MEETING ENVIRONMENTAL CHALLENGES *for Ferries*

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Passenger ferries are ready to take on an expanded role in the U.S. transportation system. To accomplish this, however, the ferry industry must meet several challenges associated with growth, including its impact on the environment. The research community and the shipbuilding and vessel operating industries must work together to meet the environmental challenges of ferry service expansion if they want to offer the American public an option for clean marine transportation. Developing the new technologies and methods to enable this option is an important goal on the transportation research agenda.

Capacity Demands

Ferries and Congestion

The principal reason that ferries are receiving increased attention is that transportation systems in many coastal urban regions are straining at the seams. This is particularly true for water crossings—bridges and tunnels are crowded for longer periods each day, and expansion is cost-prohibitive or politically infeasible.

Congestion has real costs. In its 1998 Regional Transportation Plan, for instance, the Metropolitan Transportation Commission (MTC) estimated that more than 100,000 person-hours are lost to congestion each workday in the nine-county San Francisco Bay Area; it projected that this figure would increase by more than three times during the next 20 years (*1*). Not only are person-hours lost, but so too are the rapid, reliable deliveries within the region and to the local air-freight hubs on which many businesses rely. With roads congested, businesses are finding it increasingly difficult to meet their time-sensitive shipping and delivery schedules. Growing regional populations and increased affluence alike tend to increase the demand for mobility and exacerbate roadway congestion.

Creating a new passenger-ferry service, or expanding a service, is a relatively easy way for regional transportation systems to increase their water-crossing capacities. In addition, ferry systems are much more flexible than fixed crossings, since operators can add and shift routes according to demand and can do this incrementally. Dedicated cargo ferries can add specialized capacity to the freight transportation system—cargo ferries can operate on routes, on schedules, and with fee structures optimized for freight movement without interfering with (or being compromised by) passenger modes. In this way, passenger and cargo ferry systems (ferry vessels plus terminals) can replace the need to expand a bridge and tunnel infrastructure.

Ferries and Mass Transit

Passenger ferries not only add water-crossing capacity but also are a form of mass transit. In many communities, mass transit (especially rail) is undergoing renewal and expansion because it reduces commuter trips in single-occupant vehicles and increases the transportation system capacity. However, successfully shifting commuters from personal car and truck to mass transit requires strong incentives. Since the most congested parts of transportation systems often are the water crossings, fast ferries can provide clear advantages. Yet mass transit systems also must be able to minimize the number and inconvenience of mode shifts, and this remains a key challenge for passenger ferries, which cannot provide door-to-door service.

In addition to faster, more direct water crossings, passenger ferries offer other benefits that should increase their status and attract commuters. Ferry transportation can be more enjoyable than other modes due to scenic views, the relaxation of

riding and not driving, and amenities not available on bus or rail, such as walking space, roomy seats, and food and beverage service. However, ferries also encounter the same mass-transit challenges as other modes, such as achieving time-efficient connections for modal shifts at terminals, so that people can transfer conveniently to or from cars or buses.

Other Challenges

A primary challenge for expanded ferry service is the design of a system that balances these premium-mode service advantages with basic mass-transit objectives, such as convenient access, low cost, and frequency of service. Many of the advances in this area will come from the design and operation of ferry terminals that serve as multimodal transit nodes, requiring adequate highway access and parking, and with feeder systems that transport passengers to and from the terminal and origin or destination, as appropriate.

Safety also is an issue. Adding many high-speed ferries to an already-crowded waterway may require new technologies and practices for managing maritime traffic.

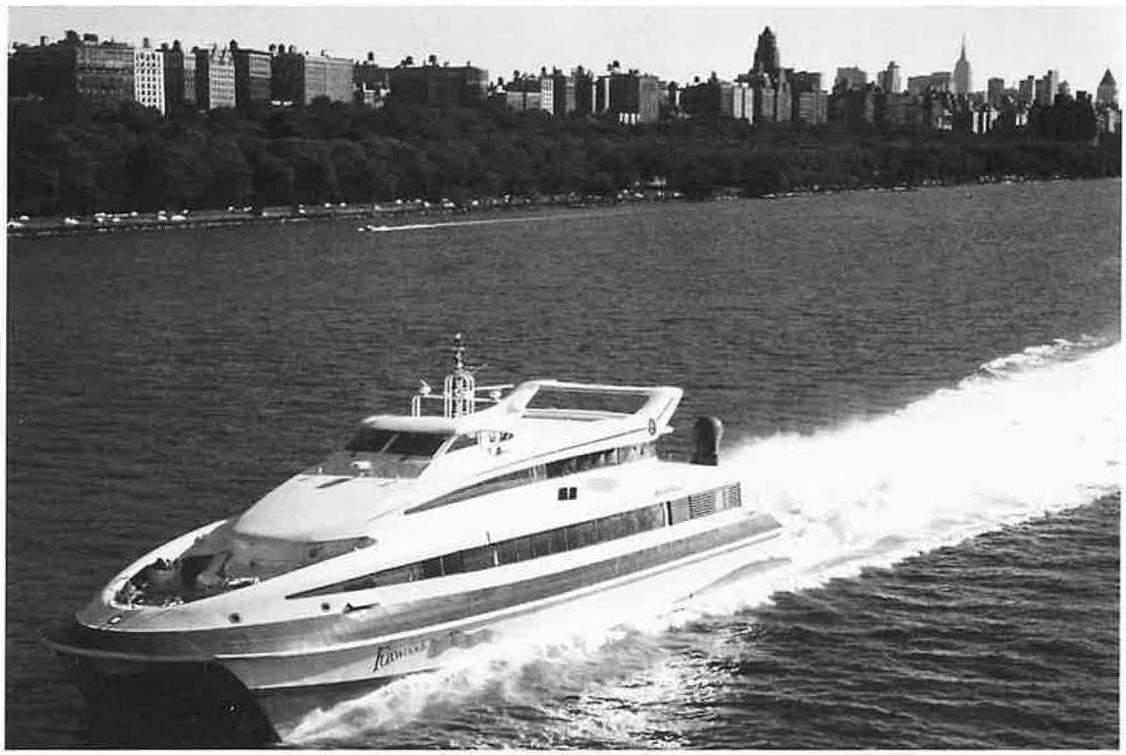
However, we must not think of the nation's waterways simply as potential highways. Increasing waterborne passenger travel also must be balanced with other significant uses, such as water recreation, aesthetics, environmental quality, and oceangoing freight transportation.

Environmental Impacts

Air Pollution

One of the biggest environmental issues facing the ferry industry is air pollution, a longstanding concern for all motorized vehicles. The typical pollutants are sulfur, nitrogen oxides (NOx), and particles (both coarse and fine). All of these affect human health adversely, particularly the health of children, elderly persons, and people with respiratory problems such as asthma. Over the past several decades, on-road vehicles have had to meet increasing controls on all of these pollutants. The toxic components of particulate matter (PM) released by diesel engines now are becoming a concern; the California Air Resources Board, for example, has declared diesel exhaust a toxic air contaminant and a potential carcinogen.

New York commuters rely on ferry service to get to work on time; expanding service may lead to increased safety management problems, especially as new technologies and practices are introduced.



Potential damage to land, property, and wildlife due to wakes is one of the environmental issues facing the ferry industry in deployment of fast vessels.

As regulatory agencies have identified and controlled the largest sources of pollution, smaller sources, such as ships, have gained attention. Marine emissions research funded by the Environmental Protection Agency (EPA) shows that after more than three decades of escaping the notice of regulators, U.S. shipping now accounts for about 1.4 percent of all U.S. NOx emissions, and 7 percent of nonroad NOx (2).

Marine engines currently produce higher emissions per power output than regulated on-road diesel engines. Estimates of average marine diesel engine emission factors are 12 to 17 g/kW-h, compared with an average of approximately 3 g/kW-h for current bus-fleet engines (*3,4*). Since these emissions are concentrated along navigable waterways, they can have significant local effects.

Similar research has shown that international shipping also affects coastal-area pollution and possibly contributes to global climate change (*5,6*). Although most maritime air pollution comes from freight traffic, passenger ferries represent an extremely visible and fast-growing presence, so that ferry emissions have become an important issue for the maritime industry.

Policy makers at both the federal and international levels are developing and implementing air pollution standards for ships. New ferries soon will have to meet emissions requirements; Table 1 compares current marine emissions standards with standards for comparable sources. All of these regulations, however, apply only to new vessels; engines already in use will continue to operate at high emissions rates. The long service lives of marine diesel engines (typically more than 20 years), coupled with growth in marine transportation, probably will increase marine emissions for the next several years despite the new regulations.

A trend of increasing emissions would cause problems for local air quality and transportation planners in major urban areas, which must reduce emissions, often by 15 percent each year. Most likely, planners will look at controlling in-use marine diesel engines as a relatively inexpensive way to meet this goal—it is easier to reduce emissions from an uncontrolled combustion source than from one that already has been controlled.

Landside Issues

Air emissions are not the only environmental issue for ferries. Also attracting attention from transportation researchers and the maritime industries are the landside impacts of ferry operations, such as the impact of increased traffic, noise, and air pollution on neighbors of proposed ferry terminals.

The dramatic increase in passenger-ferry service in some areas suggests that expanding current facilities (e.g., parking lots) will be too costly or even impossible due to space constraints and political opposition. Sustainable growth concepts applied to the transportation infrastructure may favor

expanded ferry systems, but land-use changes are rarely simple. Therefore it is necessary to consider passenger-ferry terminals as new transit system nodes, not just as berthing facilities.

Waterways Issues

In addition to these landside concerns, there are water-related environmental issues, particularly dredging, wake, and impacts on wildlife. Dredging might be necessary to provide safe channels for new ferry routes but it is always controversial, especially in older urban harbors with sediments that may be contaminated with industrial pollution from previous years. Wakes, especially from high-speed vessels, can cause or accelerate shoreline erosion, simultaneously damaging valuable property and speeding up the need for dredging. Finally, both noise and wakes from ferries can have a negative impact on wildlife, a major concern in some areas, such as Washington State.

Environmental Objectives

The U.S. ferry industry must establish two strategic objectives for meeting environmental challenges. The first is to integrate improvements in environmental performance into the modernization of ferry systems across the country. This includes reducing air emissions and mitigating other direct impacts from ferries. This will produce better ferries and ferry terminals that can provide the same level of service as today.

The second—and tougher—strategic objective is to make ferries part of integrated transportation system planning, by applying advanced technologies to increase capacity and improve environmental performance. This will require not only achieving a balance among the multiple uses of water resources but also attending to safety concerns, even while building more ferries and ferry terminals to meet demand. Teams of transportation professionals from industry, academia, and government, applying new research tools and methods, are needed to meet this second, tougher objective.

San Francisco Bay Ferries

Roadway congestion is at its most intense in fast-growing regions, such the San Francisco Bay Area, home to some of the nation's most longstanding air-quality problems and to some of its most congested traffic. The Bay Area also is the site of the highest-stake debate on ferry system expansion in

TABLE 1 Marine Emission Standards and Comparisons (g/kW-h)

Standard		Start Date	HC	NOx	HC+NOx	CO	PM
MARPOL Annex VI[a]	<130 rpm		—	17.0		—	—
	130–2000 rpm	2000	—	17.0–9.8		—	—
	>2000 rpm		—	9.8		—	—
EPA locomotive	Tier 0	2000–01	1.3	12.7		6.7	0.80
	Tier 1	2002–04	0.7	9.9		2.9	0.60
	Tier 2	2005	0.4	7.4		2.0	0.27
EPA on-road diesel engines	MD	2002			2.5		0.10
	HD	2002			2.0		0.10
EPA nonroad	Tier 1	2000	1.3	9.2		11.4	0.54
	Tier 2	2001–06			6.4–6.6	3.5	0.20
	Tier 3	2008–10			4.0	3.5	0.20
EPA marine diesel[b]	**Tier 1**	**2000**		**17.0–9.8[c]**			
	Tier 2	**2004–06**			**7.2**	**2.0–3.5**	**0.20–0.30**
	Tier 3	**2008–10**			**4.0–5.0**	**2.0–3.5**	**0.20–0.30**

Notes: HC = hydrocarbons; NOx = nitrogen oxides; CO = carbon monoxide; PM = particulate matter.
[a] MARPOL is the main international maritime treaty addressing air pollution from ships. When ratified, Annex VI will apply to all marine engines built after 2000.
[b] 40 CFR Parts 89, 92, and 94. *Federal Register*, December 11, 1998.
[c] All MARPOL requirements apply under EPA Tier 1 rules.

the country, a debate that is framing many of the most important research questions.

Bold Vision

More than a dozen ferries currently serve the Bay Area, operated by a variety of private and public entities. More than half of these are new high-speed (up to 34 knots) craft, with capacities of 250 to 400 passengers. The commuter lines carry slightly more than 11,000 passengers per day.[1] Fares cover 25 percent to 100 percent of the costs, depending on the route, and ridership on all routes has been growing over the last several years. Berthing capacity, however, is limited, with only 14 locations available, and connections to mass transit also are limited (7). As a result, the typical ferry commuter drives from home to the terminal, boards the ferry, and—after reaching the city—walks or uses other transit to the final destination.

The Bay Area's congestion spurred research by the Metropolitan Transportation Commission (MTC), which is currently responsible for administering ferry routes, and by the Bay Area Council (BAC), a group of local business leaders. Both groups called for the expansion of service but differed on specific recommendations. MTC recommended adding five new vessels to expand service on three routes but concluded that new ferry service was a lower priority than other improvements to the system (8). BAC was more visionary, calling for a "world-class system" of 125 high-speed and cargo ferries with 42 terminals, including airport and cargo facilities (7). The BAC plan would expand the number of riders vastly—to as many as 30 million riders per year.

The Bay Area is the site of the highest-stake debate on ferry system expansion in the country, a debate that is framing many of the most important research questions.

The BAC study covered many conceptual aspects of marine transportation, including route planning and terminal locations, operating cost estimates, and a plan for a new authority with public funding. However, the BAC study addressed only a few environmental issues for ferries, focusing mostly on the effects of terminal construction on wetlands and wildlife habitat, wake impacts on shorelines and wetlands, and the need for dredging. The report covered several landside issues related to the effects on surrounding properties, including potential problems for neighboring communities due to the increased traffic. Nonetheless, in its February 1999 report, BAC gave little consideration to air pollution, claiming without substantiation that there would be an "apparent" improvement in air quality when commuters opted for ferries instead of cars.

Environmentalists Sound the Alarm

The environmental community was quick to respond. In July 1999 the Bluewater Network issued a report highly critical of the environmental performance of passenger ferries (9). This study, however, relied on limited data[2] and simple calculations; it claimed that emissions from uncontrolled marine diesel engines could be 6 to 10 times greater than highway modes on a passenger-mile basis. In particular, the study showed that newer-model diesel and natural-gas transit buses could be much cleaner replacements for automobile trips than older ferries.

This conclusion should have been no surprise. The environmental performance of on-road vehicles is the result of emissions regulations, and marine engines are unregulated; no one had yet suggested low-emission ferries.

As Bluewater Network admitted in the first sentence of its study, the analysis was only a first step in understanding ferry emissions. The main point was not to declare ferries a lost cause, nor to offer potential engineering solutions, but to demonstrate the need for further study of the impacts of ferries on air and water quality before expanding service. They added momentum to ongoing research into emissions from marine transportation.

Although the government and private transportation sectors already had begun addressing concerns about marine air pollution even before the Bluewater study attracted national attention, the study proved controversial and acted as a wake-up call for ferry advocates. Throughout the summer of 1999, news reports and editorials about ferry emissions appeared in newspapers across the country, making air pollution the primary environmental issue for ferries.

Industry Response

In direct response to the Bluewater Network claims, the Maritime Administration (MARAD) and the Society of Naval Architects and Marine Engineers (SNAME) began to compare emissions from ferries and other transit modes. The Trans-

[1] Tour ferry routes (e.g., to Alcatraz) draw fewer than 2,000 passengers daily, but like tour buses, they are not considered mass transit.

[2] The few published sources of marine emissions profiles focus on oceangoing vessels.

Marine Fuel Cell Under Development

The U.S. Navy and Coast Guard are performing research and development on a diesel-fueled 625-kW fuel cell prototype for marine use. Fuel cells offer lower fuel consumption, reduced emissions, and lower thermal and acoustic signatures compared with conventional naval power plants. As petroleum supplies become more expensive, fuel cells can run on such alternatives as natural gas, methanol, and hydrogen. However, there are technical challenges, such as developing a reliable desulfurizer and onboard fuel reformer, reducing overall plant size, and designing components that can be mass produced to reduce cost.

The services evaluated two systems, one using polymer electrolyte membrane and the other molten carbonate (MC) fuel cell technologies. They selected the MC system, from Fuel Cell Energy Corp., for further naval development; the prototype completion is scheduled for 2003. Target size and weight are <2 ft^3/kW and <40 lb/kW, respectively, and target fuel consumption is <170 g/kW-h. The prototype system will be suitable for use as a ship service generator or for powering an electric propulsion motor. With marine demands for electric power increasing, fuel cells may emerge as an important energy resource.

—Information from USCG Research and Development Center

Testing for reduced sulfur at Marine Fuel Test Facility, Groton, Connecticut.

portation Research Board's Committee on Ferry Transportation sponsored a panel session at the 79th Annual Meeting in January 2000 to discuss environmental issues for ferries; the panel included representatives of BAC and the Bluewater Network. Under the SNAME Ship's Machinery Committee, an Ad Hoc Ferry Transit Environmental Impact Panel prepared a summary of the issues raised by Bluewater. Ongoing engineering studies are reevaluating the emissions comparison between ferries and buses; these studies apply updated and detailed assumptions (including current engine and emission control designs) as well as an on-road emissions model used by the California Air Resources Board.[3]

Currently, all of these calculations agree that on a per-passenger-mile basis and under assumptions similar to those of the Bluewater study, uncontrolled emissions from marine diesels could be several times greater than heavily-regulated on-road diesels.[4] However, these studies also pointed out that ferries with emissions controls could perform as well as or better than other mass transit modes.

Each of these studies went on to consider alternative ferry systems, such as new engines that comply with EPA and international emissions limits, control technologies such as selective catalytic reduction, or alternative fuels and propulsion combinations. They showed that emissions control technologies were available, technically feasible, and more affordable than many expected. These analyses strongly suggested that the ferry industry could meet the challenge of achieving low emissions.

The most direct response to the Bluewater study was the formation of the Clean Marine Opportunities Partnership, a consortium of groups in the Bay Area. This group is planning to develop, test, and commercialize new ferry technologies that meet air quality and other environmental goals, enabling the expansion of ferry service in the Bay Area and nationally.

Another important response to the Bluewater study was the ferry legislation passed and signed into law in California last year; it provided clear instructions for an environmental assessment. Sponsored by State Assembly member Don Perata, the legislation (SB-428) allowed for the creation of a new authority along the lines suggested by BAC. However, the ferry expansion was contingent on positive findings from safety and air quality studies. In conjunction with these studies, Governor Gray Davis recently proposed a pilot project of several low-emission ferries as part of a larger transportation expansion plan.

Research for Clean Ferries

Although a lot of confusing smoke and noise has been generated about the environmental impacts of

[3] *Methodology for Estimating Emissions from On-Road Motor Vehicles, Vol. I, Introduction and Overview.* California Air Resources Board, October 1996. (Cited in MARAD draft report.)

[4] Later reports use more detailed assumptions and initial results conclude that emissions from unregulated ferries are 2 to 5 times greater than from heavily-regulated on-road diesels, not the 6 to 10 times difference cited by the Bluewater Network.

ferry service in the United States, and there is much still unknown, the key implications are clear:

1. The debate should not be about ferries versus other mass transit—but about how to integrate marine passenger and cargo service into the transportation systems of growing coastal regions.
2. Ferries and their supporting infrastructure can have significant environmental impacts, but these are not necessarily better or worse than the impacts of other modes—engineering and operational choices will determine the scope and scale of these impacts.
3. An integrated analysis of increased ferry service in a transportation system is necessary, including a comprehensive study of emissions and of all potential options, such as suburban feeder bus systems and multimodal terminals.
4. There is no single right answer for ferries—fast catamarans are not always better than traditional 25-knot monohulls. It depends on the route—the best system for the San Francisco Bay will not be the best one for New York or for Seattle.

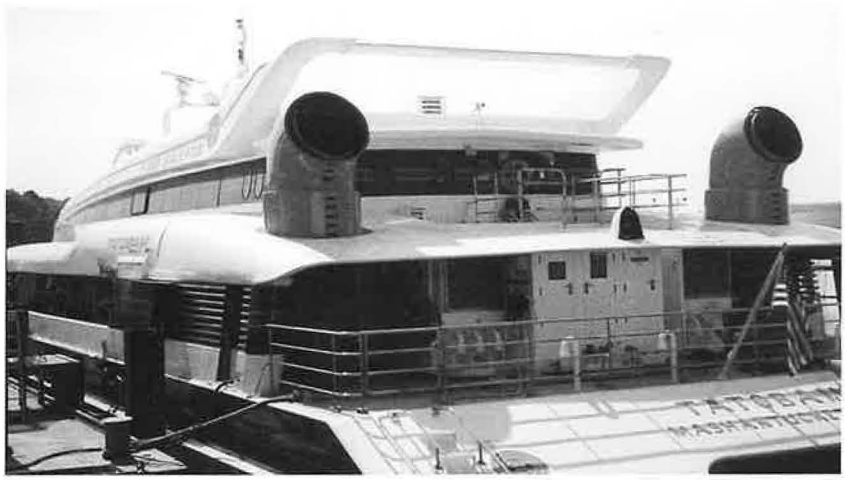
Improved Engines and Fuels

The pressing need for reduced air emissions from ferries, combined with the long life of marine engines makes it necessary to consider methods that can reduce emissions from the engines now in use. The ferry industry must go beyond current environmental regulations to assure its future success.

The technical difficulties are not daunting; in the near term, ferries can employ traditional air-pollution controls, such as selective catalytic reduction systems, water injection (direct, through emulsions with fuel, or through air humidification designs), and advanced engine control systems. Marine engine manufacturers are offering these technologies on new construction in the international ferry market.

Cleaner marine diesel fuels also should be considered. Lower-sulfur diesel fuels not only reduce PM emissions directly but also enable the use of advanced catalysts that reduce NOx. However, technological improvements should focus on developing effective and affordable emissions control equipment for retrofits.

But the greatest difficulties will be in policy and economics; the current thinking—reflected in the current regulations—is that only new vessels need to be controlled. In some cases, there may be enough political resolve to require retrofits, but a better approach would be to offer incentives to vessel owners. This would entail emissions reduction credits or public funds to sponsor emission control programs. Moreover, economic incentives often spur technological innovation, which pays long-term dividends.



Fast ferries have introduced high-tech look. These vessels are incorporating advances to decrease air pollution and minimize wakes.

Low-Emission Ferries

Although incremental improvements to vessels will be needed in the short term, ferries will need new technologies with dramatically improved environmental performance to be competitive in the future. Expanded passenger-ferry service will be possible only if it improves—or at least does not degrade—environmental quality, and ferry expansion always will be compared with potential expansions of other transit modes, such as buses or rail, which also will continue to become cleaner. Although meeting EPA standards would reduce ferry emissions, this will not suffice—ferries will have to go well beyond current emissions standards to realize their potential.

Ferries will need to run on engines with optimized emissions controls, including some traditional marine propulsion systems such as gas turbines and diesel-electric drives. However, to drive emissions as low as possible, ferry operators must look at new core technologies that have low air pollution emissions and are reliable and cost-effective.

One promising possibility is to deploy an entirely new class of ferries that operate on gaseous

Kings Pointer Tests Conversion to Natural Gas

The U.S. Coast Guard (USCG) and the Maritime Administration (MARAD) are collaborating in a ONE DOT effort to convert the diesel–electric generators on the *Kings Pointer*, one of the U.S. Merchant Marine Academy's training vessels, to operate on a mixture of compressed natural gas (CNG) and diesel fuel. This initiative seeks to improve air quality in major port cities, anticipating stringent air quality standards from state and federal regulatory agencies.

CNG burns cleaner than diesel in an engine without emissions controls and can reduce engine maintenance costs. A successful conversion would help the federal government both reduce its dependency on petroleum from foreign sources and meet strict air quality standards. MARAD is working closely with USCG's Marine Safety Center to identify and resolve safety and regulatory issues that pertain to the storage and use of CNG as a marine fuel.

Tests of the *Kings Pointer* will establish the emissions reduction and also determine the life-cycle costs of the converted engine. The results of this study will be useful to commercial ship and ferry operators in metropolitan regions that already have an infrastructure for CNG fueling.

—Information from USCG Research and Development Center

fuels, particularly natural gas.[5] These are inherently clean fuels that do not contain hard-to-remove contaminants such as sulfur and that burn much cleaner than marine diesel fuels, especially in terms of soot. In addition, natural gas is less expensive than diesel fuel in many places and the high consumption by faster ferries can more easily cover the capital costs for both fueling infrastructure (e.g., the compressor) and onboard storage. Also, the reduced noise and vibration of natural gas engines should appeal to passengers and waterfront residents. Moreover, natural gas improves the fuel diversity of the transportation system and reduces the need to import petroleum.

Natural Gas Research

Recently, the U.S. Department of Energy's Clean Cities Program and the Gas Research Institute funded a project to look closely at natural gas as a fuel for ferries. This research showed that substantial reductions in many emissions categories were possible by switching from diesel fuel (*10*). Moreover, it showed that these reductions were cost-effective compared with emissions reductions from other sources, such as highway improvements or even power plants. But it also showed that considerable work is still needed in measuring marine diesel emissions.

Ferries are perhaps better suited for natural gas than are cars and light-duty vehicles. Because gaseous fuels are less dense than liquid fuels, storing energy-equivalent amounts on board imposes space and weight penalties in vehicle design. In automobiles, this translates into less space (typically less trunk and passenger room), slower acceleration, and a reduced range for similar-sized vehicles. But consumers value the attributes of spaciousness, speed, and range (*11*). Moreover, consumers expect and rely on a ubiquitous fuel infrastructure to support their mobility; this, too, makes the introduction of alternative fuels difficult.

Both the performance and fueling problems are smaller issues for ferries, which typically fuel at a central location (often the berth); moreover, the large volume and the regularity of the fuel demands are attractive to natural gas suppliers, encouraging investment in a refueling infrastructure. Further, research shows that the most important benefit of converting fuels is the publicity from using a "green" fuel—although this affects consumer choice only somewhat, it may be important to ferry operators seeking positive public awareness (*12*).

Responding to Climate Change

During the time that the San Francisco Bay ferry system develops (assuming it goes forward), minimizing climate change likely will become a key national policy goal. The principal challenge is to reduce emissions of fossil-derived carbon dioxide from the world's energy systems. Because of the growth in energy use worldwide, the U.S. transportation system will need to reduce drastically its carbon dioxide (CO_2) emissions on a per-mile-traveled basis by midcentury. There are two main paths: using renewable carbonaceous fuels (e.g., ethanol or biodiesel) or using an energy carrier produced without releasing CO_2 (e.g., electricity or hydrogen).

A significant recent development is the discovery of a potentially low-cost method of carbon-free hydrogen production—the capture and sequestration of CO_2 in conjunction with the standard steam reforming of natural gas. Size matters for this technology—both hydrogen production and CO_2 sequestration favor centralization. All of the advantages noted for natural gas-centralized fueling and fewer space and acceleration constraints—also apply to hydrogen as a ferry fuel. In addition, ships'

[5] Biofuels such as ethanol or biodiesel provide some of the same benefits as natural gas, but are more expensive—unless subsidized—and involve a host of production-related issues.

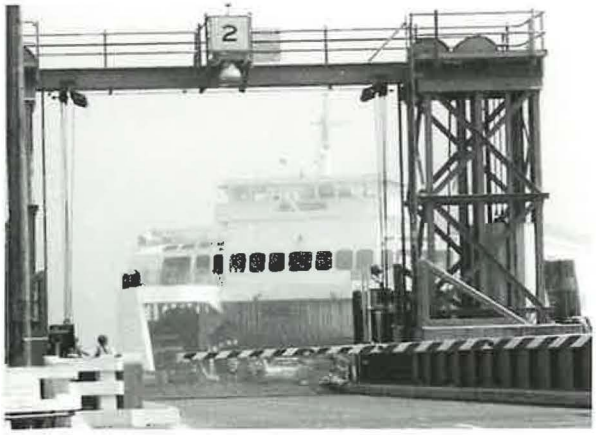
intense operational patterns can offset higher capital costs relatively quickly through lower operational (i.e., fuel) costs. In the long term, the development of designs and procedures to use natural gas will prove relevant to the deployment of ferries fueled by carbon-free hydrogen.

Hydrogen fuel also enables the use of fuel cell propulsion, which would eliminate air pollution and engine noise from ferries. However, it is conceivable that carbon-free hydrogen also could be used in a reciprocating engine. In either case, ferries could become the first true zero-emission vehicles.

Whole System Research

Meeting the environmental challenge for ferries is not about air emissions alone. Similarly, meeting the air pollution challenge for ferries is not about engines alone. In addition to addressing marine engines as the source of air emissions, transportation researchers need to consider the whole ferry system. Design choices in subsystems that do not directly involve the engines also can affect emissions reductions or increases. These research issues include the following:

- Hull form choices. Though specific to application and speed, these also determine the power and fuel requirements, which in turn are proportional to the emissions rates. In addition, naval architects should consider designs that address other important environmental issues, such as wake damage.
- Innovative terminal designs to improve passenger loading and unloading, including parking, and to reduce ferry turn-around-time. These terminals can be multimodal mass transit facilities connecting ferries, buses, and rail, similar to some international systems.
- Developing and improving a fueling infrastructure for low-emission alternative fuels (e.g., biodiesel, natural gas) for an expanding ferry system. This infrastructure may serve ferries only, or it may include other marine vessels in the region. In either case, research is needed to ensure that the fuel infrastructure responds to systemwide requirements safely.
- Understanding the delays associated with modal transfers and assessing the related environmental impacts (e.g., idling vehicles in parking lot queues).
- Comprehensive vessel safety and ferry traffic risk assessments to accommodate row boats, canoes, windsurfers, and pleasure craft on a bay with high-speed ferry crossings. Many recreational users do not listen to vessel traffic service broadcasts; maintaining safe distances while crossing the bay at high speeds may be the responsibility of the ferries or commercial vessels.
- Improved understanding of what promotes or inhibits ridership in all mass-transit modes. The course ahead involves more than the "field of dreams" approach—building a system and hoping the passengers will come. Moving the lone commuter out of the car and into any form of mass transit remains a challenge.

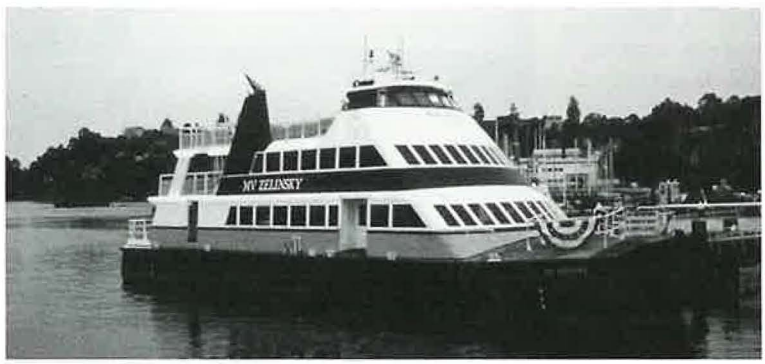


Environmentalists have raised questions about effect of increased ferry service on air and water quality and have called for further study.

Meeting the Challenges

The U.S. transportation industry can provide world-class ferry service to increase urban transit capacity and mitigate environmental damage. Ferries offer many advantages to commuters, as long as the system is accessible and meets basic transit needs. Although all projected transportation expansion costs are sizable, ferries may provide more capacity per dollar than additional highways and bridges.

However, achieving this objective requires the collaboration of the public, researchers, and industry to pursue near-term and long-term options in a context of integrated mass transit. This will require



Closely-watched ferry fleets in the San Francisco Bay Area, like Blue and Gold (*left*) and Vallejo Baylink (*above*), have an opportunity to convince opponents that ferries can increase urban transit capacity and mitigate environmental damage.

an understanding of the transportation choices facing commuters and businesses, and designing the right mix of ferries and other modes. The ferry industry has an opportunity to help meet all the transportation challenges, environmental and otherwise, in the coming decades.

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Related Websites

Bay Area Water Transit Initiative:
http://www.bay areacouncil.org/ppi/tpt/4lv_ wti1.html

Bluewater Network:
http://earthisland.org/bw/ferryreport.shtml

California Air Resources Board:
arb.ca.gov/homepage.htm

Clean Marine Opportunities Partnership:
www.calstart.org and www.ganainc.com

Gas Research Institute:
www.gri.org

Natural Gas Vehicle Infrastructure Working Group:
www.gri.org/iwg