Planning and Design of Intermodal Transit Facilities

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This paper presents an analysis of the present state of the art of transit station planning and design. It discusses the design process in terms of (a) design parameters and standards (e.g., stairways, ramps, and passageways; escalators; platforms; fare and exit control; moving walkways and ramps; bus facilities; and parking facilities); (b) design of the station environment (e.g., lighting, ventilation, acoustics, and fire control; passenger information and graphics; passenger security; commercial activities; and special provision for the handicapped); and (c) design methodology (e.g., deterministic, probabilistic, and impedance models; simulation; and validation problems). A classified bibliography is included.

The planning and design of intermodal transit facilities has become an area of increasing concern because of the major investments now being made in new rapid transit lines and the need to rehabilitate stations in older systems. The function of the transit interface in the overall system operation is to process the flow of passengers between modes. The degree with which the transition is accomplished smoothly and in a safe and pleasant environment will strongly influence system acceptance. Poorly designed transit stations can offset the advantages of the line-haul rapid transit portion of the system if the perceived impedances within the station outweigh the gains in point-to-point travel speed. Since station-to-station travel times cannot easily be decreased because of the relatively short distances involved, the influence of transit station design is critical in the overall system performance and in the share of the urban travel market attracted to new rapid transit systems.

Transit stations have been planned and designed for over a century, and there are many examples of excellent stations in both North America and Europe. Yet, the procedures and methodology for the planning and design of transit facilities have generally been piecemeal, qualitative, and limited in terms of the evaluation of alternative designs. Design data and experiences are scattered so that useful principles and techniques are not easily transferred from one situation to another.

The emphasis in this paper is on the transit facility design process, specifically those planning activities that are concerned with the selection of facility components and their spacial configuration based on parameters such as pedestrian flow and passenger processing needs. Inputs into the process are regional travel demand forecasts, transit station locations, and technology selection.

DESIGN PARAMETERS AND STANDARDS

The planning and design of intermodal transit facilities involve architectural, structural, mechanical, electrical, and transit considerations, and often component selection will involve trade-offs among various factors and constraints. The design parameters described below deal with the provisions necessary to create an environment suitable for processing and transferring passengers within the interface.

Passenger circulation requirements should be assessed prior to the selection, sizing, and location of facility components. Generally, station configurations are based on two primary objectives: to avoid conflicts and to provide adequate capacity. Guidelines for planning a transit station circulation pattern should include avoidance of unnecessary turns and dead-end corridors (i.e., direct paths), provision for unobstructed walking areas (e.g., structural columns and ticket machines in the path) and for duplicate access routes, attainment of smooth and continuous traffic flow, reduction of conflict-producing situations (e.g., avoidance of cross-circulation around fare-collecting areas), and provision of escalators where the vertical height exceeds 3.7 m (12 ft).

The capacity of a transit interface facility will be that of the weakest link, and exceeding the capacity will cause congestion, queues, and general passenger disorientation. The principal components of a station processing facility are its stairways, ramps, escalators, platforms, and fare collection areas. Some common guidelines and standards for these elements are as follows:

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Stairways, Ramps, and Passageways

Standards for stairways and ramps require a minimum width of 138 cm (54 in) between handrails, sufficient for two lanes of moving traffic. Ramp grades should not exceed 6 percent. Stairway tread width should be at least 28 cm (11 in), and riser height should not exceed 18 cm (7 in). The most favorable design (3) is a 15-cm (6-in) riser, 30.5-cm (12-in) tread, and 26.5-deg climb. A stair landing of at least 1.8-m (6-ft) depth should be provided every 16 steps within the station. The capacities of ramps and level passageways that meet the above standards are 50 and 55 persons/lane/min respectively; the stairway capacities are 25 (up) and 35 (down)/min.

Escalators

The provision of escalators in new stations is almost universal, although a ramp or stairway should be available as an alternative. Escalator specifications require a minimum tread depth of 40 cm (16 in), a riser height of 22 cm (8.5 in), and a maximum angle of inclination of 30 deg. The normal widths of escalators are 81 and 122 cm (32 and 48 in), which accommodate one- and two-lane passenger movement respectively. Escalator capacity should be sufficient to handle two-thirds of the peak half-hour traffic, and the combined capacity of all stairways, ramps, and escalators should be adequate to accommodate the peak-period traffic with one escalator out of service. Escalator speeds in U.S. transit systems are usually 0.46 to 0.61 m/s (90 to 120 ft/min) [versus 0.61 to 0.76 m/s (120 to 150 ft/min) in Europe]. At a speed of 0.46 m/s (90 ft/min), the ascending capacity is about 3000 passengers/lane/h, but only 2100 descending passengers/lane/h can be accommodated. The installation of two-speed escalators appears to be justified, as a speed of 0.61 m/s (120 ft/min) increases capacity by about 20 percent (15).

Platforms

Both side and island platforms are used in transit station design, the selection being dependent on economic and local factors. Island platforms are easier to maintain and control and can serve both morning and afternoon peaks, but side platforms may be more suitable where track alignment problems exist (e.g., cut-and-cover on street right-of-way or aboveground). Side platforms should be at least 3.7 m (12 ft) wide, with a minimum distance of 1.5 m (5 ft) between the edge of the platform and any obstructions such as railings, escalators, or stairways. Island platforms should be at least 3.7 or 5.5 m (12 or 18 ft) wide, depending on whether the access facilities are located at the ends or at the center of the platform (14). The optimal width for a side platform may be closer to 4 m (13 ft), which provides 1.8 m (6 ft) for the escalator or stairway and a 2.1-m (7-ft) clear area. This allows for two lanes of moving passengers, one standing lane, and a safety lane at the edge of the platform. By these criteria, a center-access island platform should be at least 6 m (20 ft) wide. For volumes in excess of 5000 passengers/d, these dimensions should be revised upward according to expected peaking characteristics.

Fare and Exit Control

Fare control components include change booths and turnstiles. The technology ranges from coin-operated low turnstiles to magnetically stored tickets that compute the fare and control entry and exit. Capacities of turnstiles range from 15 persons/min for coin-operated machines to 30 persons/min for machine-read tickets. Low turnstiles are not recommended where illegal entry is a problem, and exits should have sufficient capacity to permit all debarking passengers to leave the station before the next train arrives. [The Chicago Transit Authority (7) suggests a one-agent booth and a low coin-operated turnstile for each 800 peak-hour passengers. On the other hand, the New York World Trade Center has found one coin-operated machine per 2000 peak-hour passengers to be adequate.]

Moving Walkways

Moving walkways are not widely used in transit stations because the walking distances are relatively short and walkway speeds are low [maximum 0.91 m/s (180 ft/min)]. Generally, the treadway slope should not be greater than 15 deg and the walkway length should not be greater than 305 m (1000 ft). The capacity of a moving walkway depends on its width and speed. With a 64-cm (25-in) width and a speed of 0.64 m/s (125 ft/min), a walkway can accommodate approximately 3600 persons/h.

Bus Facilities

Feeder and line-haul bus service should be integrated within the terminal facility for the comfort and convenience of the passenger. Among the desirable items are (a) separation of buses from other vehicles to avoid conflicts with automobiles and to permit free flow of the buses for better schedule adherence and increased safety, (b) simple connections between buses and trains so that walking is direct and short, (c) provision for expansion to accommodate increased traffic, (d) separation of bus terminal roadways from those for parking or kiss-and-ride access, and (e) a lane for defective or pull-in buses in each turnaround area.

Parking Facilities

The provision for automobile parking at suburban transit stations is essential because park-and-ride is one of the principal access modes. Generally an area of 28 to 42 m^2 (300 to 450 ft^2)/space has been allowed for parking, but newer designs such as used by BART have higher standards that require 42 to 44 m^2 (450 to 475 ft^2)/automobile. The parking policy can influence the design, for example, in the provision of meters, spaces for business parking, or for short-term and long-term commuter parking, security, and lighting and policing functions.

DESIGN OF THE STATION ENVIRONMENT

The quality of the station environment is a design objective equal in importance to those of passenger flow and capacity. The perception of the station in terms of such human attributes as comfort, security, orientation, and scale will be reflected in passenger acceptance and use. Stations should be well-lighted, simple to negotiate, quiet, temperature controlled, and supportive of other passenger needs.

Lighting, Ventilation, Acoustics, and Fire Control

Design standards for lighting, ventilation, temperature-humidity control, and noise have been defined by the transit industry and in professional society handbooks and codes. There is also a considerable amount of

research by the U.S. Department of Transportation on noise and ventilation to assist designers in these matters.

The Institute for Rapid Transit (IRT) (10) lists the following important considerations in station lighting: minimum illumination levels, maximum brightness ratios, maximum discomfort glare rating, reflectance, and provisions for emergencies. The IRT design standards can be used to test the adequacy of lighting for each station configuration.

Station ventilation is critical for underground stations and can be accomplished by the piston action of the moving trains and mechanical means. Ventilation by piston action requires coordination of vent shafts, tunnel sections, and stair and passageway areas. Mechanical ventilation involves a system of fans, air intakes, exhaust structures, and distributive duct work.

The goals for station acoustics are to maintain noise levels in vehicles and stations within acceptable limits and to limit the noise impact of stations on the surrounding community. Noise control is achieved by the acoustical designs of the vehicle, station, and roadbed. The IRT has established design criteria and standards for noise and vibration levels that vary with their intensity and the location. The maximum tolerable noise level in a station is in the range of 80 to 85 dBA, although constant exposure to noise at this level could be harmful. Accordingly, the noise levels of the trains should be minimized, and sound-absorbing materials should be used in the stations.

Fire control is accomplished by (a) using materials that are fire resistant and produce only limited amounts of dense or toxic smoke in the station, vehicles, and equipment; (b) furnishing adequate fire alarm and detector systems, standpipes and hoses, and portable fire extinguishers; (c) providing means for passenger escape and entry for fire-fighting equipment; and (d) providing mechanical ventilation equipment that can remove smoke from tunnels in alternate directions and supply fresh air to exits as needed. Fire hazards should be eliminated and provisions made to isolate and confine danger areas.

Passenger Information and Graphics

Information and directions for passengers are essential to the functioning and operation of a transit station. Passenger orientation is the principal criterion for the effectiveness of an information system, and the design should provide a continuous path of graphic directions between the transit vehicle and the street. Messages should be simple to understand and provided at frequent intervals. Principles and guidelines for passenger information systems are (a) to use a single style of lettering, standard signs, and simple words; (b) to avoid confusion by eliminating advertising in the vicinity of information graphics; (c) to locate information at critical decision points; (d) to provide map space near fare collection areas and on platforms; (e) to minimize the number of independent messages at each point; (f) to maintain continuity, consistency, and sight distance; and (g) to furnish direct information that does not require translation into other terms or units.

Passenger Security

Transit facility design must include provisions for passenger protection from harassment and violence, the surveillance of potential criminal acts, and the means for apprehension of persons involved in vandalism and other illegal acts. The problem is complex, and the role of station design is to provide an environment in which crime is deterred or discouraged. Among the means are (a) provision of open station and platform areas in direct view of station attendants, (b) direct telephone access to the central transit office and local police, (c) television surveillance of selected station areas, and (d) direct communications for passengers via telephone or alarms.

Commercial Activities

The provision of concessions within transit stations is a matter related to management policy. The benefits of providing commercial outlets for the sale of newspapers, candy, and other short-order items are an added convenience for the transit patron, income for the transit agency, and the vitality of the area due to the life and color brought into the station by advertising and concessions. On the other hand, these facilities consume valuable mezzanine space, interfere with the traffic flow, contribute to the untidiness of stations and vehicles, require additional maintenance and cleanup crews, and promote vandalism and loitering.

Special Provisions for the Handicapped

The needs of handicapped persons are being incorporated into modern transit station design. Common barriers that have excluded handicapped persons from transit riding are steps or curbs that are too high; long flights of stairs; inaccessible elevators; steep or narrow walks; gratings in walkways; narrow doors, revolving doors, or hard-to-open doors; narrow aisles; and lack of accommodation for wheelchairs.

DESIGN METHODOLOGY

The process of transit station design involves the testing and evaluation of alternative configurations and includes the following procedural steps: (a) define the constraints on the station location; (b) develop passenger and vehicle flow data by origin, destination, access mode, line, and headway; (c) establish design objectives, criteria, standards, and requirements; (d) prepare alternative station design layouts; (e) evaluate the performance of each design; (f) select the design alternative that best meets the standards and criteria; and (g) refine and iterate the process until an optimal design is prepared.

Application of the station design process has generally followed accepted practices within the architectural and engineering professions and used design standards, codes, judgment (rules of thumb), and results gained from the experiences of established transit operations. Analytical techniques based on mathematical models and computer simulation have not been widely used in the evaluation of alternative station designs. However, a number of research studies dealing with various elements of transit station behavior (e.g., walking and waiting times and arrival and service distributions) have been incorporated into several recently developed station simulation programs. These analytical models and techniques are intended to assist the station designer to answer questions related to the amount of space required for queuing and circulation areas, the number of service (e.g., fare collection) facilities needed, and the locations and dimensions of passageways, escalators, stairs, and connections between service areas.

Simulation Models

Computer design methodology is based on the application of simulation techniques that can analyze the dynamic and microscopic performance characteristics of alternative terminal designs. The principal efforts in these areas are the works of Fausch and Barton-Aschman

Associates, who have developed computer programs to replicate transit station performance for the Urban Mass Transportation Administration (29, 30, 33, 34, 35). The intent of the project was to develop a transit station design tool that is flexible, in terms of user input, accuracy requirements, and computer time; not limited by the availability of data; and usable, in terms of its ability to evaluate a variety of design proposals in terms of specific objectives. This simulation package is designed to determine three basic types of design data for a given station layout. These are the travel times for individuals within the station, the pedestrian occupancy requirements, and the distribution of these variables for comparison with design standards. Among the unique features of this simulation package are the representation of a two-way flow pattern and passenger interaction and a station description in terms of links or nodes for both vehicles and passengers. Design flexibility is available through the capability to add or combine links and thus control the level of detail required.

Validation of Transit Station Models

Computer models for transit station design are tools with which to evaluate alternative interface facility layouts. The designs are the inputs to the model and require the creative efforts of the station design team. Verification of simulation models is generally difficult because of data acquisition problems and the complexity of the passenger flow process. The use of such models in transit station design is not common practice although there is increasing interest in these techniques. They are expensive to implement, but could pay for themselves if used from the outset on large projects in which numerous variables are introduced as time goes on.

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