Table 9. Annual benefits, scenario 1.

Transshipment Cost ($/ton)	Throughput by Supply Region (tons 000 000s)			Benefits ($000 000s)		
	CPA	SWVA	EKY	CPA	SWVA	EKY
1.0	23.50	27.44	26.51	9.6	9.6	9.2
1.5	18.27	22.87	21.95	9.6	9.6	9.2
2.0	13.60	18.10	17.42	9.6	9.6	9.2
2.5	9.25	13.80	13.30	9.6	9.6	9.2
3.0	5.01	9.47	9.03	9.6	9.6	9.2
3.5	0.62	5.13	5.01	9.6	9.6	9.2
4.0	0.00	0.79	0.75		9.6	9.2

northeastern utilities for providing valuable insight regarding the industry viewpoint on issues discussed here. We are also grateful to the personnel of coal bureaus of the various railroads used in this analysis for providing necessary rate information and to the planning staff of the Port Authority of New York and New Jersey for added useful information. Finally, we would like to thank our typist, Alice Frolo.

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Physical and Operating Characteristics of Ferry Vessels

ARNOLD J. BLOCH

The state of the art of ferry-vessel technology, including conventional slow-speed ships and high-speed ships, is discussed. The latter models, although used regularly in Europe and Canada, have had limited operating experience in the United States. Important vessel features are highlighted, including passenger and vehicle capacity, engine and propulsion systems, hull design, speed and steering control, docking procedures, and passenger amenities. Conventional low-speed diesel-powered vessels consume less energy than their high-speed gasoline turbine counterparts. On the other hand, high-speed vessels offer service-quality capabilities that are highly competitive with automobile commutation. However, there has been little opportunity to demonstrate the advantages of high-speed vessels, mainly because of legislative restrictions.

Ferry systems operate within diverse environments and serve different types and levels of passenger, vehicle, and even freight demands. Consequently, there is a wide range of vessel types now in operation. However, one generalization can safely be made concerning vessels currently in operation in the United States and Canada: Most rely on long-established and conventional sources of power and propulsion and as such are not high-speed ships. That is, most cannot achieve a speed greater than 20 knots (23 mph). Despite the existence of hydrofoils, hovercraft, and surface-effect ships, which can achieve speeds greater than 40 knots (46 mph), use of these high-speed craft is confined to service in Europe and the Far East, as well as to American military programs. In fact, the Golden Gate Ferry in San Francisco is the only system in this country that relies on relatively high-speed vessels, and they achieve a cruising speed of only 25 knots (29 mph).

There are a number of reasons that American ferry systems do not use high-speed craft, some of which are listed below:

1. Many ferry-route distances are relatively short;
2. Longer ferry routes normally serve vehicle as well as pedestrian demand, which requires larger ship dimensions than most high-speed craft now offer;
3. Many ferries operate in heavily used waterways, often against the normal stream of ship traffic, which mandates lower operating speeds; and
4. Many high-speed craft (especially hovercraft) are foreign-built and thus prohibited from U.S. service by the Merchant Marine Act of 1920 (Jones Act).

However, a number of factors make it likely that high-speed vessels may see future domestic service. First, U.S. manufacturers have built and operated both hydrofoil and surface-effect ship prototypes, some of which are in operation elsewhere in the world. Second, planning objectives in urban areas may evolve, as they have already in San Francisco, from using ferries as bridge substitutes between key highway, transit, or pedestrian links into using high-speed craft to provide a competitive alternative commuter mode to the automobile between the central city and outlying areas. For such a plan to be feasible, the ferry would have to duplicate a number of automobile characteristics, among them speed (i.e., travel time). Third, the pedestrian-only feature of most high-speed craft fits in well with both urban (and recreational) area goals of reduction in automobile use, especially during peak-demand hours.

This paper presents a state-of-the-art exposition of ferry vessels available for current use. It discusses both conventional (slow-speed) vessels, which are widely used in this country, as well as high-speed ships, which, although their deployment is limited in the United States, represent products of available and fully tested technology. The objective of this paper is to provide a compendium of vessel information for the urban transportation planner who has little information and virtually no systematic procedure for considering the waterborne alternative for passenger transportation.

Important features of ferry vessels are highlighted in this effort, specifically, vessel functions, engine types and propulsion systems, hull design, vessel-control mechanisms, docking procedures, and passenger amenities. Tables 1 and 2 may be consulted for a summary of key physical and operating characteristics of selected slow- and high-speed vessels.

VESSEL FUNCTIONS: PASSENGER-VEHICLE MIX

Slow-Speed Ships

Slow-speed vessels can carry pedestrians only (normally carry-on bicycles are allowed, too), pedestrians and passenger cars, or pedestrians and a combination of vehicle types that includes passenger cars, recreational vehicles, small trucks, tractor-trailers, and buses. Vehicular and pedestrian capacity vary widely, but some notable examples are mentioned below:

1. The largest pedestrian-only ferries will operate soon for the Staten Island Ferry in New York City. These vessels, now being built, will be more than 300 ft long and will carry about 6000 seated and standing passengers.
2. Ferry vessels that are larger but have less passenger capacity operate in limited settings. They are between 300 and 450 ft long and carry between 1500 and 2500 passengers and between 160 and 460 automobiles.
3. Typically, most vessels between 200 and 300 ft in length carry no more than 100 automobiles and 1000+ passengers; the existing Staten Island Ferry vessels are the major exception (i.e., they are nearly 300 ft long and their automobile capacity is less than 60 but their passenger capacity exceeds 3500).
4. Many small vessels (around 100 ft long) operate in mainland-to-island services throughout the United States and Canada. They normally carry less than 200 passengers and fewer than 30 automobiles. The Vancouver SEABUS, however, is a very efficient small ferry vessel. Shown in Figure 1, it is only 112 ft long but carries 400 persons (but no vehicles).

High-Speed Ships

Those high-speed ships in domestic operation or running on a test basis in the United States are vessels for pedestrians only. In San Francisco, relatively small vessels (165 ft long, less than 100 gross tons) can hold an unusually high number of passengers (750) because of minimum engine size and slight hull submergence and despite the use of oversized airplane-type seating. On the other hand, the Boeing Jetfoil, a fully submerged hydrofoil that cruises at 43 knots (50 mph) seats only about 240-260. Similarly, the other American-made high-speed craft, the Bell-Halter surface-effect ship, which cruises at 40 knots (46 mph) in calm waters and is only 110 ft long, has a capacity of approximately 240.

Hovercraft, also known as air-cushion vehicles, operate across the English Channel at capacities of between 90 and 250 persons, and some hold as many as 60 subcompact automobiles. The Bell Aerospace Canada AL-30 has been designed to hold 200 passengers (but no vehicles) while it cruises at 41 knots (47 mph).

ENGINE TYPES AND PROPULSION SYSTEMS

Slow-Speed Ships

Virtually all slow-speed vessels are diesel-powered, since they provide for adequate operating speeds while consuming less fuel than the gas-turbine-engine alternatives. In addition, diesel fuel has traditionally been a cheaper fuel than the jet fuel used in gas turbines, because fewer refining steps are required.

Diesel engine power is normally converted into forward thrust by marine propellers mounted below the water surface to a shaft driven by the engine or engines. Although the prime objective of marine propellers is to produce vessel thrust, they can also be used to increase overall maneuverability. Added vessel guidance is important in order to avoid the busy ship traffic found in urban harbors that often cuts across ferry routes. There is also a large amount of debris to be avoided in these urban harbors. But the main advantage is during docking, especially on quick-turnaround routes in which this procedure must be handled quickly and smoothly with minimum damage to the ship or the dock. The problem is that, during docking, the vessel is operating at a very low speed and thus fine directional changes by using a rudder in conjunction with propeller thrust are nearly impossible to make. As a result, some vessels (e.g., the Staten Island Ferry) literally have to crash into the dock's retaining walls in order to straighten themselves for final docking, which causes significant damage over time.

Three propeller systems have been used to provide the added maneuverability. All are similar in that the positioning of the propeller blades can be altered from their typical fixed mounting onto the drive shaft. This allows engine thrust to be redirected quickly and can be accomplished at very low speeds, whereas shifting the rudder gives only marginal response at low speeds. These three propeller systems are as follows:

1. Controllable- (or variable-) pitch propeller: This propeller resembles a conventional screw propeller, except that the angle (or pitch) of the blades can be altered during operation from the pilot house.
2. Rotating propellers: As used on the Vancouver SEABUS, the shaft to which a conventional screw propeller is mounted can be rotated 360° around its axis. Positioning four such propellers on the corners of the boxlike SEABUS vessel allows the pilot to maneuver the ship into a docking area that has only a 1-in lateral clearance on each side.
3. Cycloidal propeller: The ultimate in maneuverability, as well as in capital and operating expense, the cycloidal propeller is unlike traditional screw propellers. Blades are attached to the perimeter of a disk that faces downward, and the disk then rotates around a shaft. The blades can be shifted in any direction, which allows propeller thrust to be varied uniformly and sensitively in any direction. New Staten Island Ferry vessels will be equipped with these propellers; this will be their first appearance on domestic ferry ships. As with the rotating propellers in the Vancouver SEABUS, their use eliminates the need for a rudder and steering gear.

High-Speed Ships

In contrast to their slow-speed counterparts, virtually all high-speed ships are powered by gas-turbine engines. (The surface-effect ship is the one exception, to be discussed later.) These engines are lighter and more compact than diesels, a key factor for the smaller high-speed vessels. In San Francisco, for instance, the decision whether to use gas turbines or diesels for high-speed performance of relatively small ships (less than 100 gross tons) proved to be simple. In order to provide the equivalent 8400 total hp necessary to achieve a 25-knot cruising speed, high-performance diesel engines that weigh more than 40 times more and occupy five times more space than gas-turbine engines would have had to been used. This would have drastically reduced seating capacity.

On the other hand, gas turbines consume fuel at a greater rate than diesels, and the cost of the fuel

Table 1. Physical and operating characteristics of selected conventional (slow-speed) ferry vessels.

Vessel and System	Vessel Length	Passenger Capacity	Vehicles (no. automobile-equivalent)	Engine Type	Propulsion System	Maximum Speed (knots)	Hull Type	Docking and Loading Procedures	Crew Size	Vessel Cost[a] ($000 000s)
Large vessels										
Staten Island Ferry; New York City; under construction	310 ft	5748[b]	0	Diesel	Cycloidal propeller (two)	18.5	Steel displacement hull	Double-ended berthing and passenger loading	13	16
Washington State Ferry; Superferries, Seattle, Washington; built 1967	382 ft 2 in	2500	160	Diesel	Fixed propeller (one fore and one aft)	18	Steel displacement hull	Double-ended berthing and vehicle/passenger loading	19	6
Mid-sized vessels										
Cape May-Lewes Ferry; Cape May, New Jersey; built 1974	310 ft	800	100	Diesel	Fixed propeller (twin-screw)	15-16	Steel displacement hull	Single-ended berthing but double-ended vehicle/passenger loading	9	3.9
M/V le Conte, Alaska Marine Highway; Juneau, Alaska; built 1974	235 ft 9 in	250	47	Diesel	Fixed propeller (twin-screw)	16.5	Steel displacement hull	Single-ended berthing; vehicles load via stern door or side doors	24	5.5
Small vessels										
Vancouver SEABUS; Vancouver, British Columbia, Canada; built 1977	112 ft 6 in	400	0	Diesel	Rotating propellers (twin-screw, one fore and one aft)	15	Aluminum catamaran	Double-ended berthing; passengers load from sides	4	4
Robert Noble, Washington Island Ferry Line; Washington Island, Wisconsin; built 1979	90 ft	175	18	Diesel	Fixed propeller (twin-screw)	9	Steel, flat-bottom hull	Single-ended berthing but double-ended vehicle/passenger loading	2	0.7

Note: 1 knot = 1.15 mph.
[a]At year of completion. [b]Of which 3721 may be seated.

Table 2. Physical and operating characteristics of selected high-speed ferry vessels.

Vessel and System or Manufacturer	Vessel Length	Passenger Capacity	Engine Type	Propulsion System	Additional Lifting System	Maximum Speed (knots)	Fuel Consumption at Full Speed: Gallons per Hour	Fuel Consumption at Full Speed: Gallons per Passenger Hour[a]	Hull Type	Docking and Loading Procedures	Crew Size	Vessel Cost[b] ($000 000s)
Golden Gate Ferry; San Francisco, California; built in 1978	164 ft 4 in	750	Gas turbine	Waterjet propulsion (one unit/engine)	None	30	642	0.85	Aluminum, semiplaning	Single-ended berthing; side loading of passengers via gangways	10	8
Boeing Jetfoil; hydrofoil vessel built by Boeing Corp., Seattle, Washington, in 1977; operated on test basis by Washington State Ferry, currently operated on English Channel	90 ft	242-420	Gas turbine	Waterjet propulsion	Fully retractable foils	43+	540	2.23-1.29	Aluminum, semiplaning; rides either hullborne or on single front foil and double rear foil	Berths as conventional hullborne vessel; side loading of passengers via gangways	4-6	10.5
Bell-Halter surface-effect ship; built by Bell Aerospace Textron and Halter Marine, Inc., New Orleans, Louisiana, in 1978; operated on test runs only	110 ft	240	Diesel	Fixed propellers (twin-screw)	Fans mounted below deck create air cushion between side walls and flexible fore and aft seals	40+	176	0.73	Aluminum box-shaped hull resting on catamaran side walls; elastomer seals fore and aft	Berths as conventional hullborne vessel; side loading of passengers via gangways	4	6
Air-cushion vehicle (hovercraft); AL-30 model built by Bell Aerospace Canada, in 1970s	76 ft 3 in	200	Gas turbine	Variable-pitch propellers	Two fans mounted on deck create air cushion within flexible seal around hull perimeter	56	262	1.31	Aluminum flatbed hull with elastomer seal completely surrounding perimeter	Berths on land-based ramp; passengers loading via ramps	2	≈10

Note: 1 knot = 1.15 mph.
[a]At full capacity. [b]At year of completion.

Figure 1. Vancouver SEABUS (two views).

(jet fuel or even light diesel) is greater than that of the middle distillates used by diesel engines. The Golden Gate Ferry vessel, the Jetfoil, and the air-cushion vehicle consume more fuel per hour than the surface-effect ship does, the only one powered by diesel engines. On a per-passenger basis, however, the high passenger capacity of the Golden Gate Ferry vessel makes it nearly the equal of the surface-effect ship.

Propulsion is provided in more varied ways than among slow-speed vessels. Marine propellers are one option, although high speeds require specially designed blades that resist speed deterioration normally caused by quickly agitating water.

Another option is waterjet propulsion, in which water is drawn into the ship's bottom and then thrust out at the stern by means of a pump. Waterjets have a number of advantages over marine propellers: They are quieter; their machinery is simpler and situated within the hull, thus reducing damage due to debris; their discharge can be used as a movable rudder, which increases maneuverability; and their use enables ships to have a shallow draft. This last feature is important in that it can reduce the amount of dredging necessary to accommodate ferry vessels, an important consideration in San Francisco's decision to use waterjet propulsion for its high-speed vessels. On the other hand, waterjets are less efficient in providing thrust than marine propellers, especially at low speeds. Furthermore, due to ducting, a considerable amount of volume is lost within the ship.

A third option is air propulsion, which can be used in either of two ways. On fully amphibious hovercraft (also called air-cushion vehicles), fans mounted to the deck propel the ship over sea and onto land-based docks. Surface-effect ships (known as hovermarines in Europe) also use air propulsion but only when operating at high speeds. They can operate as conventional hullborne vessels powered by diesel engines that have thrust delivered by conventional fixed-pitch marine propellers. As such, these vessels are actually slow-speed ships that achieve a maximum speed of only 19 knots in calm waters. However, an air pocket can be created under the ship's hull, which causes a lifting, friction-cutting effect and allows the ship to achieve speeds of between 40 and 50 knots. The air cushion is produced by fans located below the hull that are powered by two additional diesel engines. Surface-effect ships are the only high-speed vessels that use diesel engines, although gas turbines are optional.

HULL DESIGN

Slow-Speed Ships

Most operating ferry vessels have a conventionally designed displacement hull, normally manufactured from steel. This design is both well proved and inexpensive. The disadvantages of this hull design are its inherent poor stability (which results in passenger discomfort when the vessel is operating in choppy waters) and the large draft that it produces. An alternative hull design employs aluminum catamarans, or dual hulls that consist of two pontoonlike structures separated by a spanning deck. The best currently operating example of this hull design is the Vancouver SEABUS (Figure 1). This design has inherent small displacement and draft and offers good stability for passengers. It also allows for a wider deck (and therefore greater passenger capacity) to be used on relatively narrow supports than could be used on a single-hull design.

High-Speed Ships

Each high-speed vessel type has a hull design that sets it apart as essentially a unique ship design.

Planing Ships

Planing ships are so named because the wedge-shaped hull design minimizes resistance and actually lifts itself partly out of the water (which is known as planing) during high-speed operation. The Golden Gate Ferry uses semiplaning vessels, in which only the bow of the ship is wedge-shaped and the stern is squared off. This affords passengers a more comfortable ride, since the ride quality of a fully planed ship at high speeds is poor.

Hydrofoil

The hydrofoil is a planing-hull vessel supported by vertical foils, so that the hull rides completely above the surface of the water and provides no resistance to high-speed (40-knot) operation. Figure 2 shows that the foils protrude from the hull in either of two configurations--the surface-piercing foil (which is a permanent, nonretractable structure) and the fully submerged foil. The latter is the design used on the Boeing Jetfoil. Its inherent advantages are that the retractable foils allow relatively normal docking procedures and the fully submerged struts make this vessel less susceptible to wave disturbances, which offers a more comfortable ride. The Jetfoil can also operate hullborne with its foils fully retracted but at exceedingly poor fuel economies and at much lower speeds (between 7 and 15 knots). Floating debris is a potential debilitating hazard for both the surface-piercing and the fully submerged hydrofoil vessels, although less so for the design that uses fully submerged foils.

Air-Cushion Vehicle (Hovercraft)

The hull of this vessel is essentially a flatbed structure. Attached to its periphery is a flexible elastomer seal that protrudes downward and completely surrounds the hull. The air cushion that is created is contained within this seal, so that while the vessel is operating at 40+ knots, only the seal touches the water surface and the vessel itself rides above the water. Since the air-cushion vehicle is amphibious, the seal also supports the vessel over land.

Surface-Effect Vessel (Hovermarine)

The Bell-Halter surface-effect vessel, designed for ferry service and other operations, is a boxlike aluminum structure as shown in Figure 3. Its hull consists of side walls like narrow catamarans. When the vessel is operating off its air cushion as a slow-speed ship, the catamarans offer good ride stability, similar to that of the Vancouver SEABUS. The air cushion, created by fans located below the deck, is trapped between these rigid sidewalls and the flexible elastomer-coated nylon seals that enclose the bow and stern. The vessel is lifted so that its catamaran walls skim along the water surface at 40+ knots. Because of the rigid sides, the surface-effect ship cannot travel over land. However, its off-cushion operating capabilities make it compatible with conventional docking procedures.

VESSEL CONTROL

Conventional Vessels

Traditionally, large ferry vessels, like other conventional ships, divide vessel control between the pilot house (in which steering is performed by rudder adjustment) and the engine room (in which speed is controlled by engine thrust). On double-ended ferries, control is shifted back and forth between the fore and aft pilot houses, although both are manned at all times. Smaller ferry vessels (e.g., the Vancouver SEABUS) may combine steering and speed controls in one pilot house.

High-Speed Ships

Speed and steering control are handled in the pilot house on all high-speed vessel types. Steering is performed by the following means:

1. Waterjet propulsion units on the Golden Gate Ferry semiplaning ships and the Boeing Jetfoil are used for steering by horizontally deflecting the jet stream.
2. Air-cushion vehicles are steered in either of two completely different ways--deck-mounted fans can be angled independently and used to make steering adjustments or deck fans may be stationary (cannot be angled), which necessitates mounting the rudder behind the fan (as in an airplane tail); in either case, the steering capability is not of a high caliber, since the vessel is riding above the water surface.
3. The surface-effect ship has a marine propeller/rudder arrangement attached to the catamaran side walls.

High speeds are achieved on the air-cushion vehicle and the surface-effect ship only when the air bubble is created and on the hydrofoil only when the foils are protracted. Conventional engine thrust is used to increase speed on the Golden Gate semiplaning vessels.

Fully submerged hydrofoils require a third element of control--the height of the vessel off the water surface--viewed alternatively as the length of the foil protraction. When the vessel is to become foilborne, foil length, direction, and speed are set in the pilot house by using the height-command lever, the helm, and the throttle, respectively. However, an additional automatic control system is also used to constantly monitor and correct foil length in relation to continually changing wave heights. This automatic adjustment system adds significantly to the Boeing Jetfoil capital costs, but it is essential in order to produce an acceptable level of passenger ride quality.

DOCKING PROCEDURES

Two critical elements of ferry-vessel docking are the loading and the unloading procedures for passengers and vehicles. Another is the need to consider variable water heights when designing berthing structures.

Vehicle Loading and Unloading

Many systems use double-ended vessels as a means of minimizing vehicle loading and unloading time. These vessels allow vehicles to drive straight onto the vehicle deck and to disembark straight off the other end.

Some systems incorporate double-ended vehicle loading into a single-ended vessel. When the vessel is berthed with its front headed into the dock, vehicles board and drive straight through to the stern. On reaching its destination, the vessel backs into the dock; this allows the vehicles to drive straight off. The vessel then takes on boarding vehicles via the stern entrance. When returning to the other terminal, the vessel docks head-in, and vehicles disembark by driving straight off, embarking vehicles drive straight through to the rear, and the process repeats itself. Systems opt for the single-ended vessel over the double-ended vessel despite the extra maneuvering necessary, primarily because of the capital cost differential between the two vessel types and occasionally because of the need to use shallow-draft, single-ended ships.

Side- and/or rear-loading vessels are used when quick vessel turnaround is not overly important or when circumstances demand (i.e., narrow river operations in which cross traffic is heavy). Vehicles drive through the boat and around the aft or stern, depending on which opening is used.

Figure 2. Hydrofoil design types.

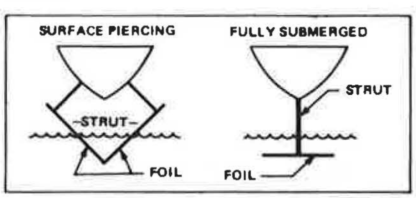
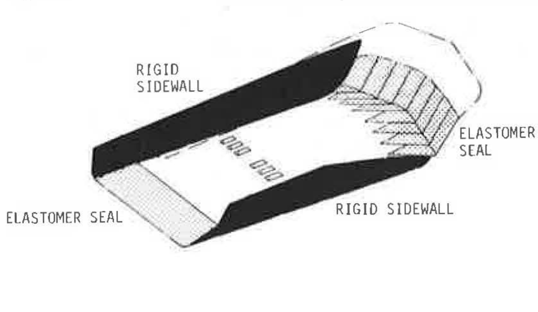


Figure 3. Bow and stern elastomer seal layout of surface-effect ship.



Passenger Loading

Since double-ended vessels are selected primarily to hasten vehicle loading and unloading, passengers are normally a secondary concern. They are usually directed along separate ramps and bridges, or else they may use the same ramp space as the vehicles do. Most passenger-only vessels also use ramps or gangways.

The Vancouver SEABUS operation is the only sevice that effectively uses double-ended vessels for passenger loading and unloading. Passengers disembark from six doors located along the vessel's port or starboard side. Meanwhile, doors along the opposite side open soon after and allow passenger embarkation to occur. The separate, almost simultaneous loading and unloading of a total of 800 passengers occurs in 90 s.

PASSENGER AMENITIES

The facilities provided for passenger comfort, convenience, and overall ride enjoyment encompass (a) passenger storage facilities, including seating, standing room, and individualized cabins; (b) food and refreshment opportunities; (c) rest-room facilities; (d) scenic view; and (e) accessibility to the elderly and the handicapped. A wide variety of amenities are provided among ferry operations. Each selects appropriate facilities on the basis of such factors as expected ridership demand, ridership makeup, trip purposes served, and total route travel time. Some amenities, such as available window view and sun-deck space, are tied directly to the type of vessel used. Most passenger-related facilities, however, can be provided in various forms and arrangements on most vessel designs. Some of these facilities are discussed below.

Passenger Storage

Seating type and arrangement ranges from the transverse and longitudinal grouping of seats familiar to buses and subways, used on the Staten Island Ferry and Vancouver SEABUS, to the first-class airline-type seats and seating arrangements, used on the Golden Gate Ferry and available on other high-speed vessels including the Boeing Jetfoil and the Bell-Halter surface-effect ship. Unlike other vessels, the Staten Island Ferry vessels provide considerable standing room, with more than one-third of the passenger capacity estimated for standees.

Scenic View

Ferry systems that cater largely to social and recreational trips normally have considerable sun-deck space available; some have nearly two-thirds of their available seating in exterior locations. Among the smaller high-speed ships, on which sun-deck space is either limited (Golden Gate Ferry vessels) or not possible (hydrofoil), large viewing windows are often used to increase passenger enjoyment. However, even simple vessels of utilitarian design like the Vancouver SEABUS (Figure 1) can incorporate large viewing windows into basic vessel design.

IMPLICATIONS OF JONES ACT

The Merchant Marine Act of 1920, commonly referred to as the Jones Act, specifically forbids the operation of foreign-built vessels for domestic passenger and freight trade. In effect, this act forbids any domestic ferry systems from purchasing any foreign-built vessel, of which there are many among the slow- and high-speed variety. Obviously designed to protect and enhance the U.S. shipbuilding industry and labor force, the act has had the effect of limiting the choice of ferry-vessel design and construction to a relatively few U.S. firms. High vessel costs, long construction periods, and limited design options are the result. The availability of high-speed-vessel manufacturers is particularly limited.

Role of Waterborne Transportation in Urban Transit

ROGER P. ROESS

The initial findings of a three-year study to prepare a manual of planning guidelines for waterborne passenger transportation systems are reported. The various roles played by five major ferry systems in the United States and Canada are investigated to determine the range and flexibility of such services as they form an integral part of an urban or regional transportation network. The conclusion is that the considerable flexibility of the mode as well as the range of technology available provide a great potential for increased use of waterborne systems as a viable modal alternative in many areas, one that should receive greater attention from transportation planners.

Water was man's original form of vehicular transportation. There is historical evidence that crude barge-type vessels were used by early man to transport goods and individuals long before the wheel made overland vehicle-aided travel feasible. Throughout history, nations have developed near and along the world's navigable waterways, from ancient Egypt along the Nile to the original 13 American colonies, which developed as clusters around East Coast waterways.

Access to navigable waterways remains critical to the well-being of nations, and such major projects as the Panama and Suez Canals have literally allowed the economic survival of areas that may well have collapsed. In the United States, more than $1 billion in revenue is earned shipping grain, coal, steel, and chemicals over the nation's 25 000-mile inland waterway system.

Despite the historical significance of waterborne transportation to the affairs of man, a review of travel patterns in U.S. cities reveals that this mode has become the "forgotten man" of urban transportation systems. This is a fact even more incomprehensible in view of the number of large urban areas in the United States and elsewhere that are adjacent to navigable waterways.

Nevertheless, there are more than 600 ferry