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DESIGN OF TRANSPORTATION INTERFACE FACILITIES

A PROCEDURAL GUIDE

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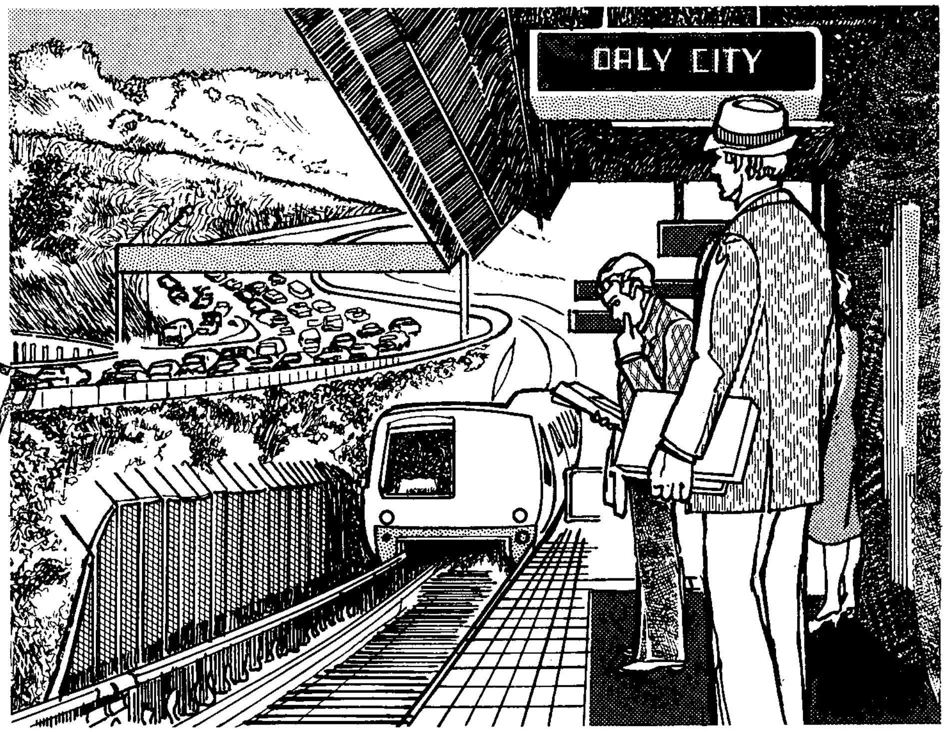

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16. Abstract

This GUIDE provides a synthesis of state-of-the-art concepts regarding the planning, design, and evaluation of passenger transportation stations. The enclosed material directs transportation planning teams to search for efficient station designs. By itself, the GUIDE describes the important stages and considerations in a comprehensive terminal analysis methodology. When it is used with the two supplementary research reports, the specific details of the various tasks are given.

This GUIDE acknowledges that the transit station design process requires contributions from many disciplines and skills. It assists to coordinate station development programs in accommodating inputs from the disciplines. It further highlights the elements of different stations to assure valid comparisons relative to performance and cost criteria.

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EXECUTIVE SUMMARY

A. INTRODUCTION

Two recent research reports describe the development of a methodology for designing and evaluating transit station designs.[1,2] The first was entitled " Criteria for Evaluating Alternative Transit Station Designs" and it develops appropriate criteria for the evaluation of alternative transportation station designs. The second document, " Methodology for the Design of Urban Transportation Interface Facilities," provides a methodological framework and identifies associated tools and techniques for designing and evaluating alternative transit passenger terminals. Specifically, methods for establishing policy for transportation station designs and for measuring the performance and economic efficiency of the functional elements of transit terminals are described.

B. PROBLEM STUDIED

This PROCEDURAL GUIDE is written to provide a general nontechnical overview of the important considerations of the planning and design methodology for transit stations. It is intended to summarize the design process for use by transit managers and policy makers. Also, station planners, architects, and designers may use the GUIDE to obtain an overview of the total interdisciplinary systems planning process which results in the construction of specific stations at

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[1] Hoel, L. A., Demetsky, M. J., Virkler, M. R., Criteria For Evaluating Alternative Transit Station Designs, RLES Report No. CE-4142-101-76, Department of Civil Engineering, University of Virginia, Charlottesville, VA., February 1976.

[2] Demetsky, M. J., Hoel, L. A., Virkler, M. R., Methodology for the Design of Urban Transportation Interface Facilities RLES Report No. UVA/529036/CE76/102, Department of Civil Engineering, University of Virginia, Charlottesville, Virginia, December 1976.

designated locations. This GUIDE can also be used to communicate to the lay public the method by which a particular transit station plan evolves.

C. RESULTS ACHIEVED

The PROCEDURAL GUIDE defines a series of tasks which, when combined, identify a systematic method for planning, designing and/or evaluating transit stations. The role of the station in the transportation system is first set forth. Categories of information about the transportation system that enter into the station design process are identified as system technology, route alignment and operating policy; station location; line haul modal demand volumes; and access mode volumes. This system data is then interpreted to establish related design requirements and constraints for the station. The interface facility design process is then initiated and includes the following tasks.

System Definition

The transportation station is defined as a system of interacting components or modules. Two primary classes of station components are specified as passenger processing elements which aid pedestrian movement, and the environment which encompasses those dimensions with which the pedestrian associates his or her personal comfort, convenience, safety, and security. The combined performance of subsystems for passenger processing and environment conditions accounts for the overall effectiveness of a station design.

Two classes of users are considered, the general user and the special user (the physical handicapped and elderly). Special devices, design features, and policies are usually required to aid the special user, and are included in the passenger processing subsystem.

Objectives, Criteria, and Measures of Performance

A listing of station design objectives is derived to reflect the points of view of the general user, the special user, and the station operator. These objectives are associated with passenger processing, the station environment, and economy, and are translated into a set of example criteria categories which can be used as indices that define explicit performance measures.

Policy and Measures of Performance and Cost

Terminal performance criteria are classified according to the manner by which they enter the terminal analysis process, i.e., as a result of an initial policy decision, or as measures of performance and economic efficiency. The former category reflects contemporary community standards, while the latter two provide physical measures of station effectiveness. This classification is used to show how decisions regarding the various design elements are treated in the transit station design methodology.

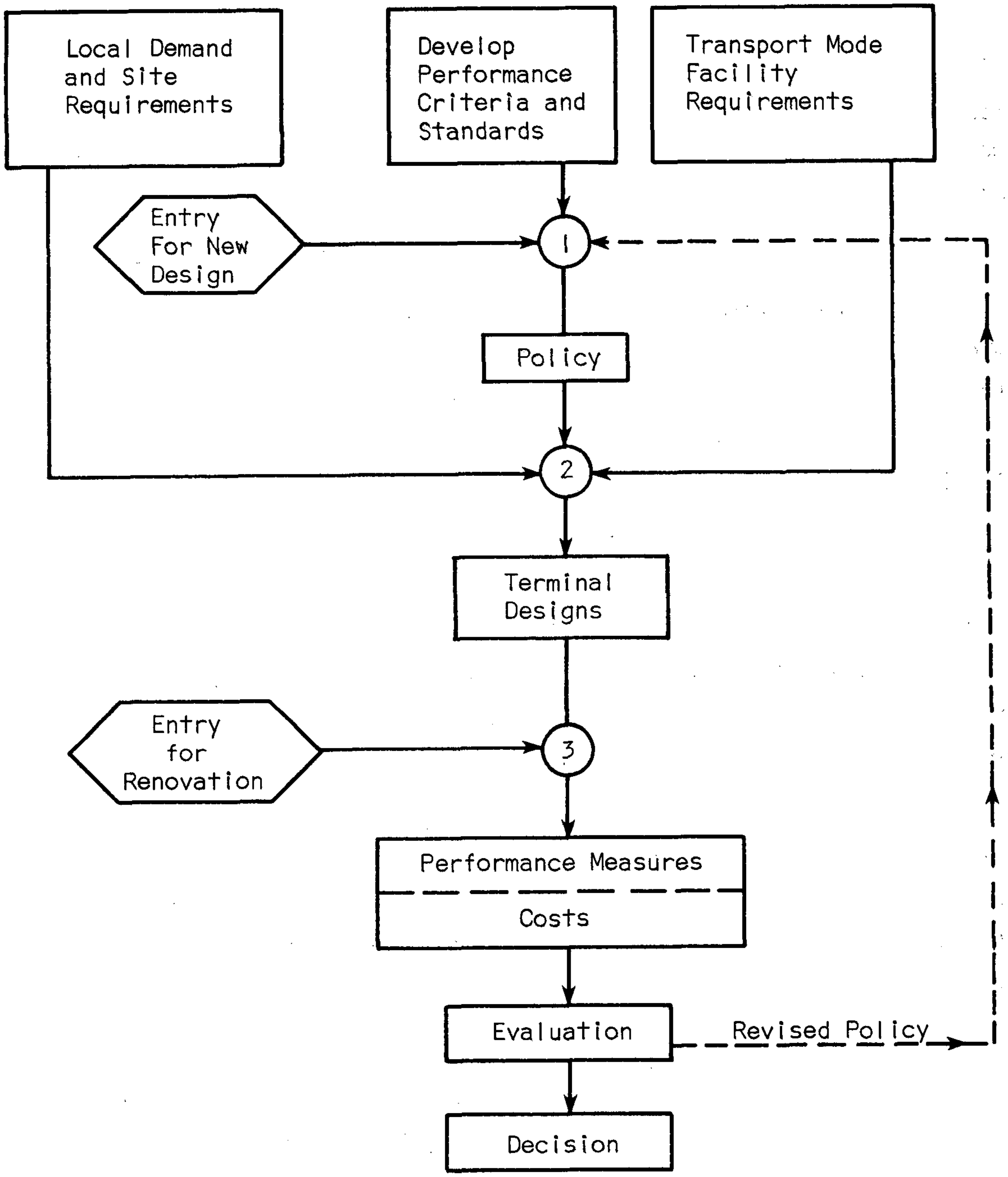
Design Process

A framework for analysis of transit stations which is based on the use of the policy, performance, and cost categories for the design criteria is shown in Figure 1. In this process performance criteria are employed in a design methodology which uses supply, demand, and policy requirements in designing and measuring the performance and cost of alternative terminal facilities.

Design Variables (Performance)

The transit station design process requires that each component be selected according to pre-established criteria. Consideration must also be given to interactions among the components to assure compatability among the different station features.

Typical station components which are considered for performance include: passenger processing, passenger orientation, the physical environment, security, and safety. Other station components are required to meet explicit policy objectives. Areas where public officials are most likely to establish policy regarding transit



◯ Indicates the application of terminal analysis procedures for the following purposes:

1. Establish policy
2. Generate alternative terminal designs
3. Establish performance and cost measures for each alternative

Figure 1. Transportation Interface Facility Design Process

terminal programs include: concessions, advertising, personal care facilities, public telephones, aesthetics and cultural environment, construction materials, design flexibility, parking facilities, and provisions for special users.

Alternative Designs

When appropriate policy has been established for a transit station, alternative physical components and layouts can be tested. The measures of effectiveness which result from the interaction of a number of station design parameters must be calculated for each alternative.

Measuring Performance and Cost

Analytical techniques are used to analyze the performance of alternative station designs. In particular, the ability of the design to meet the objectives associated with passenger processing, passenger orientation, the physical environment, security, and safety are addressed.

For preliminary planning, station costs can be estimated with cost equations which use aggregate station characteristics to reflect unit costs. For more detailed study, costs are estimated by determining the sum of costs for each individual element of the station.

Evaluation Process

The station design process as shown in Figure I terminates with the selection of a specific transit station design that satisfies the requirements. This choice among alternatives is accomplished through a structured evaluation process which compares the proposed designs in terms of the important performance measures that derive from the stated objectives for the policy, performance, and cost categories. An evaluation matrix is recommended which provides the decisionmaker with a summary of all performance parameters according to their role in the design method. Explicit measures of performance or numerical indices derived from subjective rating schemes are entries to the matrix cells.

D. UTILIZATION OF RESULTS

This GUIDE can be used by transit managers and policy makers to understand the transit station design process so that better decisions can be made. It also can be used by architects, engineers, and planners to develop an appreciation of the entire station development process. Complexities and interrelationships among various parts of the station can be studied with the given procedures.

E. CONCLUSIONS

This GUIDE provides an overview of a systematic methodology for planning and designing transit stations. The available material is sufficient to ensure that better transit stations can be developed.

PREFACE

This research is a continuation of work begun under a grant from the National Science Foundation to develop and demonstrate a methodology for the design of transit stations. The outcome of this first phase was the identification of major weaknesses and suggested improvements in station design procedures.[1]

This second phase of the study is sponsored by the U. S. Department of Transportation, Program for University Research and involves the development of a station design methodology. Two previous research reports were published for this project. The first identified criteria for the evaluation of alternative station designs and recommended a general evaluation model.[2] The second related document described the basic methodology for the design and evaluation of transportation stations.[3]

This document is a GUIDE for the application of the concepts and techniques that were researched and developed in the three earlier reports. The GUIDE represents a synthesis of the research results in a format suitable for transit managers, public officials, social planners, and other professions that are less technically oriented than engineering and planning. The GUIDE describes the important tasks and considerations that are associated with the design of

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1 Hoel, L. A., Roszner, E. S., Transit Station Planning and Design: State of the Art, Transportation Research Institute, Carnegie-Mellon University, Pittsburgh, Pennsylvania, January 1975.

2 Hoel, L. A., Demetsky, M.J., Virkler, M. R., Criteria for Evaluating Alternative Transit Station Designs, Department of Civil Engineering, University of Virginia, Charlottesville, Virginia, March 1976.

3 Demetsky, M. J., Hoel, L. A., and Virkler, M. R., Methodology for the Design of Urban Transportation Interface Facilities, Department of Civil Engineering, University of Virginia, Charlottesville, Virginia, December 1976.

passenger transportation stations.

A third phase of study is currently in progress. During this final effort, the design methodology will be tested and refined as necessary in applications to the renovation of existing terminals and design of new stations.

A PROCEDURAL GUIDE FOR THE DESIGN
OF TRANSIT STATIONS AND TERMINALS

I. INTRODUCTION

A. Purpose

Many transportation operating agencies whose systems include rail rapid transit have developed Design Standards and Design Guidelines to assist architects in the design of transit stations.[1,2,3] Though these manuals contain detailed information on many of the station design components that have become standardized, they do not attempt to describe the role of each component with respect to the major facility objectives nor do they address tradeoffs among the different design elements. In many cases, policy decisions regarding the design and renovation of transportation stations require the decisionmaker to have an explicit understanding of the impact of a specific station feature on the facility's overall effectiveness. Furthermore, in order that station designs derive from appropriate objectives, and that alternative designs be efficiently evaluated, a goal-related design methodology is desirable to augment contemporary design standards.

In other documents the authors have described a comprehensive way to organize the design process for transportation interface facilities.[4,5,6] This PROCEDURAL GUIDE has been written to provide a general non-technical overview of the important considerations in the planning and design process. It is intended especially to summarize the design process in terms of research results for transit managers and policy makers. Also, station planners, architects, and designers may find this GUIDE useful to obtain an overview of the total interdisciplinary systems planning process which results in the construction of specific terminals at designated locations. This GUIDE can be also used to explain to the lay community the method by which a specific transit plan is developed. The basic position from which the GUIDE is developed is that station design requires careful attention to assure that the sufficient conditions, the many values, interests, and concerns involved in station design find full and appropriate expression in the earliest stages and continue to be heard.

Problems involving the upgrading of urban transit passenger transportation terminals and the development of interface facilities in future transit systems make use of this methodology. The procedures can also be used for other modal interchange facilities such as intercity rail and bus stations and in the development of prototype interchange facilities for new technology such as dual-mode systems.

B. Scope and Limitations of the GUIDE

This guide describes the planning and design process for transit stations and is intended to present an overall framework for use in various applications. Particular design teams working in specific communities with unique design situations must adopt the procedures to their needs. There is no universal precisely formulated design scheme that can be applied uncritically. Thus, this guide, while resulting from extensive studies, reviews of current practice, and literature, and buttressed by significant experience among the authors, is just that-- a guide to good practice.

The scope of consideration is an urban station or terminal for bus, subway, personal rapid transit, automated guideway transit, or interity passenger rail service. Airports and water terminals are excluded as each has a literature of its own. But the very words "station" and "terminal" suggest priority to the line haul mode. In this GUIDE, the terms "interface facility" and "intermodal facility" are used to recognize the fact that stations are nodes through which travelers pass as they access the system, exchange modes or make connections between different lines or routes in the same mode. They suggest a neutrality among modes and attention to the station itself.

Terminology varies also in references to users, travelers, and tripmakers, but these terms are interchangeable without confusion. A third note on terminology has to do with "actors" in the planning or design process. References to designer, analyst, planner, and decision maker indicate the respective tasks to be undertaken, but do not presume the composition of the team. Quite obviously, the composition of a design team might be assisted by a review of the tasks described in the GUIDE, as modified by the size and importance of any station or set of stations.

C. Organization of the Guide

The following chapters are organized to show a step-by-step outline of the planning and design process. If the reader wishes to pursue the full process, he or she should follow the organization as developed. However, the extended outline also permits use for reference to specific topics.

The overall role of the interface facility in the transportation system is discussed in Chapter II. That section deals with the procedures used in selecting the basic technological components of the transit network (e.g., routes, vehicle types, inter-station spacings, etc.), leading to a synthesis of the individual station planning requirements.

Chapter III focuses on the planning of a single station, to allow passenger movement from arrival by any mode (including walking) to departure by any mode, and to attend to the environment within and around the station. From these considerations, design objectives are developed, translated into measurable criteria for performance, cost, and hence for policy recommendations.

Station design variables are then identified according to the manner by which they are treated in the design process (i.e., according to some standard, policy, or performance measure). A design and evaluation methodology applicable to transportation interface facilities is then presented to summarize the preceding considerations. Available approaches for developing performance measures with the design methodolgy and selecting station components are summarized.

Chapter IV deals with the establishment of station design parameters. Policy alternatives are reviewed for such elements as concessions, advertising, personal care facilities, public telephones, aesthetics, construction materials, design flexibility, parking facilities and provisions for the elderly and handicapped. An approach for fashioning design alternatives is shown and methods which can be used to measure the performance and cost of these alternatives are summarized. The methodology for the evaluation of alternative designs is then presented.

In summary, this report describes the series of tasks which, when combined, identify a framework for planning, designing and/or evaluating transit interchange facilities. The individual steps of the station design process are summarized in Figure I. As will be shown later, these basic design tasks are actually employed within an iterative design process which accounts for the interrelationships among the associated tasks.

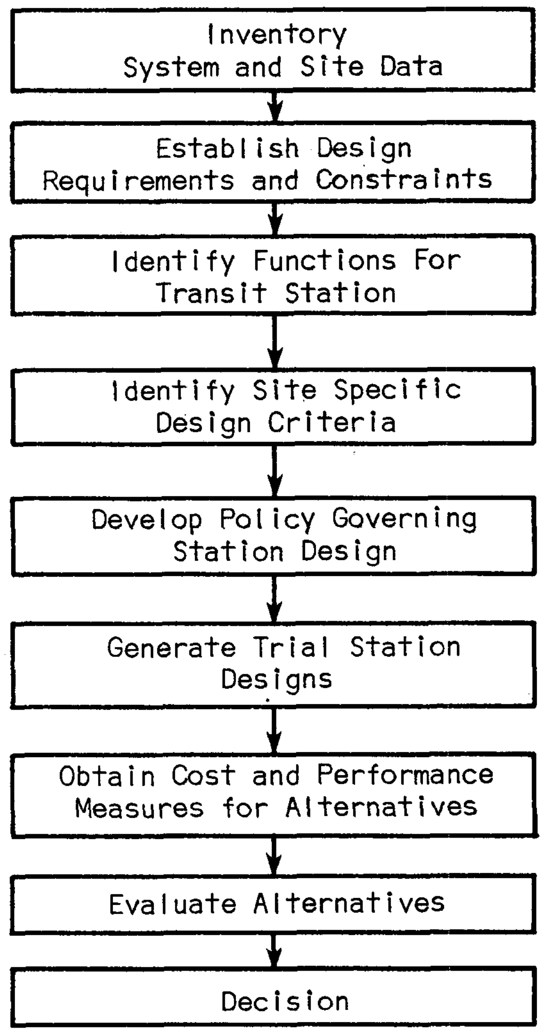


FIGURE 1: Stages in the Station Design Process

II. THE ROLE OF STATIONS IN THE TRANSPORTATION SYSTEM

A. Introduction

This section describes the process through which the system comprising all of an area's transit services evolves, identifying the information needed to develop specific station designs. During the initial transportation systems planning stage, alternative networks and/or technologies are proposed and analyzed. Each alternative is defined by a set of links, nodes, and vehicles. It is the nodal or interface points where transit stations are ultimately developed.

The total of demands for through, boarding, and departing services must be estimated for each terminal node. Typical information that is used to forecast the station demand and market area include density and location of various land uses, income levels for residential areas, demographic characteristics and expected system levels of service (i.e., frequency of arrivals, accessible destinations, etc.). Each terminal site is characterized by specific measures which can influence the station design. Important site parameters include available land, cost of land, adjacent land uses, long run expansion potential, local transportation facilities, and others.

The categories of information about the transportation system that enter into the station design process are listed below and examined in the following paragraphs:

(1) system technology, route alignment and operating policy;

(2) station location;

(3) demand analysis; and

(4) access-mode volumes.

B. System Technology, Route Alignment and Operating Policy

System technology defines the type of transportation modes used (e.g., subway train, express bus, feeder bus, personal rapid transit, automated guideway transit, etc.) in the transit system, as well as some of the characteristics of the station (e.g., underground vs. above-ground, types of line-haul modes served, etc.). Route alignment determines, to a large extent, where stations may be located. Operating policy for the transit system also has an impact on individual station design, especially in provisions for the elderly and handicapped, security measures, hours of operation, vehicle headways, and other operating characteristics.

System technology, route alignment, and operating policy can all have an effect on the distance between stations. Some types of transportation technologies, such as subway trains and personal rapid transit, require shorter inter-station spacings than others, such as commuter rail and express bus. Route alignment may often limit the available locations for stations, thereby affecting station spacing. Operating policy may dictate the spacing by requiring certain minimum or maximum spacings. There are also trade-offs to be made. The closer together the stations are, the shorter the time and distance required for riders to reach a convenient one. However, closely spaced stations increase the frequency of stops by the line-haul vehicle (increasing the line-haul travel time) and increase the number of stations which must be built.

C. Station Location

After the transit system plan has been established a number of alternative sites for each station must be evaluated. The necessary considerations, and their relative importance, will vary according to the type of transit mode(s) the station will serve (e.g., express bus, subway, inter-city rail, etc.) and the function(s) the station will have (e.g., suburban commuter, central terminal, etc.). For any type of station, the major considerations include the eight factors described below. (7)

1. Ridership Potential

The estimated passenger demand corresponding to each site can be determined from the results of the estimation of general trip-making characteristics. Some planners feel that the state-of-the-art in passenger forecasting is insufficient to sustain any great degree of confidence and that station designs should be examined to determine the effects design will have upon demand. For example, design might limit usage by providing too low a capacity or, on the other hand, might greatly increase future demand by helping to attract higher levels of land use in the surrounding area.

2. Accessibility to Major Corridor or Expressway

This might be a major consideration for express bus or commuter rail stations, or any other for which high volumes of automobiles are expected to be used at the station. However, if the large majority of users arrive by walking, such as in central business districts, this consideration may be of little importance.

3. Accessibility to Local Walk, Auto, and Bus Travel

In general, each site would be evaluated relative to the availability of existing or proposed facilities to service the arrival and departure needs of walkers, autos, and buses.

4. Compatibility with Surrounding Land Use

Stations generally have a strong impact upon surrounding land use. For this reason potential sites should be evaluated relative to their compatibility with local land uses and environmental impact. In some areas compatability with surrounding land use has led to the commuter use of parking lots of churchs and shopping centers. In some central cities transit stations have been viewed as potential focal points for the economic redevelopment of the immediate area.

5. Current Use of Site

The relative importance of this characteristic varies with the type of transit mode under consideration. For an express bus station, either vacant land or a currently under-used parking lot might be a prime location for a park and ride lot. For a system that requires much higher capital costs and has less flexibility of location, such as a subway system, the site's current use would be relatively less important.

6. Size of Site

Each site should be evaluated to determine if adequate space (land) is provided for the movement and storage of vehicles and people. Therefore, some knowledge of anticipated demand and architectural requirements may be necessary. In turn, the size of site may influence the complexity and cost of the design.

7. Potential for Site Expansion

Consideration would normally be given to future needs for expansion of the site. This would be most important in areas where large growth is anticipated in population or transit need. Stations in locations with high levels of surrounding land use, as in downtown areas, might not require future site expansion while stations in locations currently surrounded by lower levels of land use, as in suburban areas, might have a future need for expansion.

8. Cost of Construction

While candidate sites for a particular station may have identical proposed station designs, construction costs may vary significantly due to site characteristics. Therefore estimates of construction cost would be needed for each site.

D. Demand Analysis

Design of transit stations requires adequate prediction of transit ridership characteristics such as daily demand, peak hour demand, and the overall time distribution of demand. The systems planning process provides this information for each station site.

E. Access Mode Volumes

The most common transit station access modes are park-and-ride (park car, ride bus), kiss-and-ride (dropped-off at station from auto), carpool, local feeder bus, motorcycle, bicycle, and walk. Obviously the percentage of people using each access mode may be quite different for each station. The predominant access mode in central business districts is the walking mode, while in suburban areas it is the auto. Factors which also affect the percentage distribution among various access modes include station design, topography, climate, traffic conditions, traveling times, and socioeconomic characteristics of transit users.

Different access modes require different accommodations at stations. Park-and-ride and carpool users require parking facilities for their autos at or near a station. Figure 2 shows a station platform view of a parking lot. Motorcycle and bicycle users require different types of storage for their vehicles.

Kiss-and-ride patrons require a safe and convenient drop-off point, as do local bus riders. Figure 3 shows a station's kiss-and-ride cul-de-sac. Figure 4 shows a station's kiss-and-ride waiting area having space shared with a local bus stop. Finally, people who walk to a station need a safe and convenient pathway for their access.

Each access mode requires that the roadway or walkway network around the station have sufficient capacity to handle the demands placed upon it. Therefore station access mode accommodations are defined by provisions for vehicle storage, passenger drop-off, and the surrounding travel networks.

The planning and design group must consider each of the items cited above, singly and as they interact mutually, to determine the conditions for design. As in each stage described in this GUIDE, the system considerations will recur in the several stages: program development, program design, station planning, and station design. This iterative process is essential because of the complexity of design conditions and the large number of constituencies who hold stakes in the finished design.

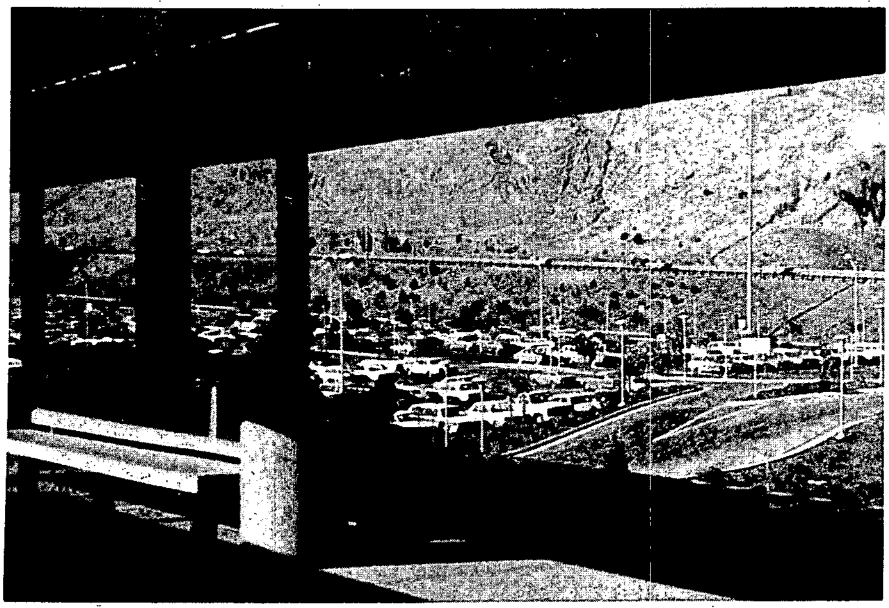


FIGURE 2: Parking Lot Viewed From Elevated Station
(BART Orinda Station)

FIGURE 3: Kiss-and-Ride Cul-de-Sac for Quick Drop-off (Stockholm)

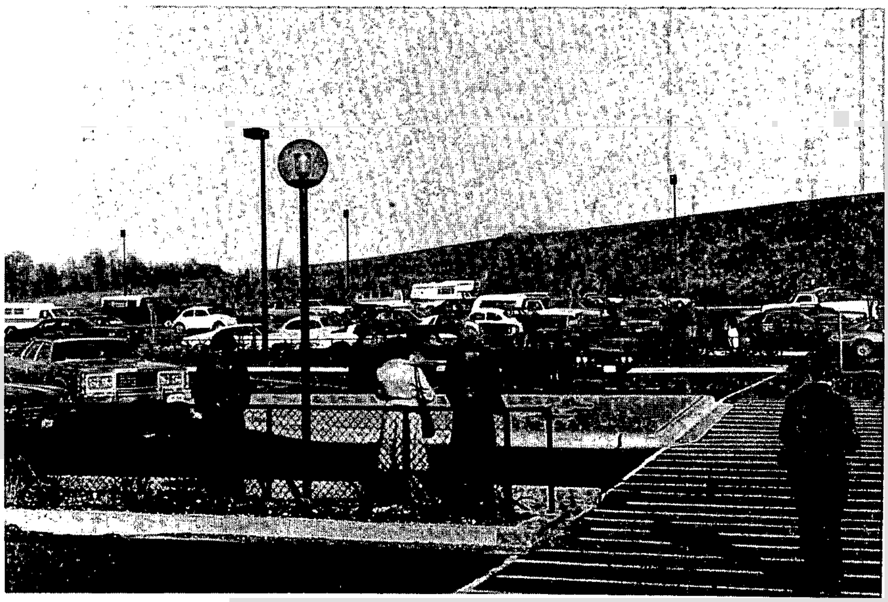


FIGURE 4: Kiss-and-Ride Pick-up Point at Rhode Island Avenue Station (Washington METRO)

III. STATION DESIGN PROCESS

Station design can proceed only when the system considerations described in Chapter II have been worked out. The station design process must account for trade-offs between the planned paths of users through the station, the environment of the station, the criteria for design performance, and standards and other indicators of adequate performance, and cost.

A. Processing of Passengers.

Some knowledge must be gained and predictions made as to the number of passengers who will pass through the station. This information must be translated into requirements for space and equipment to enable the riders to pass through the station efficiently, safely, and comfortably. Two classes of users must be considered, the general user and the special user (the physically handicapped and the elderly).

The discussion that follows focusses on the components in the station, but by inference one can see what considerations must be given to the users. Attention to the components permits the planning team to identify performance indices associated with design objectives and criteria for evaluation.

Accordingly, functional components are those elements provided to meet the operational objectives of the station. They establish the effective passenger capacity of the facility that results from the type and amount of facilities provided for pedestrian movement and staging. The major functional components are combinations of space and devices listed below:

1. Internal pedestrian movement (passageways, stairs, ramps, escalators, elevators, moving walks, ramps, etc.);
2. Line haul transit access (entry control and fare collection, loading and unloading);
3. Components which facilitate movements between the access

modes and the station (ramps, electric doors);

4. Communications (information and directional graphics, public address system); and

5. Special provisions for the elderly and handicapped.

The amount and arrangement of pedestrian travel facilities and space in terminals will affect different measures of aggregate travel times, distances, and queueing. Accordingly, the interchange system arrangment must be considered. The following measures are useful in describing the effectiveness of a station layout.

1. Coherence: connectivity, accessibility, continuity.

2. Travel distances, times and delays.

3. Conflicts (among passenger flows).

4. Security considerations (e.g., isolated paths, dark corners, etc.).

5. Path choice available.

6. Queueing points.

Accordingly, both the amount and arrangement of the interchange facility components establish the passenger processing subsystem of the station.

B. The Station Environment, Amenities, Safety, and Security

The environmental quality of a transit station is represented by those dimensions with which the pedestrian associates his or her personal comfort, convenience, safety, and security. These environmental considerations are not directly associated with the movement of people but pertain to the physical environment through which they move. Amenities are difficult to assess and produce subtle effects on people's attitudes, but for design purposes they can be associated with activity points within the interface facility. These activity modes have an indirect effect on the functional mission of the station, as their availability enhances the terminal environment. Typical environment-amenity concerns include the following.

1. The physical environment (lighting, air quality, temperature, aesthetics advertising, cleanliness, music, etc.).

2. Non-transport businesses and services (private concessions such as newspaper stands, coffee shops, barber shops and other small businesses and services).

3. Restrooms and lounges; first aid stations; public telephones.

4. Weather protection.

5. Other.

The terminal environment also affects safety and security conditions. Typical safety standards incorporated into station design include fire prevention and accident reduction measures. Security provisions are employed for protection against crime and vandalism.

The amenity, safety, and security features can be said to comprise and environmental subsystem of the transit station. The combined performance of subsystems for the passenger processing and environmental conditions accounts for the overall effectiveness of a station design.

C. Provisions for Special Users

In addition to the design considerations regarding the ordinary user, recent transportation systems designs and related legislation reflect an increased concern for special users, especially those handicapped and elderly individuals whose ambulatory functions are impaired. Devices, design features, and policies which aid these groups are included in the passenger process subsystem. Typical measures which may be taken include lanes for movement outside of crowds and special level change devices such as elevators. Some minimum standards or specific features may be required by law for future stations.

D. Objectives, Criteria and Measures of Performance

The goal of station design is to provide the best level of acceptable service under the governing financial and design constraints. Thus, the performance of the station system must be evaluated relative to a set of predefined objectives which derive from the affected interests.

The following listing of station design objectives has been derived to reflect the points of view of the general user, the special user (elderly and handicapped), and the operator.

Passenger Processing Objectives

General User

1. Minimize travel impedances (time, distance)
2. Minimize delays (queues)
3. Minimize conflicts (crossing movement paths)
4. Minimize crowding
5. Minimize disorientation
6. Maximize safety
7. Maximize reliability
8. Collect fare efficiently
9. Minimize level changes

Special User

1. Eliminate level changes
2. Reduce fare collection barriers
3. Avoid crowding
4. Eliminate physical barriers
5. Provide locational guides

Operator

1. Maximize equipment reliability
2. Control entry efficiently
3. Maximize safety
4. Process flows efficiently
5. Provide adequate space

Environmental Objectives

User and Special User

1. Provide comfortable ambient environment (heat, noise, air quality)
2. Provide adequate lighting
3. Provide clean surroundings
4. Ensure an aesthetically pleasant environment (including attractive use of spaces, provision of music, art, etc.)
5. Provide for personal comfort
6. Provide services and concessions
7. Provide adequate weather protection
8. Provide adequate security

Operator

1. Provide proper security
2. Provide adequate safety

Fiscal Objectives

In addition to the objectives associated with the functional and environmental elements of the terminal, the operating agency is concerned with the following objectives concerning economy of the operation and the potential for expanding the facility.

1. Minimize maintenance, cleaning, and replacement needs
2. Obtain an efficient return on incremental investment
3. Receive adequate income from non-transport activities
4. Utilize energy efficiently
5. Minimize total cost
6. Exploit joint development (station built in concert with adjacent retail and other businesses).
7. Provide opportunity for expansion.

The terminal planning, design, and economy objectives that have been given for the interest groups are translated into a set of example criteria categories in Table 1. The categories for a given station design are identified and then used as indices that define explicit performance measures to meet the needs of specific design problems.

Table I. Evaluation Criteria Categories For Station Performance

1. Travel Time Measures
2. Area Provided for Personal Movements
3. Queues (delays)
4. Crossing Flows for Paths
5. Connectivity (directness of travel paths)
6. Effectiveness of Directional Aids
7. Potential Safety Hazards
8. Security Risk Potential
9. Barriers to Special Users
10. Air Quality
11. Thermal Comfort
12. Noise Levels
13. Illumination
14. Personal Comfort Facilities
15. Cleanliness
16. Advertising
17. Concessions
18. Weather Protection
19. Maintenance Requirements
20. Cost Effectiveness
21. Joint Development Potential
22. Design Flexibility

E. Policy and Measures of Performance and Cost

The criteria given in Table I were selected by considering the physical elements of the station and the affected interest groups. To organize and show the roles of station components within a procedural design methodology, a further classification scheme is developed. Here the terminal performance criteria are classified according to the manner by which they enter the terminal analysis process, i.e., as a result of an initial policy decision or as measures of performance and economic efficiency. The former category reflects contemporary community values, while the latter two provide physical measures of the operational efficiency of a terminal function. It is useful to make this distinction because different decision processes govern the two areas. Table 2 illustrates examples of typical station components as classified under this scheme.

The interrelationships among the analytical measures and categories used in this categorical development of station criteria are summarized in Figure 5. This diagram shows the steps involved in defining the elements for an evaluation model. The physical terminal components are identified and those interest groups affected by their performance are considered when developing a set of objectives that apply to the general station design problem. These objectives (e.g., minimize travel impedance) are used to develop a set of criteria (e.g., walk time required) which establish a set of performance measures (e.g., minutes required). The performance parameters are then categorized as either results of policy decisions, measures of the performance of functional elements, or measures of the cost of construction, operation and maintenance. This classification is used later to show how decisions regarding the various design elements are treated in the transit station design methodology.

Table 2. Transit Station Component Classification for Analysis

Policy Elements	Cost Elements	Performance Elements
Concessions	Fixed Capital Cost	Passenger Processing
Advertising	Operating Cost	Passenger Orientation
Personal Care Facilities	Maintenance Cost	Physical Environment
Telephones	Policy Related Cost	Safety
Aesthetics	User Cost	Security
Construction Materials		
Design Flexibility		
Parking Facilities		
Provisions for Handicapped		

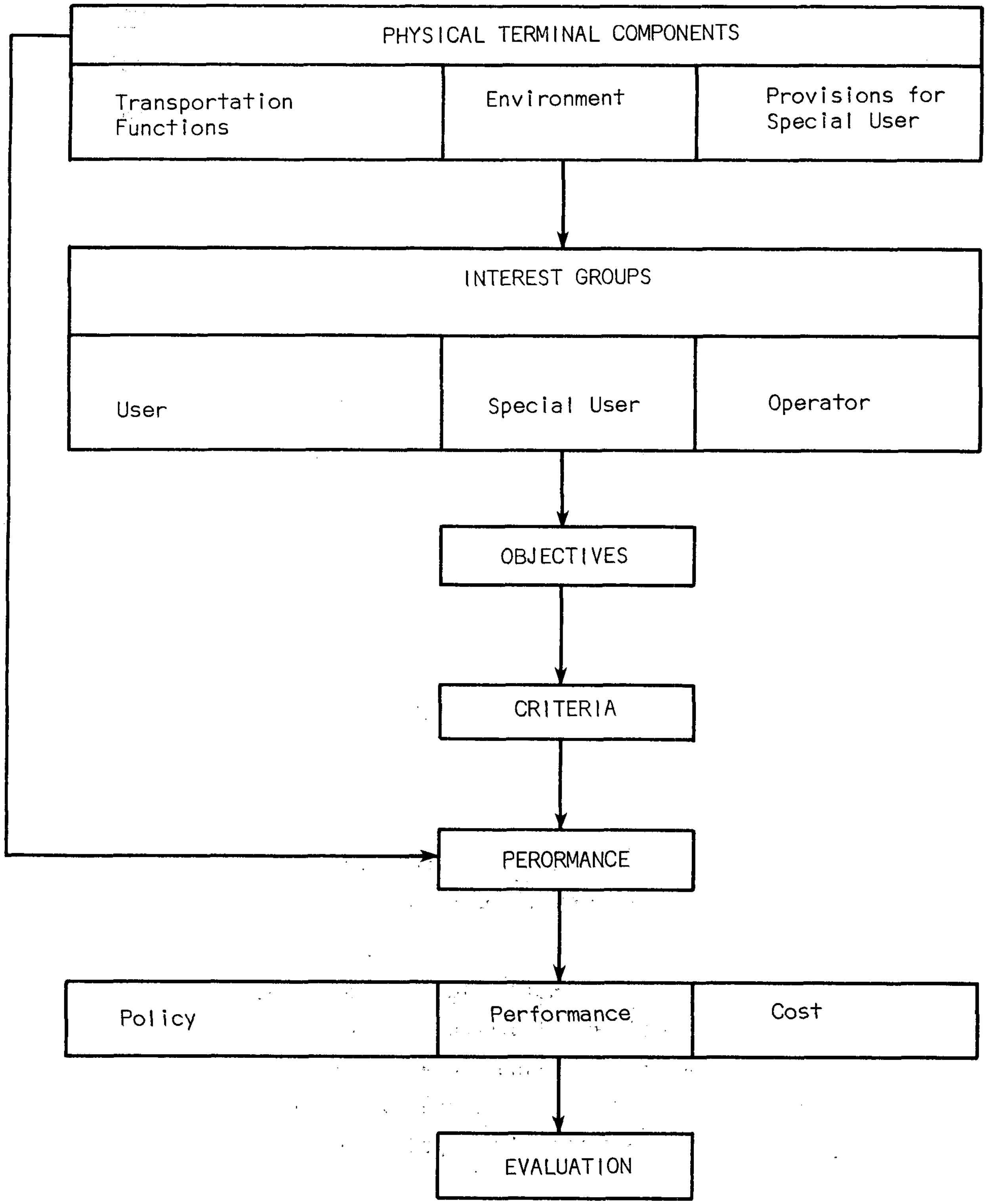


FIGURE 5: Definition of Station Performance Measures

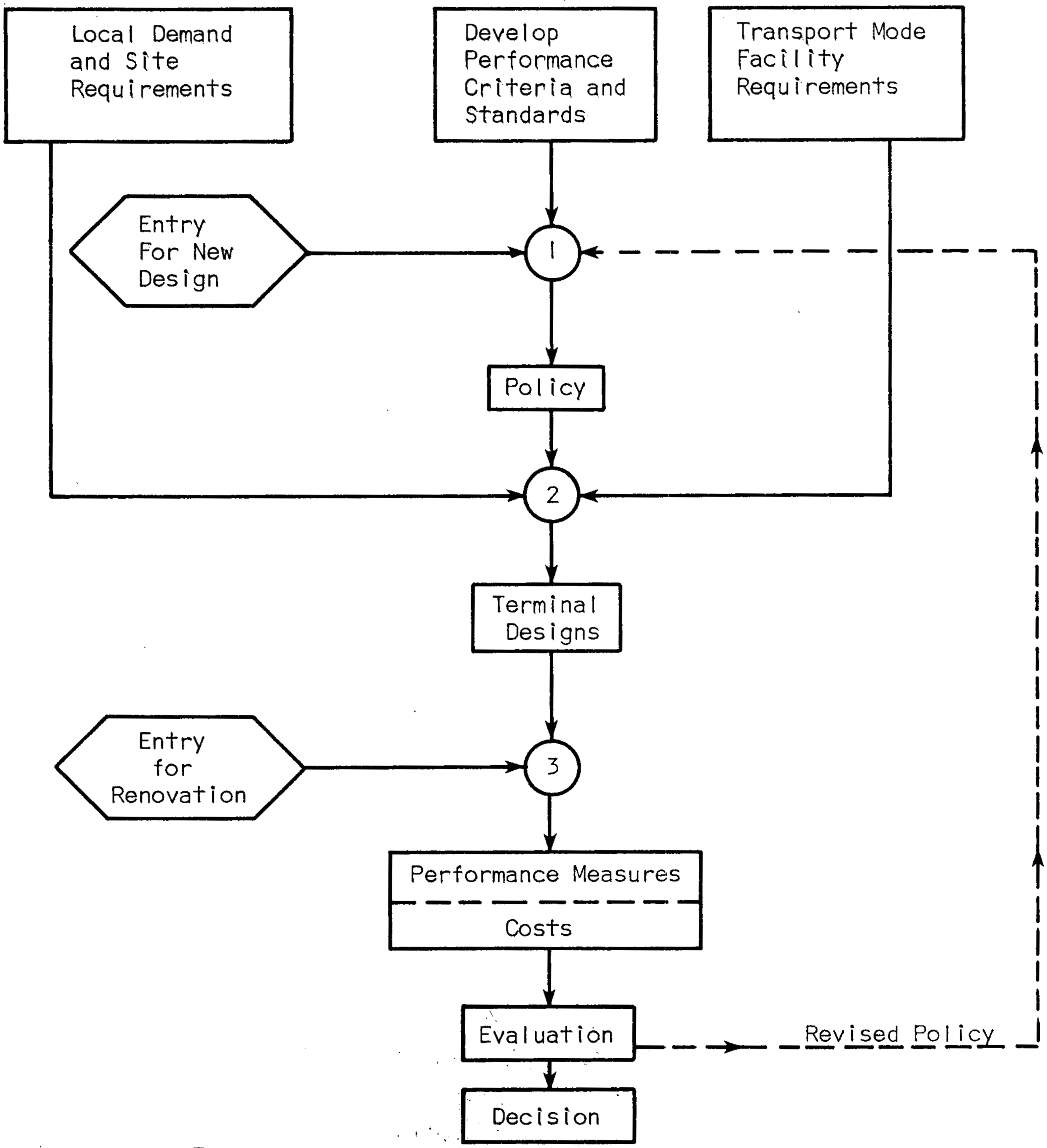
F. Design Process

A generalized transit station design and evaluation methodology must provide adequate means to estimate the expected level of station performance. A comprehensive framework for analysis based on use of the policy, performance, and cost categories for the design criteria, is shown in Figure 6. In this process, performance criteria are employed in a design methodolgy which uses supply, demand, and policy requirements in designing and measuring the performance and cost of alternative terminal facilities.

This procedure is useful in specific terminal design problems such as the renovation of existing stations, the design of new terminals for existing rapid transit or intercity ground transportation modes and the related access modes, and for the design of terminals for new systems. These three problems can be reduced to two primary applications of the analytic methodology; i.e., the renovation of existing terminal structures, and the construction of new modal interchange facilities.

The renovation problem initially requires measures of the performance and cost parameters for an existing facility. These measures are then evaluated in relation to the current terminal management policy. Site requirements and demand measures, brought up to date, are used in conjunction with the conclusions from ther terminal evaluation as a basis for recommending improvements regarding both policy and changes in the physical terminal facility. This renovation strategy enters the analysis framework shown in Figure 6 at nodal point 3.

The development of a new terminal design focuses on meeting stated design standards, modal and site requirements, and expected demand levels. Here, planners enter the process shown in Figure 6 at node I to develop policy prior to consideration of the station proper. Alternative designs are then developed and evaluated against performance and cost criteria.



Indicates the application of terminal analysis procedures for the following purposes:

1. Establish policy
2. Generate alternative terminal designs
3. Establish performance and cost measures for each alternative

Figure 6: Transportation Station Design Process

G. Estimation of Performance Measures

The criteria listed in Table I are used to compare alternative transit station designs. The information requirements for the station design and plan evaluation depend primarily on the objectives (criteria) that are associated with a particular design problem. The identified criteria use either objective measures on some numerical scale (i.e., time, temperature, noise) with clearly defined standards, objective measures relative to some subjective standard (orientation aids, concessions), or judgements related to some subjective standard (safety, security, pleasantness).

A complete design is typically developed with components which are selected in one of the following ways.

a. To meet a basic standard that is generally acceptable to the profession (for example, the specifications for an escalator),

b. As required by local policy (for example, considerations relating to concessions and advertising), and

c. The design elements and/or configuration which provides the best performance among a set of trial designs.

The transit station design process requires that each component be selected according to pre-established criteria. Typical station components which are considered for their performance are listed in Table 3. Consideration must also be given to interactions among the components to assure a compatibility among the different station features. As in most design problems, engineering experience usually accounts for the latter factor, but because many transit planners are not familiar with the complexities of interchange facilities, this issue concerning interrelationships among design components is emphasized.

The basic rules for engineering design are typically conveyed in terms of national design standards such as allowable loads on structural members. The primary elements of a transit station

Table 3. Typical Station Features
Associated With Performance

Passenger Processing

- Level Change Facilities
- Entrance-Exit Facilities
- Area Provided Per Person on Flow Paths
- Travel Distances
- Travel Paths
- Fare Collection Devices
- Vehicle Boarding and Exiting Areas

Passenger Orientation

- Directional Signs and Maps
- Visibility of Major Destination Points
- Courtesy Phones
- Information Booths

Physical Environment

- Air Flow Control Devices
- Heating and Air Conditioning
- Lights
- Weather Protection

Security

- Police Patrols
- Isolated Spaces
- Surveillance Cameras
- Alarms
- Entry Control

Safety

- Number of Levels
- Walking Distances
- Curbs
- Stairs
- Escalators
- Platform Edges
- Lighting

Table 4. Station Parameters Associated With Design Standards

Physical Environment

- Odors
- Suspended Aerosols and Particulates
- Inflow Air
- Air Discharges
- Air Velocity
- Pressure Changes
- Temperature
- Noise

Lighting

Energy Requirements

Structural Elements

Safety Features

Mechanical Movement Aids

Construction Materials

Maintenance Program

design which are associated with typical design standards are shown in Table 4. This listing is not exhaustive, but provides an indication of the type of station components for which design standards have been established.

Another set of station components is specified for design purposes as a result of policy established by the operating agency. Table 5 lists these areas where public officials must establish policy regarding transit terminal programs. Some of these components associated with local policy decisions may be retricted by their impact on the environment, usually as determined in environmental impact studies required for the transit system. Other station features may be influenced by local Transportation Systems Management (TSM) plans which are directed at providing for short-range transportation needs of urbanized areas. This is done by making efficient use of existing transportation resources and identifying improvements in traffic engineering, public transportation, regulation, pricing, management or operations, not including the construction of major transportation facilities or major changes in existing facilities.[8] For instance, TSM plans may call for widespread use of low-cost express bus stations, or low-cost improvements to subway stations rather than major renovation.

Using information from these sources, the designer proposes a set of design variables and a station configuration plan for testing against certain performance criteria, including passenger processing, passenger orientation, the physical environment, security, and safety. The performance of a design relative to some standard or expected level is then estimated through use of manual tools and computer models. Manual techniques for measuring lighting adequacy, safety, security, and passenger processing characteristics are reported in Reference 5. The computer techniques available include the Subway Environmental Simulation (SES) Model [9] and the Urban Mass Transportation Administration Station Simulation (USS) Package.[10]

The SES is a high speed digital computer model which can continuosly evaluate the piston-action air flows created by a series of trains traveling through a subway system. This type of dynamic simulation may be required to determine air flows and heat flows in the complex geometrical configurations of subway tunnels and stations.

The USS Package is currently being considered for its utility in the Urban Transportation Planning System (UTPS). The program, for a given station design and passenger demand, can estimate areas for walking and waiting, area characteristics and their distributions, over time for comparison with standards for design or level-of-service.

The final criteria for selecting elements in a transit station design are associated with cost. The effectiveness of any improvement of a design over minimal performance levels must be justified in economic terms. The transit station design is therefore constrained by the contemporary design standards, established policy and by budgetary limits. The planner must first establish the design standards, policy, and budget for each specific station plan. The remaining design parameters can then be varied and tested to determine which alternative performs best in view of the stated criteria. This design and evaluation process is addressed in the remaining sections of this report, beginning with a consideration of policy issues.

Table 5. Station Components Associated with Local Policy Decisions

Concessions
Advertising
Personal Care Facilities
Public Telephones
Aesthetics and Cultural Environment
Construction Materials
Design Flexibility
Parking Facilities
Provisions for Special Users

IV. SPECIFICATION OF STATION DESIGN PARAMETERS

A. Policies for Station Design, Operation, and Maintenance

Major policy issues include concessions, advertising, personal care facilities, public telephones, parking facilities, and provisions for the handicapped. Each of these items must be studied carefully in order to provide for maximum usage and acceptance of the station while remaining within the limits of the cost and design constraints.

Concessions

The general policy concerning concessions must be developed at each facility site or for each system of stations. Some planners have felt that the disadvantages of having concessions far outweigh the advantages. For instance, the residues of chewing gum, candy, and coffee cups may be difficult and expensive to clean up. Concessions can also cause problems in pedestrian flow if they are improperly designed or controlled. It is at least partly for these reasons that Washington METRO station plans do not include provisions for concessions. On the other hand, the color and vitality that can be provided by concessions might bring a special addition to the aesthetic appeal of a station. The potential monetary advantages of renting space for concessions and the convenience provided to station users should also not be overlooked.

The BART system architectural standards call for space for vending machines and a manned concession booth in each station. The two basic concession goals the BART system is seeking to fulfill are: (1) to provide facilities and space for concessions required for the convenience of BART system patrons, and (2) to establish vending and manned concession standards which will facilitate a systemwide concession operation.

Space to be provided for concessions and businesses must ultimately be based upon local goals and objectives associated with land use and transportation. One objective measure of the feasibility of concessions might be a comparison of the cost of development including space, utilities, maintenance, and security with expected income. Also, the increased travel times of tripmakers due to the larger distances caused by the concession area might be used as an objective measure.

Figure 7 shows concession stands in the middle of a station walkway. Figure 8 shows a floral shop located to the side of a station movement area. There examples illustrate the potential for creatively using concessions to enliven a station's atmosphere.

Advertising

Advertising is a source of additional revenue to support operation of the terminal. Advertising should be sanctioned only if it is controlled by location, content, and size. It should not be placed where it detracts from the aesthetics of the station. Also, advertising should not be placed close to passenger guide signs and other directional aids. It is noteworthy that in the past advertising has been located in a wide variety of places in and around transit stations including on kiosk-type structures in station parking lots and mezzanines, along passageways, on both center and side platforms (see Fig. 9), on walls alongside escalators, and even on the vertical faces of escalator steps (see Fig. 10).

Personal Care Facilities (Restrooms, Aid Stations)

Many of the locational and aesthetic considerations given for concessions apply to restrooms and other personal care facilities. These facilities are sometimes required by building codes that specify the type, number, and location of toilets and aid stations to be provided in public buildings.

Transit agencies usually develop more appropriate standards which coincide with local building practice. The results are wide-ranging. The New York City Transit Authority policy provides public toilets at transfer and major stations only. The BART system provides public restrooms, but entrance to them is controlled through television

FIGURE 7: Contemporary Concession Stands
(Paris Regional Line)

FIGURE 8: Floral Boutique in Modern Station (Montreal)

surveillance by an operator at a remote location. The Washington METRO system, however, has selected to provide no public restrooms in their stations. If there is no local policy requiring restrooms or aid stations, their inclusion or exclusion will be judged on their own merits for the system.

Public Telephones

Pay telephones play a significant role in American life and are available in almost all public places. Therefore, as a matter of policy public telephones should be available at selected places throughout the station. The telephones should be located so that they are visible but do not interfere with pedestrian movements. The number should be based upon passenger volumes and nature of the trips passing through the terminal.

Aesthetics and Cultural Environment

These design elements provide the tripmaker with a pleasant and positive experience at the terminal. Music, art, open assembly areas, unique lighting and other artistic features apply. The addition of refinements to a transit station cannot be warranted by objective measures such as a comparison of direct costs and benefits. Decisions concerning aesthetic and cultural dimensions must be based solely on their role to the total system and the available resources. The current treatment given to the stations of the Washington, D. C. Metro System attest to the fact that considerable expense can be justified to give transit stations landmark status. Figures 11 and 12 show how artwork can be used to focus outside attention to a station.

Another important aesthetic policy consideration is standardization of design. Recently some transit systems have emphasized individualized design of their stations so they blend in well with the architecture of each surrounding neighborhood. On the other hand, some systems standardize design to reduce costs and aid in the identification of any station as a part of the transit system. For example, Figure 13

FIGURE 9: Advertising Poster on Side Platform (Paris)

FIGURE 10: Advertising on Escalator Step Faces (Hamburg)

FIGURE 11: Artwork Around Station Entrance (Minneapolis/ St. Paul)

FIGURE 12: Fountain Near Station Entrance (Minneapolis/ St. Paul)

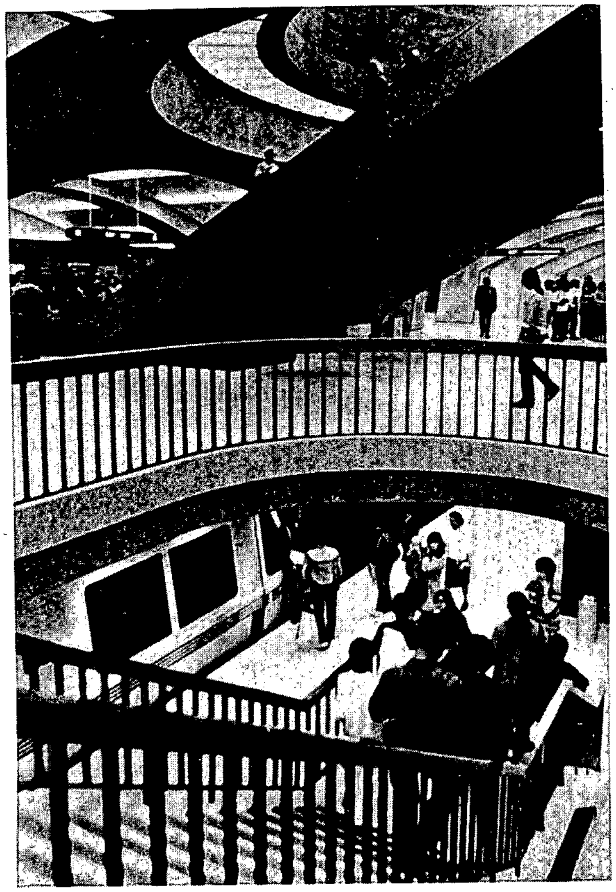


FIGURE 13:
Unique Multi-Level Station
Interior Design
(Bart Berkeley Station)

FIGURE 14:
Coffered Walls of
Washington METRO
Underground Stations
(Metro Center Station)

shows a unique interior station design while Figure 14 shows the standardized coffered walls used in Washington METRO underground stations.

Construction Materials

As the station ages, visual effects must be maintained. This means that the cleaning and maintenance program is directly related to the selection of finish materials and has a considerable effect on the total cost of operating the transit system. For instance, if materials are immune to graffiti artists by being out of reach or easily cleaned, significant cost savings may result. It is important that construction materials, including the desired finish, be considered in depth in the early planning stages so that appropriate materials can be selected during the station design process. This consideration should include the installation and maintenance costs of different materials used for floors, walls, ceiling, doors, railings, and other salient features of the station.

Design Flexibility

A station design must be related to the potential for expansion and/or joint development with other facilities, as for example, a multi-story terminal building that maybe expanded to more floors, or be integrated with a shopping or apartment complex. The latter, joint development, includes coordinated planning and development of transportation facilities and changes in land use over, under, and in the immediate vicinity (one-half mile radius) of the facility. Both public and private development activity may be accommodated. Joint development considerations will be most important when the terminal is a focal point in an activity nucleus.

Expansion considerations are important in areas where population growth and more intense land use have been forecasted. This would apply primarily to areas outside of the central business district where there is currently an ample supply of open space.

Parking Facilities

The important issues concerning parking facilities at transit interchange facilities include the following: number of spaces, mode of operation (i.e., degree of automation), location (i.e., adjacent to or within the station proper), terminal access pathways and vertical movement aids, weather protection, rate structure, public or private management, and visual and other impacts to the surrounding area.

The number of spaces required are determined from the size and nature of the transit demand and the parking requirements for appropriate non-transport activities in the station vicinity. Alternative parking design concepts are then considered, and the cost-effectiveness of alternative parking supply strategies considered. It should be noted that some transit stations have experienced problems, including loss of potential riders, by underestimating parking demand and providing an insufficient number of parking spaces.

Provisions for the Elderly and Handicapped

Devices and design features which aid the mobility of the elderly and handicapped people have been included in recent transit system designs both independently of and as the result of related legislation. This problem is, therefore, a concern to all levels of jurisdiction over transportation systems.

Specific design objectives for transit stations which are identified with special users include minimal level changes (or special aids such as elevators), special restroom facilities, ease of passing through fare collection areas; special facilities (such as passenger separation) to avoid being crowded (see Figure 15). locational and directional guides, and the elimination of other physical and psychological barriers. The extent of special facilities to aid the mobility of the elderly and handicapped can be associated with estimates of the demand for travel by this group at a given site, i.e., a station proximate to a home for the aged would need special considerations; while one located in a suburban area populated by

FIGURE 15: Signing for Handicapped Entrance (Stockholm)

mostly young families would only need to meet minimal standards.

When considering a certain terminal for accommodations for the elderly and handicapped, the reponsible agency must be first alerted to those provisions which are required by law. Secondly, they can examine various design standards for buildings in general which are developed for accommodating the handicapped.

Summary

The information given in this section provides the planner with a basis for showing public officials those areas where policy is needed for transit terminal programs. Also, this review ensures that each resulting policy arises from a systematic appraisal of its impact on the cost, performance, and social acceptance of the transit station.

B. Alternative Designs

When appropriate policy has been established for a transit station design, alternative physical facility components and layouts can be tested. It is at this stage in the design process that those variable details of transit stations associated with optimal passenger processing and user acceptance are tested. The primary station subsystems that are addressed here include passenger processing, passenger orientation, the physical environment, safety, and security. The parties involved can include elected officials, in their role as public representatives, concerned citizens' groups, and neighborhood organizations, along with the engineers, architects, planners, and operators of the station. If the elected officials and concerned public groups are not included here, projects may face long delays due to political and legal actions claiming improper planning procedures.

The evaluation of alternative designs will incorporate performance and cost measures. There are two types of performance criteria, the necessary, in which standards must be met (noise levels, temperature, maximum delay, etc.) and the conditional, in which the best performance among a set of alternatives is sought. In both cases, the measures of effectiveness which result from the interaction of a number of station design parameters must be calculated for each alternative (as opposed to those standards which can be met by specifying certain features such as width of doorways or number of ticketing points.).

During this stage the design team, including architects, planners and engineers, collaborate, first to generate alternative design concepts and then to design facilities which meet the stated requirements and objectives. Design concepts refer to those broad considerations which account for major differences in terminals such as multi-level vs. single level, underground vs. aboveground, exclusive shopping mall zones, automated pedestrian movement aids, etc. This stage generally includes estimates of environmental impacts, the incorporation of local transportation systems management plans, and a public hearing process to determine opinion on the alternative design concepts. After specific concepts are agreed upon by the design team, detailed facility designs are prepared.

After an acceptable design basis has been established by the policy statements described above and these design concepts, detailed designs reflecting alternative facility components and layouts can be tested. It is at this point that those variable details of transit stations associated with optimal passenger processing and user acceptance are considered. The analyst has the option to consider variation in the design relative to the physical environment, passenger orientation aids, safety and security, if they have not already been established as a result of policy.

C. Measuring Performance and Cost

Performance

The next step in the station design process uses analytical techniques to analyse the performance of alternative station designs. In particular, the performance of the design in meeting the objectives associated with passenger processing, passenger orientation, the physical environment, security, and safety are addressed.

Passenger Processing

Manual techniques have been developed[5] which estimate passenger flow characteristics from data on terminal design plans and passenger demand. These techniques are used:

(1) to provide sufficient space in queueing and movement areas for a safe, convenient, and comfortable pedestrian environment

(2) to provide enough service facilities (e.g., doors, gates, stairs, etc.) for passenger convenience and comfort

(3) to connect queueing areas, movement areas, and service facilities to assure a secure, continuous, convenient, coherent and safe pedestrian environment.

These techniques measure the extent to which these design objectives are met by estimating the time spent walking and waiting within a station and the area per person provided in the walking and queueing areas of a station.

Another method is available for measuring these variables. This is the UMTA Station Simulation Program (USS) which will be available in the Urban Transportation Planning System (UTPS).[10] The USS would be used primarily in cases where a large number of evaluations of relatively large and sophisticated facilities are considered.

Passenger Orientation

There are no existing models or methodology for explicitly measuring the adequacy of the passenger orientation system of a terminal. Many different approaches have been used. However, a regular set of procedures for reviewing the design can be used to test for minimal disorientations:

(1) Layout the terminal system

(2) Identify O-D flow channels

(3) Place passive and/or active orientation aids

(4) Determine total number of decision points along flow paths.

(5) Determine number of decision points where uncertainty can be expected.

(6) Establish a level of "orientation certainty."

The above procedure is rather judgemental but can guide the designer to improve upon the orientation problem by, say, providing 95% certainty that users will correctly and comfortably pass in their all decision points in their paths. Figure 16 shows some platform level signs with individual train information. Figure 17 shows a map of the area surrounding a station.

Physical Environment

Performance variables related to the physical environment are temperature, air quality, air flow, lighting, noise, and weather protection. Measures of temperature, air quality, and air flow for subway stations are available through the Subway Environmental Design Handbook and its companion, the Subway Environmental Simulation (SES) Model.[9] The handbook provides manual computation methods for design analysis and the SES computer model can be used for dynamic simulation to yield greater accuracy. The best method to use for a specific design problem (computer simulation or manual) is a function of the level of detail needed.

Lighting design is a rather straight-forward process involving standard principles which have been used for many years. Care must be taken, however, to ensure that brightness and brightness differences do not produce glare.

Design for acoustics basically involves the use of data from other systems to determine the volumes to be expected from noise sources and the effectiveness of noise abatement procedures.

A measure of the weather protection provided by a terminal is

FIGURE 16: Platform Level Directional Information (London)

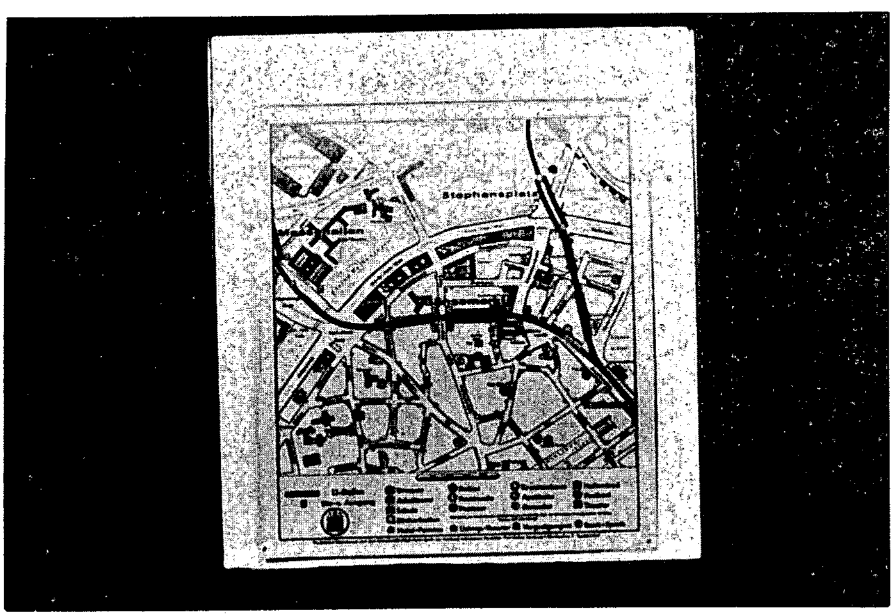


FIGURE 17: Map of Area Surrounding A Station (Hamburg)

derived from the functional area of the facility that is exposed to weather. This functional area is that which accommodates movement by users, exclusive of parking lots. Exposure to weather is defined by the lack of complete enclosure by roof and walls.

Security

Security is defined here as freedom of the station user from the danger of crime. There are three basic ways to decrease the likelihood of a crime in an interface facility. These are: deterrence, making the situation such that a potential crime cannot be successfully initiated; thwarting, providing means for stopping a crime once it is initiated; and apprehension, providing means to aid in the capture of the violator after a criminal act is completed. The effect of station design characteristics on these crime abatement methods is the major analysis objective in measuring security. Figures 18 and 19 show a station's security camera and a central closed-circuit TV moitoring station.

Safety

Safety is defined here as freedom of the station user from undergoing or causing hurt, injury, or loss, not including that caused by criminal acts. A method to analyze safety in transportation interface facilities derives from a Department of Defense standard for the protection of the public from unsafe conditions.

This standard provides a comprehensive framework for safety analysis through the following analytical methodology:

(1) Identify hazards and determine any needed corrective actions.

(2) Determine and evaluate safety considerations in tradeoff studies (relative to other objectives).

(3) Determine and evaluate appropriate safety design and operational requirements.

(4) Determine whether the qualitative objectives or quantitative numeric requirements established by the operating authority have been achieved.

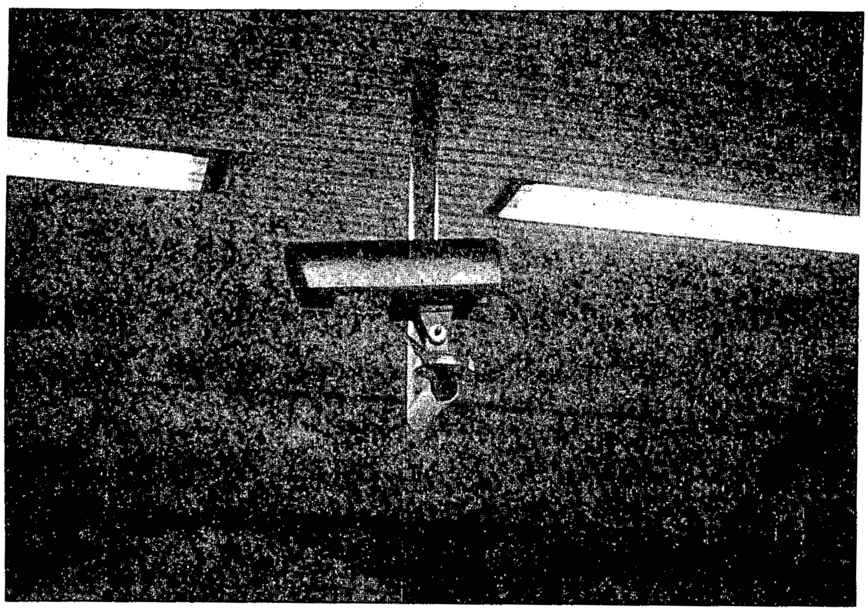


FIGURE 18: Security Camera in Transit Station

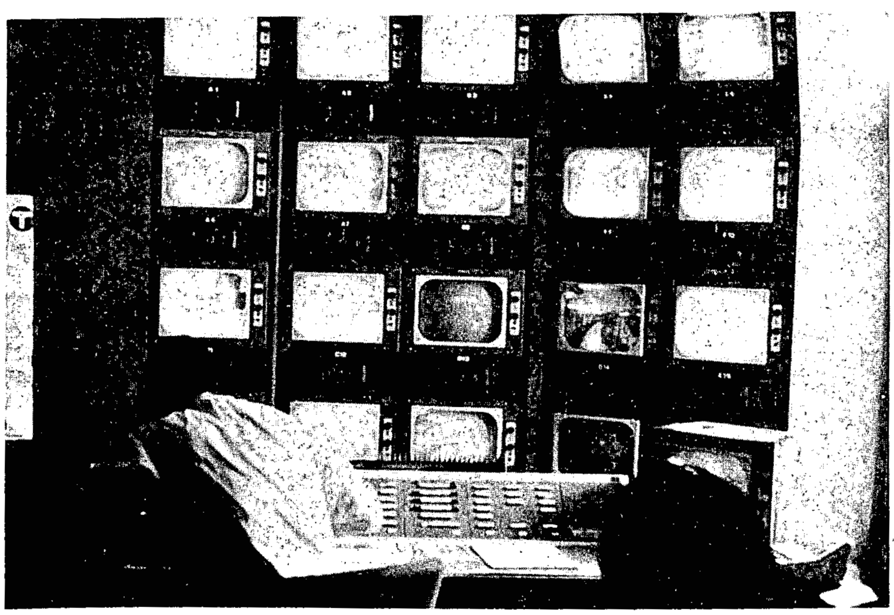


FIGURE 19: Closed Circuit TV for Monitoring Station

Cost Analysis

The total cost associated with a modal interchange facility is basically due to:

a. The first (capital) cost

b. Operation and maintenance costs

c. Costs resulting from policy decisions

d. User costs (e.g., travel time, etc.)

For preliminary planning, these various costs can be estimated with cost equations which use aggregate station characteristics as the means of analysis (independent variables). These station characteristics might include the areas of the terminal, the number of levels, annual demand, hours of operation, presence of concessions, and user travel time in the facility, among others.

For more detailed analysis, costs are estimated by determining the sum of costs for each individual element of the facility. For instance, the first (capital) cost is determined from the sum of the costs of including each element which is a component of the facility.

It is noted that the initial cost of terminals can vary widely, dependent upon location and type of structure. Because of this wide variation in cost, care should be taken when predicting costs for facilities with total cost data from other transportation systems

D. Summary

This chapter has described two distinct steps in the station development process which combine to provide a particular station design. First, policy is established for those elements which are variable from locality to locality and are not especially associated with passenger movement, per se. The major policy considerations focused on concessions, advertising, restrooms, aid stations, telephones, aesthetics and cultural environment, construction materials, design flexibility, parking facilities, and provisions for the elderly and handicapped.

It was shown that when appropriate policy has been established for the above station components, the variable details of transit stations associated with passenger processing and user acceptance are tested. The primary considerations here included passenger movements, passenger orientation, the physical environment, safety, and security. These latter elements were then viewed with respect to performance and cost measures.

V. EVALUATION PROCESS

The terminal design process as shown in Figure 6 culminates with selection of a specific transit station design that satisfies the requirements. This choice among alternatives is accomplished through a structured evaluation process which compares the proposed designs in terms of the important performance measures that derive from the stated station objectives.

A. Evaluation Method

Station performance is examined according to the policy, performance and cost categories. Once these performance measures are identified with an impact group(s), an evaluation matrix can be constructed such as shown by Table 6. This evaluation matrix provides the decisionmaker with a summary of all performance parameters according to their role in the design methodology, and their impacts on the appropriate interest groups. Explicit measures of performance or numerical indices derived from subjective rating schemes are the entries to the matrix cells.

This tabulation shows raw criteria measures in a decisionmaking framework. For example, the decisionmaker can review Table 6 for dominances and tradeoffs and select a "best" design or, at least refine the total set of criteria by eliminating those which do not show significant variance among the alternatives. The various tradeoffs which may be considered include those among impacts, interests, and alternatives.

This general model for terminal evaluation closely parallels the cost effectiveness evaluation technique which separates the criteria into two categories, costs and effectiveness. The total information is listed for the decisionmaker so that the plan can be selected which best suits the represented interests. An example of specific criteria entries for Table 6 are shown in Tables 7 and 8 for the user and operator groups respectively.

Table 6. Evaluation Matrix Model

INTEREST/CRITERIA	EVALUATION MEASURES			
	ALTERNATIVE			
1. User				
1.1 Policy Elements	1	2	j	n
1. Personal Comfort (rating)	5	4	.	3
2. Number of Levels (#)	3	2	.	3
.	.	.	.	.
.	.	.	.	.
m.	.	.	.	.
1.2 Performance Elements				
1. Total Walk Time (min.)	2.5	3.0	.	2.2
2. Design Hazards (#)	4	3	.	5
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
r	.	.	.	.
1.3 Cost Elements				
1. Capital Cost ($\$10^6$)	10	11	.	9.5
2. Maintenance ($\$10^6$)	1.0	1.2	.	1.1
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
t	.	.	.	.
2. Special User				
2.1 Policy Elements				
1. Level Change (#)	5	4	.	3
2. Weather Exposure (rating)	3	5	.	4
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
u	.	.	.	.

(etc.)

3.	Operator				
	3.1 Policy Elements				
	1. Entry Control (rating)	5	3	.	4
	2. Station Size (rating)	4	5	.	3
	.	.	.	.	.
	.	.	.	.	.
	.	.	.	.	.
	p	.	.	.	.

(etc.)

Table 7. Terminal User Evaluation Matrix

CRITERIA/CATEGORY	EVALUATION MEASURES							
	ALTERNATIVES							
	1	2	3	4				n
POLICY ITEMS								
1. Personal Comfort Facilities								
2. Cleanliness								
3. Pleasantness								
4. Advertising								
5. Concessions								
6. Weather Exposure								
7. Number of Levels								
8. Back up Facilities								
9. Inspection Procedures								
10. Mechanical Level Change Aids								
PERFORMANCE MEASURES								
1. Total Walk Time								
2. Total Time in System								
3. Route Travel Times								
4. Area Per Person								
5. Total Delay Time								
6. Number in Queue								
7. Crossing Flows								
8. Connectivity								
9. Orientation Aids								
10. Safety Features								
11. Design Hazards								
12. Odor Concentrations								
13. Suspended Aerosols and Particulates								
14. Inflow Air Rate								
15. Air Contaminants								
16. Air Discharges								
17. Air Velocity								
18. Pressure Changes								
19. Thermal Comfort								
20. Noise								
21. Lighting								
22. Security								

Table 8. Terminal Operator Evaluation Matrix

CRITERIA/CATEGORY	EVALUATION MEASURES						
	ALTERNATIVES						
	1	2	3	4			n
POLICY ITEMS							
1. Fare Collection and Entry Control 2. Station Size 3. Maintenance and Repair Requirements 4. Cleaning Requirements 5. Joint Development Provisions 6. Expansion Potential							
PERFORMANCE MEASURES							
1. Security 2. Energy Needs							
COST MEASURES							
1. Funds Available 2. Funds Required 3. Income (Non-Transport Activity) 4. Incremental Return (Relative to Low Cost Alternative)							

B. Design Sensitivity Analysis

The application of the model summarized by Tables 6, 7, and 8 to generate an acceptable terminal design is now considered. This is a repetitive process in which an initial design is created and evaluated relative to established criteria and then incrementally modified until all of the objectives are satisfactorily met. This strategy is referred to as the "sufficient design" approach because it guarantees that all criteria are met wherever feasible. The combined application of both the design and evaluation processes is warranted since the selection of the "best" design from a set of alternatives does not necessarily guarantee a satisfactory design. It should be recognized, however, that a sufficient design strategy can be used to improve upon the best of a set of designs.

This design strategy requires that the design methodology account for the effects of slight changes in a design with minimum effort on the part of the analyst. The procedures described in this GUIDE can be used for sensitivity analysis with the process given in Figure 6.

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