prevalent in the earlier version of the model. Pedestrian behavior, as handled by the USS program's path-choice model, was always one of finding the shortest path, which is true for most of the station network. However, on the platform a different type of behavior takes over, particularly if the vehicle is not waiting at the platform. USS should now be able to simulate this non-minimum-path type of behavior.

These improvements, as well as giving USS the ability to operate interactively, should result in a vastly improved and easier-to-use model. An improved USS program should be a valuable tool for station designers and planners. The model can help in the sizing of stations, particularly complex station areas that are difficult to analyze by manual techniques. It can assist in analyzing special situations, such as emergency evacuations. This ability is a significant improvement in the program. In this light, the program could aid in the evaluation of present fire and safety codes and regulations, which, in many cities, are not responsive to the needs of transit systems. The model could also help in developing operating strategies for stations, particularly during construction, maintenance activities, and special situations such as a vehicle breakdown. Simulation models offer a tool for use in sensitivity analysis of station concepts and layouts. This is particularly valuable, given the error that is inherent in patronage forecasts. The simulation model would impose a planning discipline on the user, a discipline that is often lacking. USS requires designers and users to analyze station plans in terms of pedestrian paths through the stations and not just as an arrangement of spaces.

UMTA should continue development of the USS computer program, including demonstration of its capabilities through case studies. If USS helps to reduce the capital cost of just one transit station, UMTA's investment in the computer program would probably be more than recouped.

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Functional Design Elements for Ferry Terminals

PHILIP A. HABIB AND ROGER P. ROESS

The functional design of ferry terminals requires the exercise of a variety of skills and knowledge from such diverse areas as traffic engineering, pedestrian design, transit planning, and vessel operation. Specific types of ferry services are defined, and research findings are presented on how the terminal should be selected and the facilities planned to accommodate these services. For passenger-only ferry operations, planning guidelines are presented for passenger storage and processing facilities, including parking areas, waiting rooms, gangways, and other terminal elements. For vehicle-ferry terminals, guidelines are presented for toll facilities, vehicle sorting and holding areas, discharge demand needs, and other elements of vehicle-ferry terminals.

In March of 1979, the Transportation Training and Research Center of the Polytechnic Institute of New York was awarded the first year of a proposed three-year study to prepare a manual on the planning and functional design of ferry systems. The study is being funded under the University Research Program of the U.S. Maritime Administration. The first year of the study (1) focused on issues of functional design of various system elements. This paper treats these aspects with respect to the complex interface between the vessel and land: the ferry terminal.

CLASSIFICATION OF FERRY SERVICES

There are distinct relations between various characteristics of the ferry service provided and the internal environment that the terminal will require. The project has resulted in the identification of the following list of such characteristics: mode and purpose of ferry service, range and number of stops, frequency of service, and ferry capacity and design.

Mode of Ferry Service

The planning and design of the terminal are controlled by the mode of service provided. The principal modes are (a) passenger only and (b) vehicles and passengers ("passenger" denotes a walk-on rider without a vehicle).

Terminals that service "passenger-only" ferries (i.e., those that carry no vehicles) generally require large park-and-ride facilities as well as efficient transit access. In terminals that serve vehicles as well as passengers, smaller park-and-ride facilities are needed. The major element of ferry terminals that serve vehicles is the extensive amount of holding space required for the sorting and queuing of waiting vehicles.

Purpose of Ferry Service

There is a general relation between the principal purpose of a ferry service and the mode as defined above. The principal purposes of ferry services are commuter journey to work, recreational, and maintenance.

The commuter ferry services generally have a downtown urban center as their base. These ferry services are inclined to have a higher percentage (up to 100 percent) of walk-on passengers who access the terminal by various means. The recreational service, on the other hand, is primarily vehicle oriented and may also carry a moderate number of bicycles. The maintenance service is a mixture of all purposes, including journey to work, delivery of essential services and freight, and recreational trip making. The maintenance purpose applies to routes that service relatively isolated (with respect to land access) locations and effectively "maintains" the principal connection to nearby population centers.

Range of Service

The range of the service describes the total one-way trip length (in terms of travel time) and the number of intermediate stops (destinations). The longer the range and the more numerous the destinations, the more complicated is the vehicle loading-unloading process at the terminal. This process ensures that vehicles can get off in sequence at each stop along the route.

Figure 1. Flowchart for passenger-only ferry terminal.

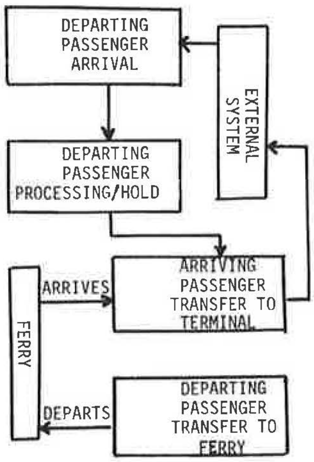


Figure 2. Passenger flow separation at Vancouver SEABUS terminal.

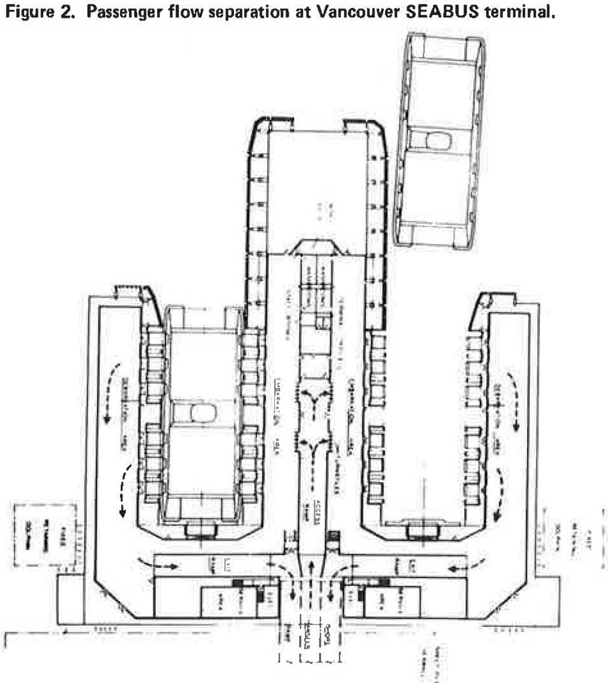
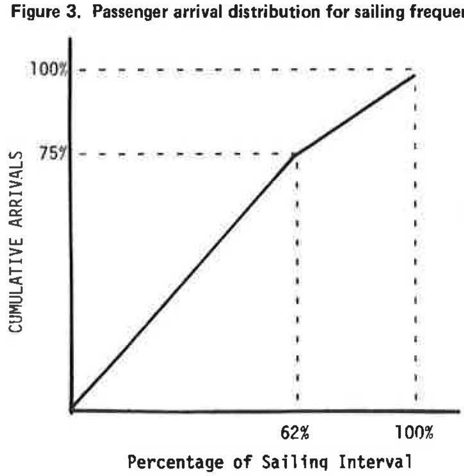


Figure 3. Passenger arrival distribution for sailing frequencies of 30-90 min.



Frequency of Service

The frequency of service in each route used by the terminal is defined by the interarrival time of the ferries. The arrival pattern for vehicles and pedestrians at ferry terminals is controlled by the frequency of scheduled departures. The lower the frequency, the earlier passengers and vehicles will generally arrive at the terminal.

Vessel Capacity and Design

The design features of the vessels also control the functional as well as the detailed design elements of the ferry terminal. End-loading ferries have different terminal needs than do side-loading ferries. In practice, end-loading ferries have achieved wider acceptance for vehicle-carrying ferries, and side loading has been the most accepted design for passenger-only ferries. The discharge characteristics of all ferries will control the processing compatibility of the terminal for both passengers and vehicles. The size of the ferry, in terms of its passenger and/or vehicle capacity, directly controls the scale of the terminal holding facilities.

PLANNING AND DESIGN ELEMENTS FOR PASSENGER-ONLY TERMINALS

The general flowchart for a passenger-only ferry terminal is shown in Figure 1. The departing passenger can access the terminal by various means, including walking (or bicycling), transit (all forms), park-and-ride, taxi, and kiss-and-ride. The departing passenger is processed (if necessary) through turnstiles to a holding area. Depending on the demand at the terminal and climatic conditions, the holding area may be an enclosed structure. When a ferry arrives, arriving passengers disembark first, after which departing passengers are loaded onto the ferry. For most passenger-only operations, the arriving passenger flows have complete physical and temporal separation from the departing flows for control and ease of movements. Figure 2 shows this physical flow separation for the Vancouver SEABUS ferry service.

The departing passengers leave the terminal by various means. When the terminal is in (or near) the downtown, the predominant mode is walk or transit. For instance, at the Manhattan end of the Staten Island Ferry, the split for passengers is 61 percent walk, 37 percent transit, and 2 percent automobile-taxi. Where the terminal site is outlying, the predominant modes are usually park-and-ride and kiss-and-ride as well as transit.

Landside Terminal Access Facilities

The interface between the existing road system and the terminal is generally one or more at-grade intersections. The number and operation of these intersections are governed by the use of automobiles and buses to access the terminal. The automobile population consists primarily of park-and-ride users, but kiss-and-ride and employee traffic are also present.

The design and operation of the intersections are governed by peak traffic flows, both through on the arterial and into and out of the terminal. The traffic pattern, in turn, is governed by the sailing interval of the ferries. For intervals of 30 min or less, a uniform distribution of arrivals (over the 30 min) can be expected. However, data from British Columbia Ferries indicate that, where the sailing interval is 30 min or more, approximately 75 percent of the departures arrive in the first 62 percent of the interval between successive scheduled sailings. Figure 3 shows this arrival pattern.

Figure 4. Theoretical layout of maximum-sized park-and-ride lot.

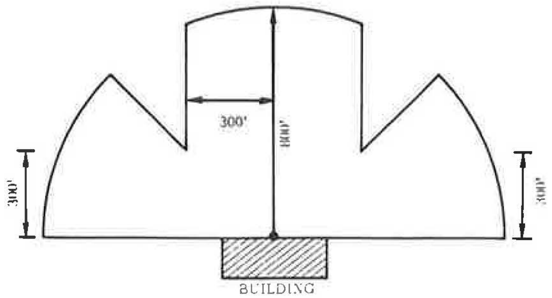
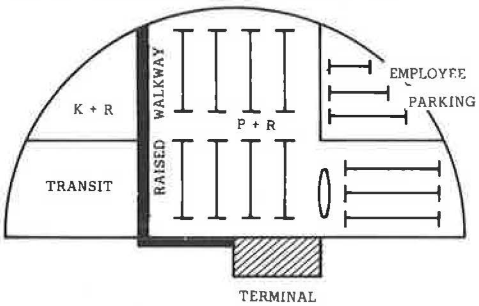


Figure 5. Field applications of hat-shaped layout.



Vehicle departures from the terminal peak more severely than arrivals. Each ferry that discharges park-and-ride users will cause automobiles to arrive at the intersection in the outbound direction at an average rate, which is controlled by the processing capabilities of the terminal and the ferry interface. As passengers discharge from the vessels, usually in the batch mode, the planner should calculate the processing rates of key terminal elements (stairways, ramps, and doorways) along the path from the vessel to the parking lot to determine the expected arrival rate of passengers to their automobiles.

The ability to discharge vehicles rapidly from the terminal to the land-access system is not necessarily critical. The planner should review the capabilities of intersections near the terminal to handle the additional loading rate. The limited use of the terminal as a "reservoir" to dampen the discharge rate of vehicles onto the access system should be considered where necessary, practical, and/or in the community interest.

Parking Facilities

In a passenger-only terminal, parking facilities must be provided for park-and-ride, kiss-and-ride, employees, local transit, and the handicapped.

The demand forecast provides the basis for estimating the number of park-and-ride spaces needed in the terminal. The demand forecast also assumes a terminal "level of service" with respect to parking facilities. The number of spaces is based on the maximum accumulation of vehicles expected over the service day, considering the total number of park-and-ride users expected, their arrival patterns, and automobile occupancy. The final layout will be governed primarily by the shape of the available land. However, several features of the parking area can be controlled by the terminal planner. The set objectives to be used in guiding the planner are

1. To minimize walking distance from automobile to ferry,
2. To minimize walking conflicts with other automobiles, and
3. To maximize the use of available land.

Pedestrian walking distance should be kept to a desirable maximum of 244 m (800 ft) where possible and an absolute maximum of 305 m (1000 ft). Lots that require a walking distance in excess of 305 m from the extremity to the ferry building should not be considered, and the feasibility of a garage should be investigated. In order to minimize pedestrian conflicts, the aisles of the parking layout should be perpendicular to the shoreline (or ferry building). Aisles that are parallel to the shoreline provide minimum safety due to the number of potential conflicts between pedestrians and circulation automobiles.

Figure 4 shows the theoretical layout of a park-and-ride lot for a ferry terminal that satisfies the following criteria: (a) maximum walking distance of 305 m and (b) directness coefficient (ratio of walking path to aerial path) of 1.3.

The "hat-shaped" layout shown in Figure 5 does imply an inefficient use of a symmetrical lot, but it provides a high quality of pedestrian service. The terminal planner should try to adapt the theoretical criteria to actual field conditions. In the adaptation shown in Figure 5, transit facilities, employee parking, and kiss-and-ride are all incorporated with the park-and-ride scheme.

The layout of the individual parking stalls should recognize that automobiles are being downsized. It should also be noted that, for this type of parking facility, the stall turnover rate would be barely more than one per day. Therefore, the stall dimensions should be the smallest allowable for self-parking facilities. Due to the radical mix of automobile sizes at this time, it is necessary to provide parking facilities that can accommodate large and small automobiles simultaneously. This can be accomplished by (a) providing special "small-car" lots and (b) incorporating all automobiles together in the same stall design.

To accomplish the special-lot technique effectively, the planner must adequately estimate the population of large automobiles. Since this population is dynamic, the estimating process will be imprecise. To incorporate both vehicle sizes in the same layout is inefficient, since the "design vehicle" will necessarily be the large automobile.

There is, however, a method that provides a remedy for this problem: the transitional layout. Under this scheme, the desired design vehicle for the long term would be a compact automobile with the following characteristics: 188-cm (74-in) width, 279-cm (110-in) wheelbase, and 508-cm (200-in) overall length. The compact vehicle (not to be confused with the subcompact) requires a parking module (two stalls and aisle) of 16.8 m (55 ft) for two-way operation (90° parking) and a stall width of 2.44 m (8 ft). For the present vehicle mix, a parking module of 18.3 m (60 ft) and a 2.6-m (8.5-ft) stall width are required. Use of the subcompact as the design vehicle, which would require a parking module of 15.24 m (50 ft) for 90° parking, appears to be unattainable for the foreseeable future. In order to accommodate tomorrow's needs in today's design, it is recommended that an angle-parking scheme with a module of 16.8 m be initially striped for use and that, as the complete downsizing of the automobile fleet takes place (1988-1990), restriping for 90° parking be done to correspond to the compact automobile as the design vehicle. Figure 6 shows this transitional parking scheme.

In addition to the parking elements presented above, special parking stalls for the handicapped must be provided at the most accessible locations to

Figure 6. Transitional parking scheme.

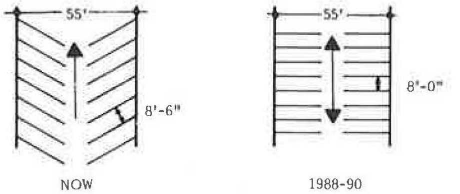


Figure 7. Two-stall configuration for handicapped drivers.

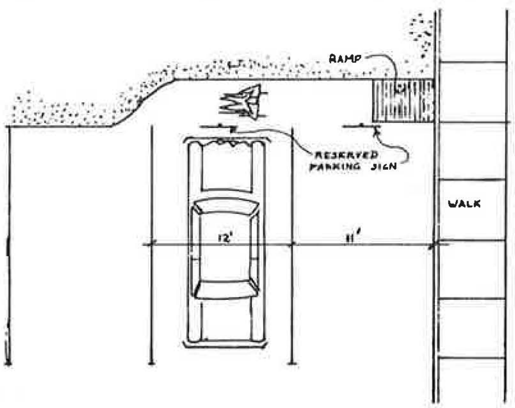


Table 1. Levels of service for pedestrian facilities.

Level of Service	Flow Rate (pedestrians/ft/min) Walkways	Stairs	Storage Area for Waiting Areas and Queues (ft^2/pedestrian)
A	<7	<5	>13
B	7-10	5-7	10-13
C	10-15	7-10	7-10
D	15-20	10-13	3-7
E[a]	20-25	13-17	2-3

[a]Capacity.

the terminal building. A minimum of two spaces and a maximum of 2 percent of all spaces should be designated for the handicapped. The parking stalls are 3.66 m (12 ft) wide except adjacent to a walkway, where a 3.35-m (11-ft) stall width is acceptable (4). Such parking spaces must be immediately accessible to the walkway system of the terminal. Figure 7 (4) shows a typical layout for a two-stall configuration.

Pedestrian Facilities

Pedestrian processing and storage are the key functions in the passenger-only terminal. The prerequisite in the development of pedestrian facilities is the development of service standards. Certain qualities of service are mandated by local or federal standards, including requirements related to the handicapped, minimum lighting, and others.

Facilities of special interest are processing facilities and storage facilities for pedestrians. In a ferry terminal, the possible processing facilities are walkways (and gangways), stairs, doors, turnstiles, escalators, and elevators. The pedestrian storage facilities are lounges and other waiting areas.

Levels of service for pedestrians have been established by Fruin (2) and are widely accepted as a base for planning. These levels of service, graded A through F in deteriorating order, give the planner a guide to facility design. Table 1 quantifies these levels of service for walkways, stairs, and waiting (standing) facilities.

It is critical that a pedestrian flow plan for each terminal be developed. It is also critical that it be recognized that passengers are batch unloaded from ferries, which implies that the rate of passengers arriving at the first processing facility (e.g., a walkway or a staircase) is governed by the rate at which the ferry gangways can discharge passengers. As a principal means to minimize in-berth time, passenger-only ferries are designed for a maximum feasible batch discharge rate. Thus, the design of selected processing facilities must be coordinated with the design of the ferry itself.

Since passengers arrive at the ferry terminal in a relatively uniform manner, the facilities provided for processing arriving passengers are of a lesser scale than those provided for batch-discharged passengers. The facilities of principal interest that are provided for accommodating and processing these departing passengers are (a) turnstiles at some point in the flow process, (b) a holding area for passengers, and (c) a facility for processing passengers from the holding area to the ferry.

Turnstiles provide a means of fare control as well as for accumulating passenger statistics. The following are expected processing rates per turnstile:

Type of Admission or Exit	Rate (persons/min)
Free	40-60
Single coin or token operated	25-40
Double coin operated	15-25

Lounges and other waiting areas for passengers are essential for most high-volume ferry operations. Where the service interval is 15-20 min, only a moderate percentage (20-40 percent) of seating need be provided for waiting passengers. When the sailing interval is longer than 20 min, a gradual increase in seating should be provided to ensure a high quality of service. The maximum seating should be based on a selected maximum allowable standing time for passengers. The literature is void in this respect. As a general rule, however, 15 min appears to be a tolerable maximum.

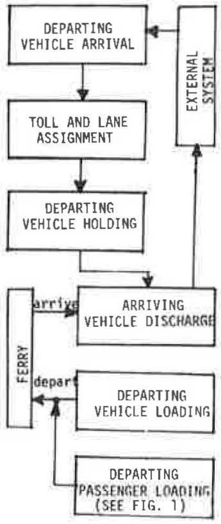
The method for estimating seating requirements is as follows: Determine the sailing interval to be T min. T - 15 is the time after which guaranteed seating may not be provided. (T - 15)/T is the portion of the sailing interval for which seating is provided. By using Figure 3, determine the percentage of passengers arriving in this portion of the sailing interval. This percentage multiplied by the expected departures determines the necessary seating.

The terminal planner can select a different maximum standing time to conform to another quality of service (other than the 15-min maximum) that needs to be provided or to conform to budgetary constraints (or the lack of them).

Other Processing Facilities for the Elderly and Handicapped

Standards of the American National Standards Institute (ANSI) and its amendments relating to accessibility for the handicapped must be built into U.S. ferry terminals that are financed in part with federal funds. Almost all states in the union have

Figure 8. Flowchart for vehicle-ferry terminal.



their "barrier-free" standards, which, essentially, are replicas of the ANSI standards. Fully accessible terminals are one of the design goals in the planning design process. Thus, the terminal must incorporate ramps or elevator alternatives to stairways, provide facilities for the handicapped in restrooms, and provide wheelchair capacity on vessels and in waiting areas.

Detailed design criteria and standards for the handicapped are given in a report by the Eastern Paralyzed Veterans Association (4).

Transit Access

Depending on the extent of use of park-and-ride and/or kiss-and-ride, transit may play a significant role in serving passengers. Facilities for buses are usually provided in a separate area but may be on the perimeter of parking areas closest to the terminal. The walking distance from transit to the terminal should be minimized, and bus schedules and ferry schedules should be carefully coordinated.

PLANNING AND DESIGN ELEMENTS OF VEHICLE-FERRY TERMINALS

The vast majority of ferry operations in North America are vehicle ferries that transport automobiles, buses, trucks, and bicycles as well as walk-on passengers. The layout of a vehicle ferry terminal is conceptually different from that of a passenger-only ferry terminal. Although the passenger components are similar, the vehicle storage and processing (VSP) operations at a vehicle terminal are radically different, especially if multidestination services are offered.

The layout of VSP facilities is done to ensure (a) a minimum amount of in-berth time for the ferry and (b) an effective use of the available land. By their nature, vehicle-ferry terminals are more expansive than passenger-only operations. Figure 8 shows a flowchart for a typical vehicle-ferry terminal.

The departing vehicle accesses the terminal through an intersection with the access road system. In selected terminals, when a road extension (sometimes as much as a mile) has to be built from the proposed terminal site to the existing road system, terminal access is gained via a toll facility placed directly on this extension. The need to construct a new road to gain accessibility to a terminal site is a negative attribute of that particular site. However, such a road does provide a contingency backup storage function that, in general, reduces the ultimate size of the terminal itself.

At the toll facility, the appropriate charge is made and the vehicle is routed to a specific holding (stacking) lane. The vehicles are stored in the stacking lanes until the appropriate ferry is ready for loading. The arriving ferry first discharges vehicles destined for the terminal (which may not be all of the on-board vehicles) and then loads vehicles from the holding area. In cases where multiple stops are scheduled on a particular route, only a limited number of vehicles may be allowed to board at any one terminal in order to reserve room for vehicles boarding at downstream terminals.

The principal functional elements of a vehicle-ferry terminal are facilities for vehicle discharge from the ferry, toll collection, vehicle holding and sorting, vehicle parking, and vehicle loading onto the ferry.

Vehicle Discharge from Ferry

The discharge of vehicles from a ferry must be addressed from two viewpoints: (a) circulation within the terminal and (b) exit onto the external road system. The circulation pattern of discharged vehicles should be separated from other flows in the terminal in order to ensure a safe and expeditious discharge. Once they make their way through the terminal, the vehicles must be transferred to the adjacent road system. Most terminals will have one exit point to the adjacent system.

The objective in laying out the exit intersection is to ensure that its processing capacity is greater than the discharge demand from the ferry. This is especially true for vessels carrying 150 or more vehicles. Queuing cannot be tolerated in most vehicle terminals due to the rapidity with which the ferries must discharge and load vehicles. Therefore, the planner should conservatively assume that 40 percent of the signal green time at the exit intersection will be available for terminal discharge at "urban" terminals and 50 percent at outlying terminals. Each approach lane can therefore process 600-750 vehicles/h. Although these rates may seem high, consider that vehicles being discharged from a ferry at 3.5-s headways (per ramp lane) will result in a demand at the intersection of slightly more than 1000 vehicles/h/lane, which is greater than the capacity of each approach lane at the intersection. It is therefore recommended that, for planning purposes, two approach lanes be provided for ferries discharging from a one-lane ramp and three approach lanes be provided for ferries that discharge vehicles from a double-lane ramp. These requirements should be adjusted to conform with the geometry of the external roadway system and with the actual turning movement anticipated at the exit intersection.

As an example, the vehicle ferry terminal in Seattle, Washington, handles discharged vehicles from a two-lane ramp exiting each ferry. Significant queues will build up at this exit intersection. In most cases, due to the location and design of the vehicle (departing) holding area, almost all exiting vehicles must be discharged from the terminal before loading operations can begin.

The prudent terminal planner should also conduct an intersection capacity analysis at all on-street signals in close proximity to the terminal by using the Highway Capacity Manual (5) and Transportation Research Circular 212 (6). It is realistic to assume that queues can build at downstream intersections, causing congestion and disruption within the terminal itself. A 200-car ferry has a standing queue capacity of 610 m (2000 ft) in each of two adjacent lanes. Where intersection capacity is exceeded, backups into the vessel itself can easily occur.

Toll-Collection Facilities

The principal functions of toll facilities at ferry terminals are fare collection and destination identification. The latter function is critical in order that vehicles can be stored in an orderly manner before loading. Most ferry fares are controlled by vehicle type, number of passengers, and destination. Considerable time is consumed in processing vehicles through such toll facilities. For the simplest of cash operations (only one destination), a mean of 30 s/transaction can be assumed. For multidestination ferry services, especially on recreational routes, the mean time per transaction can range up to 2 min. For ferry operations in which monthly passes are sold, the average time per transaction at these booths may be as little as 10 s except when the new monthly pass is being purchased.

The need to establish a planning guide for toll processing is not critical except for very large terminals, which may be processing 300-400 vehicles/h for several different routes. Based on conversation with various ferry operators, a mean processing rate of 60 vehicles/h/tollbooth is recommended for multidestination service and 120 vehicles/h/tollbooth is recommended for a single-destination service.

The number of tollbooths needed at any one time can be calculated from the demand forecast. The maximum number of toll facilities needed can be calculated by assuming 100 percent occupancy of each scheduled departing ferry. The location (and number) of these toll facilities should ideally be such that queues never back up out to the access road system.

Vehicle Storage and Processing

After proceeding through the toll facility, the vehicles are stored in a holding area until the appropriate ferry is to be loaded. The operations of this holding area become increasingly complicated as the number of possible destinations increases. In the simplest case, a one-route-destination service, vehicles are stored on a first-come-first-served (FCFS) basis by vehicle type (usually automobile versus trucks and buses). There is a need to segregate large vehicles from automobiles because in most ferries trucks and buses are carried in special parts of the vessel.

A more complicated case is a single route with multiple destinations. Vehicles must be ordered in the ferry by sequential destination. Thus, storage in the terminal must be segregated by FCFS, vehicle type, and destination. When a terminal services more than one route (with and without multiple destinations per route), vehicle holding must be done by FCFS, vehicle type, destination, and route. In addition, due to unequal demands and ferry sizes per route (or even within a route), control of the holding area of a vehicle terminal can be an enormous task. Figure 9 shows an aerial view of a multiroute, multidestination ferry terminal on the British Columbia Ferries system.

The layout of the holding facilities is destination sensitive. Data from British Columbia Ferries show that drivers will arrive as much as 100 min before a scheduled departure. For departures more frequent than every 110 min, Figure 3 can be used to determine the arrival pattern. The demand forecast, the sailing frequency, and the size of the vessel all interact to control the size and layout of the storage facility. Storage is commonly accomplished by using parallel stacking lanes 3.35-3.56 m (11-12 ft) wide.

The objectives of the design for the layout of stacking lanes are (a) to accommodate the maximum accumulation for each destination in a whole number of stacking lanes and (b) to minimize the wasted space for each layout configuration. It is generally true that the shorter the length of the stacking lanes, the less will be the overall unused space. The following example shows one recommended method for determining the number and length of stacking lanes in a vehicle-ferry terminal.

Consider a ferry terminal serving two distinct routes that carry automobiles only (for problem simplicity). Route A is a direct route to city X, and route B is a one-stop route to city Y. The demand forecast and the projected sailing schedule provide the planner with the means of predicting an accumulation pattern by destination. The table below gives such an accumulation pattern for this problem. Route A leaves every hour on the half hour, and route B leaves every hour on the hour:

Time	No. of Automobiles		
	Route A,	Route B	
(a.m.)	City X	Stop 1	City Y
8:00	100	80	150
8:15	150	20	30
8:30	200	40	65
8:45	50	60	95
9:00	100	70	130
9:15	150	15	30
9:30	200	30	60
9:45	40	45	90
10:00	80	60	120

The maximum length of a stacking lane will be controlled by the physical layout of the available land. The maximum number of stacking lanes is also constrained by the geometry of the terminal land area. In this example, stacking-lane length can range up to 40 cars and the maximum number of lanes is 15. From the practical viewpoint, the minimum length of a stacking lane should be 15 cars for most terminal conditions in order to reduce the expanse of the holding area and to maintain visual control over this area.

The solution to the problem is iterative. The planner begins with the minimum stacking-lane length of 15 cars and determines the number of lanes required for this configuration. The planner increments the length by 5 cars until a solution is found within the defined constraints. Table 2 gives the number of stacking lanes required for lengths of 15, 20, and 25 cars. These results are summarized below:

Lane Length (no. of cars)	No. of Lanes	Time (a.m.)
15	23	8:00
20	17	8:00
25	14	8:00

An acceptable solution is reached with the 25-car stacking-lane length, with minimum total requirement of 14 such lanes.

It is clear to the reader that scheduling of service will have a critical effect on the number and use of the stacking lanes, especially in multidestination terminals. In addition, the planner should also conduct an evaluation of the design and layout under conditions in which one or more sailings are late. This latter evaluation is conducted in the same way as that presented above, but the

Figure 9. Multiroute, multidestination ferry terminal.

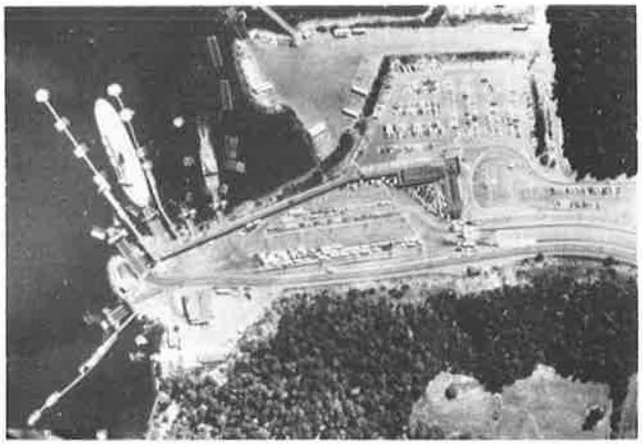


Table 2. Number of stacking lanes required for lane lengths of 15, 20, and 25 cars.

Time (a.m.)	Route A, City X			Route B Stop 1			Route B City Y		
	15	20	25	15	20	25	15	20	25
8:00	7	5	4	6	4	4	10	8	6
8:15	10	8	6	2	1	1	2	2	2
8:30	14	10	8	3	2	2	5	4	3
8:45	4	3	2	4	3	3	7	5	4
9:00	7	5	4	5	4	3	9	7	6
9:15	10	8	6	1	1	1	2	2	2
9:30	14	10	8	2	2	2	4	3	3
9:45	3	2	2	3	3	2	6	5	4
10:00	6	4	3	4	3	3	8	6	6

accumulation for each scheduled departure is carried forward by a specified length of time. The prudent planner will design a terminal to accommodate a sailing delay of 15 min for the conditions that determined the optimum design.

Vehicle Parking

Apart from the sorting-holding area for departing vehicles, there are additional parking needs. These include park-and-ride parking, employee parking, kiss-and-ride parking, and bus-transit parking. The need to provide a high quality of passenger service at a vehicle ferry terminal is somewhat overshadowed by the need to process vehicles with a maximum of efficiency. Therefore, the placement park-and-ride and kiss-and-ride parking facilities will generally not conform to the criteria suggested for passenger-only terminals.

The layout of the parking facilities for a vehicle terminal eliminates most pedestrian-vehicle conflicts. Pedestrians include passengers walking from park-and-ride and kiss-and-ride to the terminal building, passengers who leave their cars temporarily in the vehicle holding area to seek refreshments in the terminal building, and employees. It is desirable to consolidate all pedestrian demand on one side of the terminal grounds and to have this demand access the terminal building without crossing traffic flows. In order to satisfy these objectives, the planner should coordinate building location and parking field layout to minimize design difficulties.

Vehicle Loading

The transfer of vehicles from the holding area to the appropriate ferry should be an efficient and direct operation. The planner should recognize that the loading operation will be manually controlled by "dispatchers". Larger ferries that load from two lanes simultaneously are usually loaded in less time than much smaller ferries that load from one lane. The design of the vessel and on-board control of the loading operation both have more influence on the efficiency of the loading process than the design (location) of the holding area.

Trucks and buses are usually segregated from automobiles in the loading process. The principal reasons are

1. Trucks and buses are routed to wider on-board parking lanes than automobiles;
2. For double-deck ferries, head-room restrictions would be such that trucks and buses could only park in specific portions of the lower parking deck; and
3. To ensure ferry stability by distributing the weight of heavy trucks to both sides of the vessel.

In order to encourage passenger use of vehicle ferries, most ferry operators will assign the highest loading priority to buses. This frequently occurs on a route that serves a large metropolitan center. The planner should ensure that this prioritizing can take place in the layout of the holding area and in the loading operation. It should be noted that vessels are licensed (for safety reasons) to carry a maximum number of passengers at any one time. Where buses frequently use a ferry route, the ferry may leave port half empty of automobiles because the maximum allowable number of passengers has been reached. This usually causes a high degree of frustration for automobile passengers who see the ferry sailing supposedly loaded to capacity.

At larger ferry terminals, where more than one vessel may be simultaneously in port, the layout and operation of the vehicle holding area will generally not allow for simultaneous vehicle loading of ferries. However, provision for an unloading operation from one ferry and a simultaneous loading operation for another should be built into the process. That is, where two ferries are scheduled within 15 min of each other, the terminal manager should route the first arriving ferry to the slip closest to the vehicle holding area. This would ensure that the loading operation of the first arriving ferry can generally occur at the same time as the discharge operation of the later arrival.

SUMMARY AND CONCLUSION

Of necessity, this paper covers only a portion of the material synthesized for the current study. Even the full report can only extract the most pertinent information and criteria. Ferry terminal planning involves the broad use of principles of traffic engineering, pedestrian design, vessel operation, and others. These skills are brought together in a unique type of facility to serve a mode that has great potential.

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The views, findings, and conclusions expressed here are ours and not necessarily those of the Maritime Administration or any other government agency.

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Analysis of Rapid Transit Access Mode Choice

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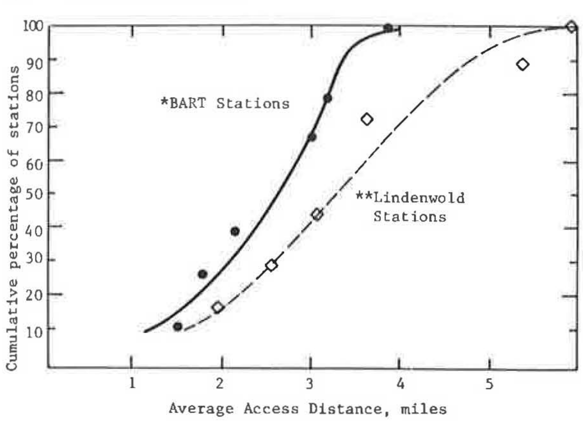
The application of the logit modeling methodology to the development of rapid transit access-mode-choice models that are transferable among different stations in a system is described. Rapid transit stations are classified into groups by using discriminant analysis to test for common behavior at sites within groups and to verify differences in behavior among groups. Eighteen variables are used to define the physical nature and accessibility of the terminal and the socioeconomic structure of the surrounding area. Five station groups are identified: (a) central city; (b) dense residential; (c) predominantly residential, some commercial; (d) predominantly commercial, some residential; and (e) sparse residential and undeveloped land. Multinomial logit access-mode-choice models are described for the different station groups in the Bay Area Rapid Transit system. The modes considered are drive alone, kiss-and-ride, bus, carpool, and walk. An areawide model is compared with the station group models. The results show that models for classified station groups have coefficients that differ from each other and from a model calibrated with the data for all stations in all groups. These models, however, do not offer sufficient uniqueness to justify recommendations. More precise, detailed calibration data are needed to establish transferable models.

This paper reports on the results of the application of the Urban Transportation Planning System (UTPS) ULOGIT calibration program in the analysis of rapid transit access-mode-choice behavior. The choice of mode of arrival at the line-haul rapid transit station for the journey to work was the principal focus of the study.

In spite of the extensive research on and application of travel demand models, few instances have been reported in which the principal focus was on the choice of access mode (1). This is the case because the access-mode-choice scenario is much more complex than the primary-mode-choice situation. For example, a basic problem associated with the use of a model based on a single station in a given area is that parameters are biased by the characteristics of the particular location, environment, station design, and interconnecting modes. On the other hand, a model calibrated with a cross section of data from all of the stations in a system may be representative of no particular station.

The fundamental hypothesis underlying this modeling method is that logit models of access mode choice must consider all viable alternatives and should be constructed in a manner that allows them to be transferred among different areas. The access modes considered in this study are drive alone, kiss-and-ride, bus, carpool, and walk. The data set did not permit consideration of the bicycle and motorcycle as rapid transit access modes. Station location characteristics, together with socioeconomic variables, are used to classify a station in a way that permits logit models to be compared for differences among station types.

Figure 1. Cumulative distribution of average access distance for BART system and Lindenwold Line.



*8 BART Stations: Concord, Pleasant Hill, Rockridge, El Cerrito Del Norte, N. Berkeley, Ashby, Union City, and Bay Fair

**7 Lindenwold HSL Stations: Lindenwold, Ashland, Haddonfield, Westmont, Collingswood, Ferry Ave., and Broadway

STATION INFLUENCE AREA

The average distance of all trips to and from a particular transit station is an indication of the size of the area that the station services. Figure 1 (2) shows the distribution of average distances traveled in accessing eight Bay Area Rapid Transit (BART) stations and seven stations on the Lindenwold High-Speed Line. The average access travel distances ranged from 2.4 to 6.1 km (1.5-3.8 miles) and 3.1 to 9.1 km (1.9-5.6 miles), respectively, for these two systems. Figure 2 shows the distribution of travel distances for specific access modes.

These data show that the range of access distance differs between systems and among modes. The observed patterns are a result of complex interrelations that complicate the development of a prediction methodology.

An analysis of the data from the BART system and the Lindenwold Line reveals little increase in transit-station trip production when the market area goes beyond 6.5 km (4 miles). Therefore, for the purpose of this study, a distance of 6.5 km from the station is used to define the influence area, the distance from which trips are considered to be attracted to the station.

The station area is defined as the area within