both.

Planners know this, and usually do their best to compensate. Ideally, public officials should try to restrict their use of pubic hearings to flagging unanticipated problems and generating new ideas. But the squeaky wheels still get more oil, and most public undertakings rely on a preponderance of favorable public comment, biased heavily in favor of those who have their weekday evenings free.

Ferry service can motivate some powerful interest groups, and their participation in the public discourse can easily shift this perceived balance of public opinion in favor of a project that includes them.

Aside form political expedience, inclusion of user groups not served well by other transit modes is one of the things that ferries can do best, and is perhaps one of the more valid arguments in their favor.

Bicycles are not allowed on BART during commute hours. A ferry with large outside deck areas and multiple gangways can accommodate bicycles with almost no annoyance or inconvenience to other passengers. Bicycles are also a useful strategy to defuse the charge that ferries are elitist, provided their riders enjoy a deep discount.

Wheelchairs are now accommodated on all public transit, but a good case can be made that wheelchair access to ferries is - or at least can easily be - relatively seamless compared to bus or rail.

Powered scooters present interesting possibilities. Like bicycles, they allow the ferry passenger to exploit the efficiencies of a "dual mode" transportation system, greatly extending range at the destination without the delays associated with a mode transfer. New configurations of electric scooters (e.g. the Segway, invented b the author's long-lost fifth cousin) offer particularly compact stowage possibilities.

Dogs can evoke the most controversial reaction, but their owners represent approximately one-quarter of the population. A pro-dog policy can have a profound positive effect on any proposal - although care must be taken insure effective separation for the considerable segment of the population that does not want to share space with dogs in any way.

Once again, multiple gangways and large deck areas make a dog-friendly policy feasible. But can dogs, bicycles and wheelchairs can mix it up on gangway number 3 while everyone else boards quickly through gangways 1 and 2? Temporal separation seems appropriate - i.e., they can take turns. Total numbers are likely to be a small fraction of the total passenger load, and with terminal and vessel design that anticipates these users they will not add anything to the turn-around time.

One of the few areas of small-craft recreation that is now experiencing a strong growth rate is hand-launched watercraft, e.g. kayaks, windsurfers and outriggers. They have one major obstacle to water access over most of San Francisco Bay: Lack of parking near the water. Ferry terminals, because they usually involve large parking areas with peak use periods that generally do not overlap with recreational use periods, have these recreational communities as a natural ally if minimal access facilities are provided. Ideally, the hand-launched watercraft dock and the ferry boarding area would be at opposite ends of the parking area, so that neither user group competes with the other for prime parking spaces.

The importance of these user groups at contentious public hearings cannot be overemphasized - they are generally articulate, credible with the environmental community, and often have a strong emotional attachment to water travel.

***8) Respect the parking resource***

WTA proposes to charge for parking. This is likely to meet strong opposition in any location adjacent to businesses and organizations that currently rely on ample free parking.

One of the advantages of a terminal location in or adjacent to a yacht harbor is that it is already a commercial and recreational center. The Berkeley Marina is host to a number of restaurants, a hotel, several non-profit and commercial organizations and about a thousand private boat berths. They all depend on free and ample parking, made possible by reasonably good planning and the low-density nature of the existing waterfront.

Turn a parking area into a fee lot in close proximity to any of these services, and it is not necessary to run simulation software to predict what would happen.

Fortunately the solution is fairly obvious - leave the parking free and raise the ferry ticket price instead. Offer deep discounts to people coming by bus and bike. The bus discount is easy to implement via transfers. The bike discount requires bringing the bike on board, and is subject to some level of abuse, but there are equally obvious countermeasures.

These discounts can result in exactly the same economic incentive as a parking fee to leave the car home, without destroying the neighboring parking resources.

By this logic, pedestrian access should also be rewarded by a deep discount. But there is no clear way to accomplish this. Fortunately, one feature of the marina location is that there are very few residents within walking distance, so non-transit non-bike pedestrian access is not likely to be a significant factor. The ferry service could easily make some other contribution to the small (but vocal) Marina live-aboard community to retain their allegiance.

***9) Scale the service to the market***

Higher ticket prices will affect the ridership levels, but the degree of elasticity for any given market is not really known. Considering the value of time lost during a Bay Bridge commute, and the possible productive value of time on the ferry v. time driving in traffic, it is likely that a significant market segment will happily pay the actual cost of the service - approximately $7.50 per one-way trip.

***10) Set the Price to Minimize Subsidy and Maximize Revenue***

Current WTA proposals suggest a $3.50 ticket price and a per-one-way-trip subsidy of about $4.00.

Sources close to city government (identity protected by the author's journalistic ethics, such as they are) have stated flat-out that various Council members are in favor of a ferry service run by a commercial operator, with no public subsidy at all. But they could not support a subsidized service of any kind.

This may be the Sierra Club influence - it is difficult to win an election in Berkeley without the Sierra Club endorsement. Or it may be the fear that every dollar spent on ferries means one less dollar spent on busses and rail. This despite the fact that SB 346, part of WTA enabling legislation, calls for all subsidy to come from new funding sources. No matter - the money may come from a different pocket, but the feeling that it ultimately affects the money available for other forms of transit is not entirely without justification.

For this reason it is critical to keep fares relatively high and subsidy levels low.

How low is low enough to satisfy the politicos?

BART subsidizes every trip to the tune of about $3.23 (1999 data - and it's about double that if we include capitalization of the ongoing route expansions, and there's no good reason not to.). Golden Gate Transit subsidizes each bus trip at the $1.93 level. AC Transit Transbay service is not easily separated from local revenue and costs, but it is probably somewhat less than the Golden Gate Transit figure.[14]

All this suggests a maximum defensible subsidy of about $2.00 per trip. Otherwise, the "concerned public" (or perception thereof) will conclude that the money should be spent on more busses instead.

The more sophisticated argument is that the subsidy to compare is the marginal rate, not the average. The question to ask is "How much more public money do we have to spend to get one more commuter out of their car and on public transit?" With an extensive bus and rail system already in place, the number is considerably higher than the system-wide average per-passenger subsidy. New bus routes and schedules serve the less popular areas and times, and load factors are unfavorable. New rail service can only be provided at astronomical infrastructure costs.

Here is where ferry economics look great: Hardly any new infrastructure is required (except relatively cheap, by rail transit standards, terminal development). And, with some high-demand routes now going totally unserved, a well targeted service with a high ticket price and low subsidy is likely to work.

In other words, busses and trains have to attract that last passenger, who comes at a high price. But ferries on new routes can go after their first customers, and they come relatively cheap.

Is this line of reasoning too complicated for the average Councilmember? You decide.

***11) The Diamond Lane Strategy***

The political downside of ticket pricing set at or near market rate is that the service proposal will be wide open to charges of blatant elitism. "Ferries are only for rich people" is the call to action against new urban routes.

Actually, this charge has little merit as long as the cost of a round trip ferry ride is less than the cost of a daytime parking space in the financial district. But the charge will be made nonetheless, and a successful plan needs to defuse these criticisms.

The diamond lane strategy takes the same approach as the free HOV lanes found on many urban bridges: If you are treading lightly on the infrastructure and the environment by driving a carpool across the bridge, then you get a free pass around the traffic and don't have to pay the toll.

There is equal justification for doing the same thing for ferry passengers who arrive by bus or bike: A free ride, or at least a very deep discount.

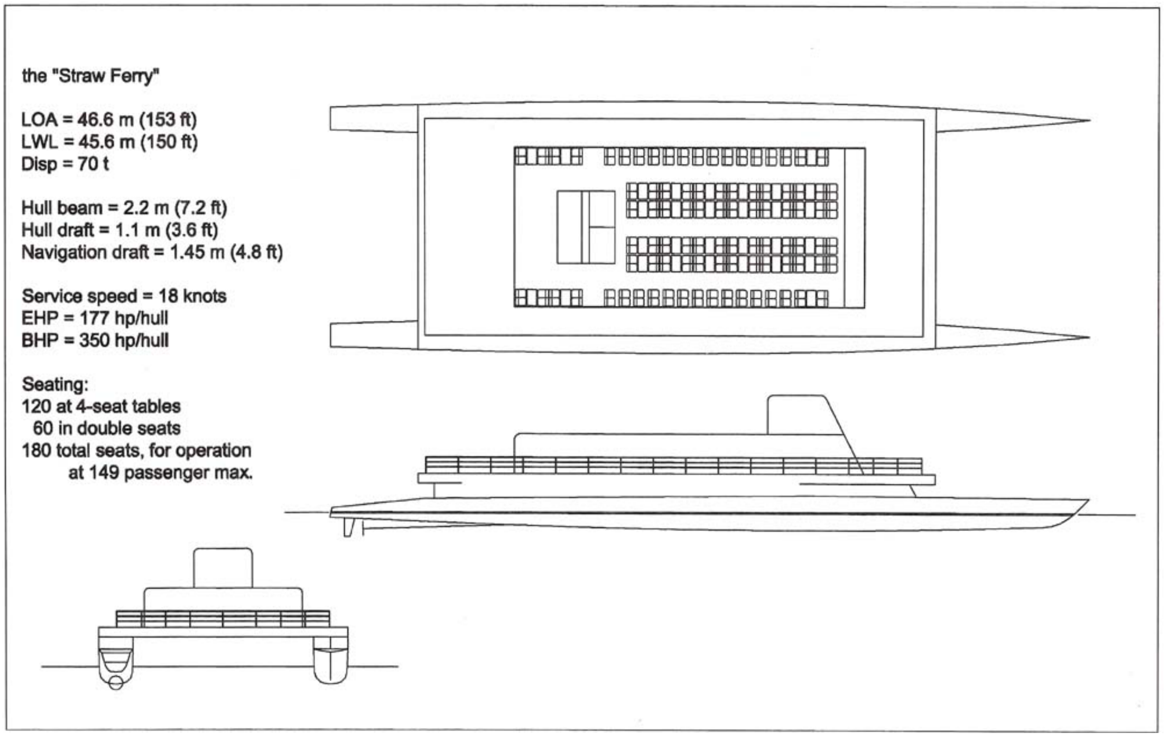



**Figure 6**

This policy has two desirable effects: It essentially charges for parking without the negative impacts that fee parking would have on adjacent uses that depend on free and ample parking; and it also makes the ferry a very accessible option to people who would otherwise be priced out of the ferry market.

Another important part of this strategy is to maximize "back haul". An empty seat costs the same to move as a full one, so selling it at a discount is free money – "nothing thrown away is ever sold at a loss". This is the same sort of problem that results in the whimsical world of air fares, but in this case, we know when and where the low occupancy runs are, and we can develop strategies to maximize occupancy on them. We could, for example, have a deep discount for the counter-commute direction. Since counter-commuters generally drive alone, this is could have a better impact on reducing emissions and even congestion – the counter commuter is on downtown San Francisco city streets getting on the bridge at the same time everyone else is on the street getting off.. In the specific case of Berkeley, students from San Francisco would be counter commuters. Even if a boat slow steams during the day, it is still spending crewing pay, and off hours discounts could help fill the boat.

This strategy might not, strictly speaking, reduce congestion much, because the users would probably be many people who wouldn't travel at all otherwise, but it would improve mobility and transit opportunity equity and provide some farebox revenue, all legitimate goals. This could be further "sweetened" by targeted discounts, such as student and senior reduced fares for these periods, which would increase special interest group support. One of the authors has some experience with some of these lobbies, and though our references to the dog lobby may seem whimsical, this one of many special interest groups that have substantial "bite" and well as "bark".

***12) Design Details for Passenger Comfort***

Considering the relatively expensive ticket price, passengers will expect a "first cabin" experience. This is not very expensive to provide.

Figure 6 is the result of the "straw ferry" design exercise. It carries 149 passengers in 180 seats, giving all passengers a choice of seating in an uncrowded cabin. There are lots of tables for en route office work. Service speed is 18 knots with installed BHP of only 350 HP per hull. Isolation of hulls from superstructure makes the cabin quiet and vibration free, and the long small-waterplane hulls provide a much smoother ride than much shorter conventional 149 passenger designs.

Also note that the small-waterplane and low volume hulls will only work safely at the relatively wide transverse spacing shown - otherwise there may not be sufficient reserve buoyancy to meet damage stability requirements. This feature follows naturally from the requirement for large areas of outside deck space.

The ferry ride must be smooth, quiet and comfortable in order to fully exploit the irrational attraction of humans to water-borne travel.

***13) Use Proven Technology for Emissions Reduction and Energy Efficiency***

WTA and other agencies have directed considerable resources at new technologies to reduce emissions from ferry propulsion. Compared to the existing base of commercial and recreational marine diesels in daily service without any emission controls, this may be seen as a kind of drop-in-the-bucket environmental tokenism.

Nonetheless, tokens can be important, and can stimulate cultural changes that are far more important than the tokens themselves. And of course the political reality is that ferries will have to leave a spotlessly clean wake in the air, water and land in order to avoid continuing and damaging attacks from organizations like Bluewater Network.

But accepting the need to dramatically reduce emissions does not mean that WTA needs to engage in original research. Spark-ignited CNG engines are already in widespread use for applications that require extremely clean exhaust. The mandated 80% reduction in emissions has already been achieved on a commercial scale for applications very similar to the ferries proposed for the new routes. Currently available marine Roll-Royce/Bergen engines meeting WTA's target emissions – without exhaust gas treatment - have been specified for a new "green" Norwegian ferry.

CNG may be much better suited to short-range ferry service than to many other applications, due to the bulk of the fuel containers and the limited range between refueling. CNG also slightly reduces carbon dioxide emissions – methane ($C H_4$ - the principle component of natural gas) has 28,691 Btu per pound of carbon whereas as decane ( $C_{10} H_{22}$ – a typical component of diesel fuel ) has 22,690 Btu per pound of carbon.

Where we go astray is confusing the more exotic, less reliable or more controversial technologies (fuel cells, wind assist, biofuel) with mature technologies offering proven solutions.

The most egregious error remains the one that is the simplest to fix: speed. Most projects that purport to demonstrate the feasibility of sail assist, solar-electric or fuel cell propulsion appear to be extremely energy efficient because they go slow, and not because of their alternative energy source.

WTA still proposes 25 knot ferries for a route that only requires 18 knots. Approximating by means of the V-cubed relationship between speed and power, this is the same as asking for an engine 2.7 times as powerful as needed. In other words, the continued "fast ferry" mentality, misapplied to a short route, results in almost triple the propulsion system cost for acquisition and maintenance. The extra weight impacts the capacity and efficiency of the vessel at lower speeds.

Per/mile fuel consumption varies by the square of speed, so the 25-knot boat will burn about 93% more fuel per mile than its 18-knot counterpart (neglecting the increased weight of the larger engines) over the same route.

This simple solution - slowing down the boat - allows low power engines that will tolerate emissions controls without as much added weight or cost.

In a rational ferry service proposal, existing technology will solve the emissions problem. For better door-to-destination travel time, innovative design resources are better spent on efficient deck and terminal design for fast boarding and quick turn-around than on new ways to go fast.

***14) Keep It Local***

Local jobs have always been a powerful incentive for development, and a ferry system is no exception. One of the authors originally entered the marine industry (at least in part) because he grew up in Vallejo, and was unaware that there were any other occupations than ship building and design. New technologies and methods have made it possible to increase productivity enough to build ferries competitively at very high labor rates. US shipyard productivity varies by a factor of at least three to one from average to best, and those shipyards with the best productivity are in relatively high wage areas (the Pacific Northwest and the New York / Connecticut area) anyway. There is no reason that a Bay Area or at least California shipyard could not "leapfrog" to best practices and produce ferries and similar ships at reasonable prices. The National Shipbuilding Research Program has been advocating and enabling just such a strategy for US shipyards for over a decade.

A shipyard building ferries could also take advantage of another trend; superyacht construction by using ferry building as an entry into this market. There has been a boom in the superyacht market for several years now with no sign of an end. The current production is limited by construction slots, not the market. The slide of the US dollar has also made US construction much more competitive, since most builders of superyachts are in the EU, with a few in Canada, New Zealand and Australia, all of which have seen their currency rise substantially against the dollar. At least one major US ferry builder also builds superyachts, and since superyachts are often aluminum and generally registered as small passenger vessels to allow chartering, there is substantial synergy between the two product lines. A shipyard building ferries could also build a few MCA limit (500 Int'l GRT – about 150' long) yachts a year and employ two or three hundred people at competitive wages. Fortunately, superyacht construction can be massively profitable as well. Though construction in the Bay Area specifically may be difficult due to limited facilities or labor shortages, it is worth noting that the Humboldt Bay area has substantial surplus waterfront capacity, a job shortage, and a substantial base of skilled trades that could be readily converted to small ship construction, and this would at least keep jobs in California. The authors are not familiar with capacity in other areas such as Stockton or Southern California, but there are probably opportunities in numerous California communities. It is also worth noting that Washington State legally requires ferries used in Washington be built there.

## Part III

**The Future of Urban Ferries**

***Configurations for Low Resistance at Medium Speeds***

We have a pretty good idea of what the next generation of urban ferries will look like. But what comes after that?

Many analysts believe that 2005, give or take a year or two, is the year of peak global oil production. The inflation-adjusted price of oil is expected to cross previous high value from the early '80s, with no relief forecast. Fuel efficiency, for reasons other than the political constraints already discussed, will become critical.

The historical solution, when propulsion power was limited to sail and muscle, was the long slender displacement hull. Multihulls will continue to dominate new designs, but some interesting variations involving asymmetric proa configurations may evolve. Keep in mind that as vessel size increases the relative negative effects of one or two amas diminishes, so trimarans or proas with almost vestigial amas, possibly augmented by foil-stabilization schemes, become more viable.

Asymmetrical configurations also show some interesting possibilities for wake reduction in sensitive areas. Figure 7 shows a numerical wake wave calculation for a proa configuration that leaves virtually all of its wave energy on one side only - perfect for lake service (although different boats would be needed for clockwise and counterclockwise service).[15]

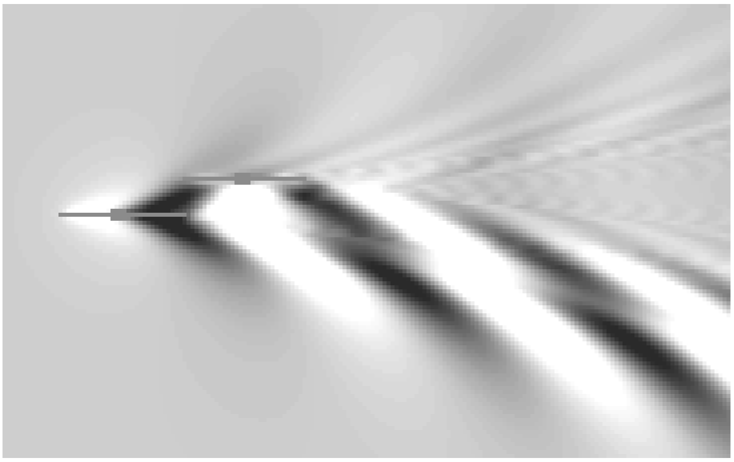


**Figure 7**

***Structural and Product Models***

Long term maintenance and related support costs will have a greater influence during on design. Two new technologies that apply to any sort of vessel are offered here:

Structural modeling – The Coast Guard, and Defense Research and Development Canada as well as numerous commercial shipowners are maintaining whole ship Finite Element Analysis models of their fleets as a means of monitoring structure and optimizing maintenance and emergency response. This process generally uses MAESTRO or related software (ABS SAFEHULL for example) that uses a super-element approach to economically model and load the whole ship. Multihulls are especially sensitive to cracking and it may be wise to either obtain a FEA model of the vessel from the builder (which would allow early optimization of structure) or to obtain one subsequently.[16]

3D CAD Product models – The Coast Guard, the Navy and many commercial ship owners are getting the Product Model that was used to design and build the vessel in the first place and adding links to integrate all aspects of vessels management and training. This uses Internet and video gaming tools to produce essentially a virtual ship. A user can click on an item of equipment and bring up links to manuals, maintenance records or even supply information. This is a rapidly evolving area of technology in all industries, especially consumer product lifecycle management and facilities management and the WTA is urged to keep an eye on developments. [17]

***The Return of the Mono***

Although multihulls have become fashionable for ferries, there may still be conditions in which monohulls are superior. Multihulls are not necessarily better than monohulls with regard to resistance, especially a slender monohull. A cat is better than the "equivalent" monohull assuming the two hulls are "squished" into one sideways, but quite inferior if they are squished into one lengthwise. Cats have an advantage of greater deck area per weight, but have more structural weight per payload weight, and tend to cost more per unit structural weight. They can have better roll motions, but can also develop severe snapping motions in adverse sea states. Slender monohulls don't tend to be treated kindly by the current U.S. tonnage regulations, though. In the case of a short run ferry where there is little need for passengers to wander about during the short duration passage, a slender monohull with "bus style" seating and roll stabilizing fins or tanks might be a very effective design, with lower first cost and lower fuel costs than a cat. (There are also a number of new roll stabilizing systems coming on line that use large gyros to actually produce roll resisting forces. Though gyros were occasionally used for roll control in the 30's, advanced materials and low friction bearings have made very high rotational speeds feasible and thus reduced the required rotating mass substantially.) This is an example of the type of study that is important to optimization of the whole system – would such a vessel result in reduced level of service as required for a given route? Would the reduced level of service be compensated for by reduced costs?

**Figure 8**

***Configurations for Best Efficiency at High Speeds***

Despite the inefficiency of high speed ferries compared to wheeled modes, there will be routes demanding high speed across water. Planing hulls, hydrofoils, air cushion vehicles and wing in ground effect are all candidates over various speed and size regimes.

Nature, however, gives us clear instructions for best efficiency at high speed over water: wing in ground effect.

Despite the incredible diversity and variety among biologically evolved systems, observe that there isn't a single species of animal that propels itself over water by planing.

We find abundant examples of waterfowl that travel in displacement mode as surface vessels, we have oceans full of fish moving fully submerged, and we even have examples of marine mammals that surf, although they do this from just below the wave surface.

There is, however, a huge variety of bird species, and a few fish, that use wing in ground effect. But aside from a waterfowl skiing to a stop from a water landing, there are no animals that plane. No biological analogs to hydrofoils or active air cushion support either, for that matter.

Why? Because when traveling fast at the interface between a dense medium (water) and a thin medium (air) it is far more efficient to get lift from the thin medium near the surface of the dense one, instead of the other way around. More specifically, hydrofoil efficiency degrades near the free surface, because downwash angles increase and induced drag increases along with it. A planing hull is subject to induced drag losses too, and is always bound by the limitations surface effects. But to the wing in ground effect, the water surface is for all practical purposes a solid wall, and it enforces a plane of symmetry. This suppresses downwash and reduces induced drag.

The fast ferry of the future will derive most of its lift from wind in ground effect, because when the technology matures this will prove to be the most energy efficient by a substantial margin.

***Propulsion Technology***

A large fraction of current waterjet applications would be more efficient with surface-piercing propellers. Unlike fully submerged propellers, surface-piercing propellers can be of arbitrarily large diameter and have arbitrarily large hubs, without hitting the bottom of the boat, the bottom of the ocean, losing efficiency from angled shafts or incurring a significant parasitic drag penalty.

Although they are still considered best for high speed race boats, the possibility of large diameters and deep reduction ratios means that the potential efficiency increment of surface-piercing propellers over other systems is greatest at medium speeds.[18] [19]

Deep reduction ratios and the large propellers and high torque drivelines that go with them are expensive, and first cost issues have kept this solution away from most of the market to date. But higher fuel costs are likely to boost the popularity of optimized surface-piercing propellers over waterjets. (Disclaimer - both authors are former employees of Arneson Marine, manufacturer of a surface-piercing propeller drive system).

Figure 8 shows an optimal biological solution: The flying fish uses wing in ground effect for lift, and a reciprocating surface-piercing propulsor for thrust.

Prime movers are likely to be spark-ignited natural gas or steam-injected natural gas-fired gas turbines. Both are uniquely suited to short runs where relatively bulky fuel and frequent refueling is not a major problem.

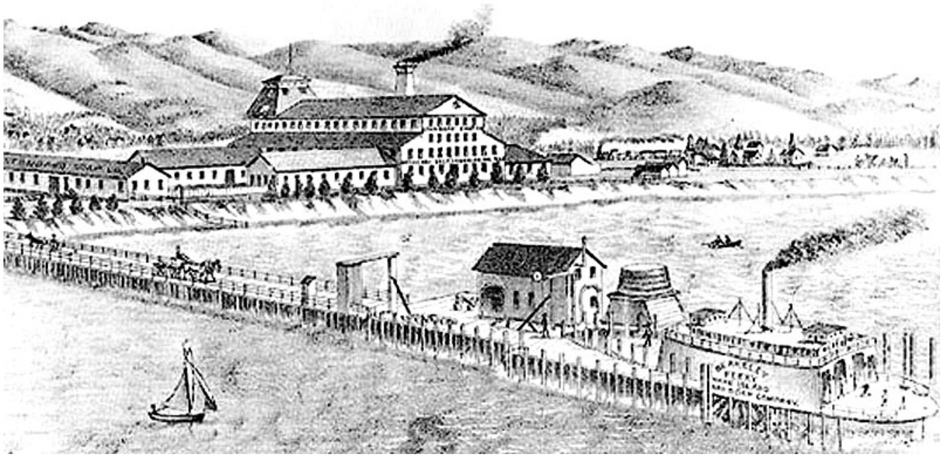


**Figure 9**

In the case of steam-injected turbines, a shoreside supply of purified feed water is important. But this is nothing new - consider the woodcut of Jacob's wharf, on the Berkeley waterfront, c. 1880 (Figure 9). Note the circular tank on the pier, presumably to supply feed water to the walking beam engine.

**Figure 10**

***Dual Mode***

Looking further into the future, our speculative crystal ball shows a return to the dual mode ferry. Bicycles are the immediate practical dual mode application, but electric scooters are not far behind if ferry operators decide to allow them.

Taking the paradigm to land transportation, many transportation academics are advocating "dual mode" vehicles as the most likely long-term reconciliation between the car culture and sustainability.[20] Dual mode promises the best of both worlds, providing the convenience and privacy of the auto, but attaining efficiencies comparable to rail when they enter a guide way and hook up with each other to form automated trains. One such system, developed in Denmark, is described in detail at http://www.ruf.dk/. Figure 10 shows what these vehicles and their guide way might look like.  Why is this important for ferries?

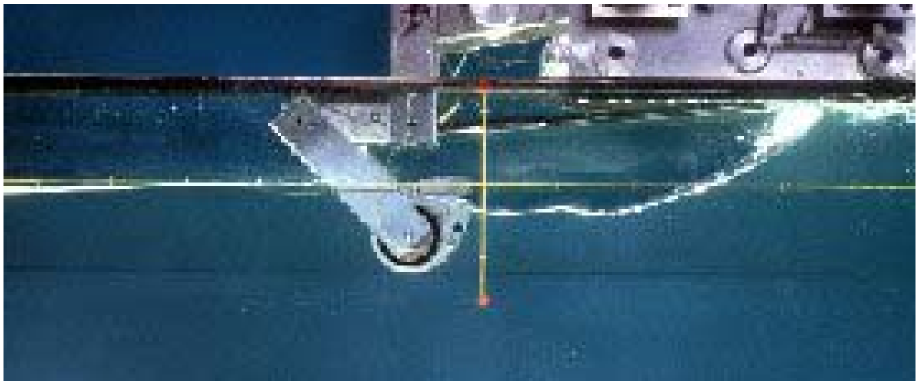


**Figure 11**

Dual mode vehicles are likely to be very compact, have uniform cross-sectional dimensions, nest very tightly front-to-back, and have the ability to be remotely and automatically driven with high precision, especially when on a guide way system. This means that a car ferry designed for these vehicles could carry them at much higher density and load them much faster, forwards or backwards, than conventional cars driven on and off by humans. Plus there are no clearances required for access because the passengers are out of the cars before they are boarded.

***Terminal Design***

At least half the capital cost (and probably more than half of the operating cost) of the system is in the terminal, especially the breakwaters. Much of the environmental "cost" is in the terminal as well. An interesting strategy to minimize these costs is innovative design of protection systems. Floating breakwaters may have been discredited in the Bay Area by Pier 39, but this was a system that was widely predicted to be a failure by real ocean engineering professionals. (A wave barrier has to have a resonance frequency in the range of what it is intended to absorb, otherwise it is transparent.)

The author would like to suggest that terminal breakwaters be designed to operate optimally in the band of wave energies between those that make boarding and other quayside operations dangerous and those that prohibit sailing at all (if you can't sail, there is no point in loading). In more sever sea states, the vessel can be moored off the quay where more motion is survivable. Determining the limits of boarding will require studies of the relative motions and accelerations of the ferry and the quay, and the limits of passenger movement, and the vessel motions induced by various sea states. (These limits might be extended by clever boarding system design (one of the authors worked on such systems for transferring between supply vessels and offshore oil platforms, and there are a number of interesting schemes.)

Once performance requirements of the breakwater is determined, then a floating system can be tuned to cover this band. Basically this simply requires that the ratios between the waterplane properties (area and momoments of inertia) and the underwater volume be selected correctly. One very interesting option here is to use "Salter's Duck" as a component. This device is an egg shaped cylinder, with the point facing the waves. The Duck "nods" – pitches - with the point rising and falling. This absorbs and reflects wave energy, but since the down wave end is round, no energy in pitch is transmitted through the device. These devices absorb as much as 85% of the wave energy. However, what is really interesting is that the Duck was invented not for coastal protection, but for alternative energy – the Duck contains a generator powered by the nodding motion. This means the terminal protection would also provide power. Though the use of these types of alternative energy schemes has always been limited by the capital cost compared to the value of the power they make, in this case we are saving the capital cost (and environmental impact ) of a traditional bottom founded breakwater, and getting energy in addition. Even if the energy doesn't amount to much, the symbolism is huge. Figure 11 shows a Duck being tested in a wave tank – note the amazing reduction in wave energy from the oncoming sea spectra (from the right).[21]

## APPENDIX A

**BTU/passenger-mile: Notes on the relative energy efficiency of ferries, cars, busses and trains**

There are several ways to calculate the fuel efficiency of a transit vehicle. Power can be measured at the engine flywheel, at the propeller or at the wheels, or as the chemical energy of the fuel consumed. Passenger-miles can be determined using any one of several assumptions about load level or the overhead of deadheading. For this analysis, BTU/passenger mile is based on the chemical energy of the fuel, approximated as 17,500 BTU/lb or 140,000 BTU/gallon for all liquid fuels. For diesel engines, a fuel rate of 0.35 lb/hp-hr is assumed.

Passenger loading for a commuter ferry, bus or train is assumed to be 50%, allowing for less then full passenger loads in the commute direction and very low passenger loads in the "reverse commute" direction. Home porting strategies can reduce the number of reverse commute runs, but this is offset by light passenger loading during mid-day service.

**Single-occupancy car:**
7,000 BTU/pax-mile
(assuming 20 MPG and 140,000 BTU/gal)

**AC Transit Bus:**
660 BTU/pax-mile one-way with 56 passengers
1,320 BTU/pax-mile at average 50% load.
(from http://www.watertransit.org/pubs/eir/Section3.13_Energy.pdf)

**Light Rail**
91 BTU/pax-mile, full passenger load
182 BTU/pax-mile, 50% load.
(from http://www.watertransit.org/pubs/eir/Section3.13_Energy.pdf)

**BART**
68 BTU/pax-mile, full passenger load
136 BTU/pax-mile, 50% load
(from http://www.watertransit.org/pubs/eir/Section3.13_Energy.pdf)

**Ferries currently in service between the East Bay and San Francisco**
"Peralta" - 3200 HP, 26 knots, 331 passengers
2,280 BTU/pax-mile, full passenger load
4,560 BTU/pax-mile, 50% passenger load

"Encinal" - 3600 HP, 24 knots, 388 passengers
2,370 BTU/pax-mile, full passenger load
4,740 BTU/pax-mile, 50% passenger load

"Bay Breeze" - 1285 HP, 26 knots, 250 passengers
1,210 BTU/pax-mile, full passenger load
2,420 BTU/pax-mile, 50% passenger load

"Express II" - 850 HP, 28 knots, 149 passengers
1,250 BTU/pax-mile, full passenger load
2,500 BTU/pax-mile, 50% passenger load

**Historical:**
Ferry "Berkeley" (1889) - 1250 HP, 12 knots, 1700 passengers
536 BTU/pax-mile, full passenger load
1,072 BTU/pax-mile, 50% passenger load (assuming fuel rate of 0.5 lb/hp-hr)

**Proposed:**
New design based on "Express II" with maximum speed 20 knots:
640 BTU/pax-mile, full passenger load
1,280 BTU/pax-mile, 50% passenger load (Reducing fuel consumption/mile by square of speed ratio.)

New design based on "Express II" with maximum speed 18 knots:
515 BTU/pax-mile, full passenger load
1030 BTU/pax-mile, 50% passenger load (Reducing fuel consumption/mile by square of speed ratio.)

## Appendix B

**Parking Lot Capacity in the Berkeley Marina**

| Spaces | Location |
|---|---|
| 25 | Circle at end of Spinnaker Way, Cesar Chavez Park |
| 77 | Northside Launch Ramp, Cesar Chavez Park |
| 161 | A - E Dock A-E Docks and overflow for Cesar Chavez Park |
| 495 | Doubletree Hotel |
| 105 | East Side of Marina Docks F-I |
| 200 | South Sailing Basin Windsurfing area |
| 105 | J - K Dock Docks J-K, Marina Adm. Bldg, Bait Shop |
| 115 | Southside Cal Sailing and Cal Adventures |
| 220 | L - M Dock Docks L-M, Berkeley Co., Corporation Yard |
| 133 | Skates Restaurant Skates, Horseshoe Park |
| 87 | N - O Docks, Yacht Club |
| 320 | HS Lordships Rest. HS Lordships, Shorebird Park Spinnaker Way |
| 65 | On-street Cesar Chavez Park |
| 90 | Seawall Drive (End of University Ave South of Berkeley Pier) |
| Total: | 2,198 |

SOURCE: Berkeley Marina Master Plan, Revised Draft 4/3/03.

Spaces that would directly serve a ferry terminal at the Berkeley Pier:

| | |
|---|---|
| Hs. Lordships: | 320 |
| Seawall Drive: | 90 |
| L-M docks | 220 |
| Skates | 133 |
| Total: | 763 |

Caption: Aerial photo showing parking within 300 meters of a possible terminal location just south of the Municipal Fishing Pier (a 3.7 minute walk at 3 mph).

In addition there are about 200 spaces of viable overflow parking at the South Sailing Basin, and 87 spaces at N and O-docks, although these will require another minute or two of walking.

Summary: We have about 1,000 spaces that could realistically serve passengers on the Berkeley Ferry. Hourly service by a 149-passenger ferry, assuming 80% arrive by car (from WTA study) and assuming that all cars are single-occupancy (worst case, neglecting multiple-passenger vehicles and "kiss-and-ride" drop-offs) and assuming full boats on three departures, results in an upper bound for parking demand of 358 spaces over the morning commute. Without these worst-case assumptions, the actual parking demand probably drops to somewhere around 300 spaces or less.

To avoid negative impacts on Skates and Hs. Lordships, it may be desirable to designate some spaces as 2-hour time limit for restaurant customers.

There appears to be no practical alternative for incorporating dedicated ferry parking. Multi-use is critical. The spaces used by ferry passengers during commute and working hours will be needed by restaurant customers in the evenings and Marina users on weekends.

A parking fee is desirable from a transportation planning point of view, but the close proximity of numerous other parking areas and the reliance by businesses, organizations and Marina users on these parking areas for all-day parking will make this very impractical. The same economic incentive can be achieved with a higher ticket price and a deep discount for bus transfers or bicycle riders.

*The views and opinions expressed herein are those of the authors and are not to be construed as official policy or reflecting the views of the U. S. Coast Guard or the Department of Transportation.*

*The trade names used are the property of their respective owners.*

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