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Transit Station Design: Case Studies of Planning and Design Method

FINAL REPORT

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16. Abstract

The application of a previously developed and documented transit station design methodology is described. Two example design scenarios, a central area bus terminal and a rail rapid transit station are illustrated. In addition a summary of two further case studies is included to strengthen the conclusions derived concerning the recommended use of the method by design practitioners. Due to the varying circumstances surrounding any particular transit station and the numerous design options that are available, it is unrealistic to attempt to make conclusions regarding specific design practices such as advertisements should be permitted in all stations. The experiences with the station design procedures have shown the method to be very useful in selecting and improving upon a station design that compares to the stated design objectives. Technically, many subjective decisions are required even with the formalized method and, thus, objectivity must be stressed in terms of procedure rather than practice. The findings indicate that if the station design is developed using the formal process, the least cost alternative typically prevails.

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METRIC CONVERSION FACTORS

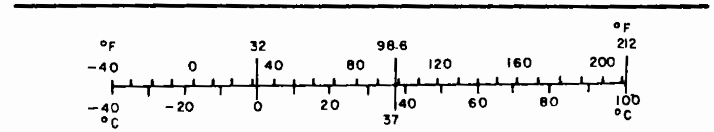
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

INTRODUCTION

A package or general procedures and techniques to define, measure, and evaluate the performance of transit interface facilities has been developed (1,2,3). They are summarized in Figure 1. This study addresses the application of the methodology in the design of new modal facilities which begins with an inventory of data and design objectives and proceeds through a complete terminal development program. This problem is summarized by Figure 2.

Various types of line haul mode, station location and surrounding land use, and levels of demand were considered to establish example station design problems. Two general station types are dealt with in depth:

1. A central area bus terminal with intercity and commuter operations that is located on the fringe of a CBD, serving high volumes of users, and

2. A subway station, located within the CBD of a large city, serving a high volume of users.

Supplementary summaries of the analyses of an express bus park and ride facility and a dual mode station are included.

PROBLEM STUDIED

The problem addressed by this study concerns the testing and validation of a comprehensive transit station design methodology in the planning of new terminal facilities. In order to use the method, data were first synthesized to establish specific station design objectives and requirements for different case studies. Policy was then established for each design problem that represent a range of policies found in current transit systems. The methodology was applied in a straight-

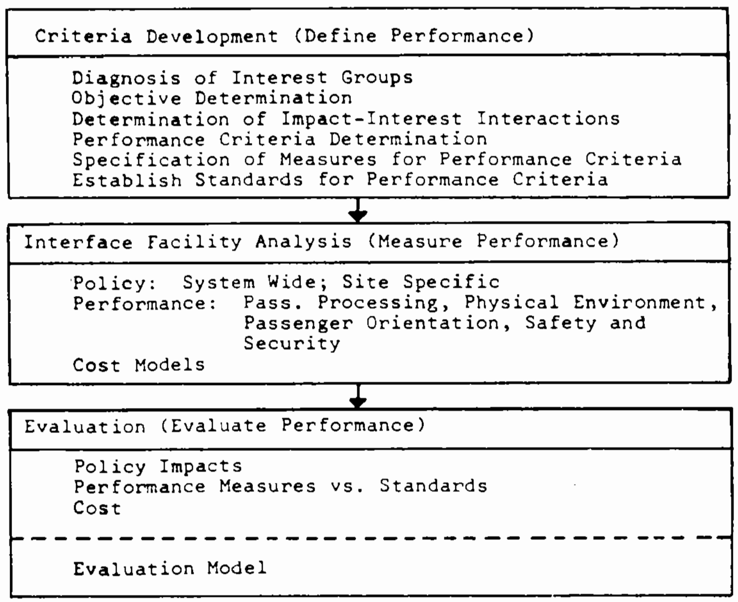

Figure 1 Transit Station Evaluation Process

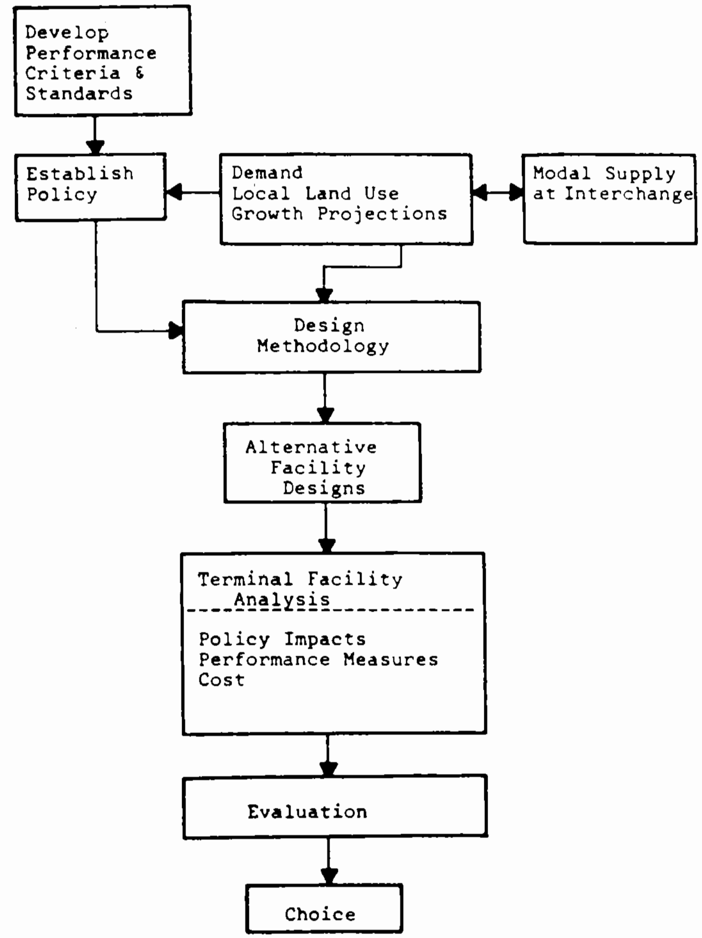

Figure 2 Facility Design Process

forward manner to propose and evaluate design different concepts, and improve upon features for a specific design configuration.

The objective for conducting these analyses and using the findings is to provide a practical description and explanation of the previously derived procedures so that they are useful to the transportation planning procession. Whenever possible, specific design guidelines are derived from interpretations of the study findings.

RESULTS ACHIEVED

The case study applications of the transit station design methodology provided a broad range of station design problems in view of technology, demand volumes and urban location. Under such circumstances it is difficult to justify conclusions regarding specific design practices such as all stations should permit advertisements or a certain type of security plan is best suited to all transit systems.

These applications of the transit station design methodology did show how the procedural method can be used to select and improve upon a station design that derives from station design objectives. Technically, many subjective decisions are required even with the formalized method and, thus, objectivity must be stressed in terms of procedure rather than practice.

Of the forty-four performance measures used for the rapid transit station, only 15 differed among the alternative designs. These differnces provided the bases for selecting the best design.

For users and special users, variation was present in travel time, number of level changes, potential for concessions, and number of separate spaces. For the operator only cost and joint development potential differed.

While the concurrent format used for design and analysis may have contributed to this uniformity, the results appear to indicate that many criteria can be replaced by "minimum desirable standards" with little impact on the quality of design or the evaluation of designs.

The experiences with the example applications support the following statements regarding the performance of the transit station design methodology.

1. If the station design is developed within the formal process, the least cost alternative will usually prevail. This is so because the methodology directs the planner to propose only those alternatives that satisfy the important planning and design objectives.

2. If policy is not varied during Evaluation I, there will be no basis to negate it.

3. After a certain design concept is selected for a particular station, the following items will generally the considered for improvements.

    1. Level change capacity
    2. Improved security
    3. Improved aids to special users
    4. Transparent elevator walls, and
    5. Amenities.

UTILIZATION OF RESULTS

The results of this research can be used by transit planner, facility designers, architects, policymakers, and citizens to understand the process of developing a transit station design. The method assists the responsible agency to identify transit station designs that satisfy stated objectives with a cost effective solution.

CONCLUSIONS

The study findings and conclusions support the importance of the transit station design methodology as a format for organizing station design variables and performance data to efficiently develop transit station designs that satisfy governing objectives. The example applications show a step by step method for developing information to make decisions; they do not tell how to make such decisions.

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CHAPTER 1

INTRODUCTION

PURPOSE

This report describes the application and testing of a previously developed methodology for the design of urban transportation interface facilities (1,2,3). Two example design scenarios, a central area bus terminal and rail rapid transit station are used to illustrate the general characteristics of the procedures to transportation station planners and designers. In addition, a summary of two additional case studies is provided to strengthen the data base for deriving conclusions regarding application of the methodology and citing general principles for transit station design.

The transit station design methodology is summarized in the next section. The reader is encouraged to consult the basic references for more detail on the mechanics and concepts underlying the method (1,2,3).

Station Design Methodology

Inventory

The stages in the station design methodology are shown in Figure 1.1.

The first stage, inventory, involves the compilation of the necessary information on site characteristics, demand, supply (e.g. modal requirements), local objectives, system objectives, user attitudes and preference, performance standards, and cost constraints. Once the inventory data are compiled, the formalized design/evaluation process begins (2).

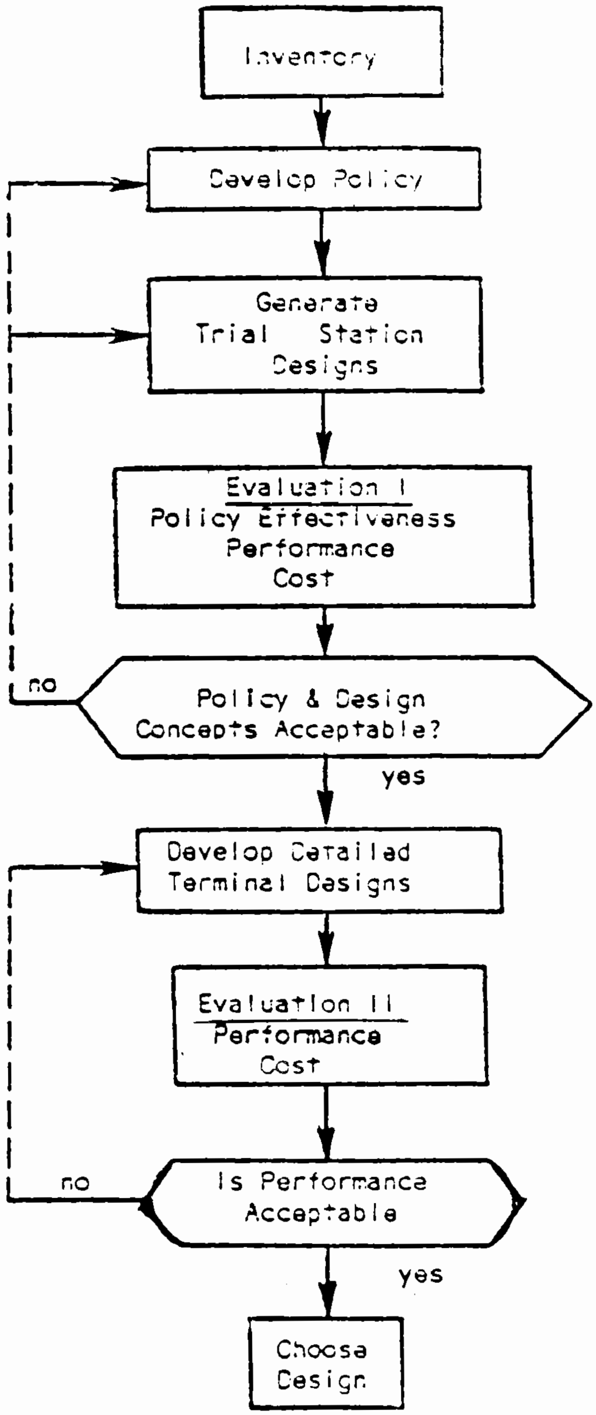


Figure 1.1 Stages in Transit Station Design Methodology

Policy Development

This stage of the process involves the formulation of relevant policy concerning the design, operation, and maintenance of the station. Major policy decisions must be made by local officials for concessions, advertising, personal care facilities, public telephones, aesthetics, station environment, construction materials, and provisions for special users. In existing transit systems some or all of these policy decisions may have been previously made and apply to all system stations.

Some station characteristics that might usually be established after a performance analysis might also be dictated by policy. These characteristics may include passenger orientation aids, the physical environment (e.g. thermal comfort, lighting, noise levels, etc.), safety, and security.

Trial station designs

During this stage a design team, generally consisting of architects, planners, and engineers, generates alternative design concepts. These design concepts can cover a wide range of station types. After specific design concepts are agreed upon, more detailed designs are prepared for further analysis.

Evaluation I

At this stage the effectiveness of each of the trial station design concepts is evaluated. This preliminary screening resolves issues of policy and basic design concepts. The process is repeated until governing policy and design issues are resolved.

The effectiveness measures that are used during Evaluation I are derived from the inventory data. The meaures used within an effectiveness analysis framework include feasibility cost considerations and limited performance analysis.

Development of detailed designs

After the preliminary screening of design concepts leads to an acceptable design basis, alternative physical facility components and layouts are tested. Variations in station details can be made in an attempt to optimize the performance of the facility from the perspectives of users and the operator.

Evaluation II (Detailed Analysis)

The selected terminal designs are now evaluated relative to performance, from the user's and operator's perspectives, and cost, from the operator's perspective. A wide range of performance meaures can be used in conjunction with an evaluation model to determine the "best alternative." When the evaluation detects design improvements that are warranted and feasible, further modifications can be made and Evaluation II is repeated. This iterative approach continues until an acceptable final design evolves.

STUDY METHOD

Various types of line haul mode, station location, surrounding land use and levels for demand were considered to establish example station design problems. The two general station "types" that are dealt with in depth in Chapters 2 and 3 are:

1. A central area bus terminal with both intercity and commuter operations located on the fringe of a CBD, serving high volumes of users, and

2. A subway station, located within the CBD of a large city, serving a high volume of users.

Supplementary summaries of analyses of an express bus park and ride station and a dual mode station are given in Chapter IV.

Three major points of view were considered in formulating design objectives and evaluation criteria: station users, special users (elderly and handicapped), and station operators. The objectives of station users and special users are associated with pedestrian travel in the terminal and the internal environment of the facility. The station operator is concerned with these objectives plus cost considerations. A general list of criteria for evaluating alternative designs that derive from a broad set of transit station design objectives for the different viewpoints has been compiled (1). Accordingly, that source is used to specify the criteria for the case studies presented here.

Two approaches were available for obtaining inventory data for this study. Data for planned or newly constructed stations could be used, or prototype station conditions with synthetic inventory data could be developed. The latter method was employed because prototype station conditions could be developed to adequately reflect conditions normally found in station design problems. Further, the use of prototype station design conditions facilitated the display of attributes, capabilities, and shortcomings of the design methodology for a wide range of station design conditions.

Initial policies were established for each design problem that represented a range of policies found in actual application. Station characteristics such as concessions, advertising, restrooms, public telephones, aesthetics, parking, provisions for special users, and thermal comfort were treated as both dictated by policy and subject to design evaluation decisions in the example design problems.

The evaluation procedures used here are similar to those originally described in the station design methodology report (2) but not identical. Preliminary alternative designs were more detailed than originally recommended for the methodology. The preliminary screening of alternatives (Evaluation I) involved a large number of performance measures. These measures were used in detailed evaluations of station performance and policy analyses were performed.

Since the detailed performance measures were available for the basic design selected in Evaluation I, Evaluation II was used to test incremental changes in a chosen design.

CHAPTER 2

CENTRAL AREA BUS TERMINAL

Central area bus terminals are important components of local freeway and intercity bus services where centralized off-street loading and unloading is provided. A prototype central area bus terminal design problem is considered in this chapter.

INVENTORY

The bus terminal inventory under construction is located within a city, whose SMSA population is 3,000,000 and whose CBD work force is 280,000. Automobile congestion is widespread, but is partially alleviated by an extensive bus system. Various parts of a new subway system are proposed, under construction, or completed and providing service.

Location of The Station

The station will be built on the fringe of the CBD, adjacent to a subway station. The subway station is to be built at the same time and will serve two lines. At the station the two lines will be running on the same tracks, so only two tracks will be needed. The bus and subway stations will be within short walking distance of the CBD, between the CBD and an Expressway. This expressway will have two exclusive bus lanes and a grade-separated access to the bus terminal.

Surrounding Land Use

The surrounding land use is primary multi-story retail and office space. The downtown street system consists mainly of one-way streets. The use of air-rights above the bus terminal is both practical and desired. Several private developers have shown interest in purchasing the air rights if they find the station design complementary with their needs.

Transit System Description

The transit system basically consists of three major modes: rail rapid transit, express bus, and local bus. The rail rapid transit network, when complete, will serve most parts of the central city at a relatively high level of service. The express bus operations provide transit for commuters outside of the central city. The local bus service provides transit through all parts of the central city area and some suburbs. While the rail rapid transit network is being completed, both the express and local bus operations are being modified to complement the rail service.

Vehicle Characteristics

The vehicles to be used at the bus terminal are standard bus types but the intercity buses different from the commuter (city-suburban transit) buses, due to their types of service. To insure satisfactory design, the upper limit of the typical range of vehicle dimensions will be used (see Table 2.1).

Demand Levels

Since intercity and commuter buses can provide very flexible service, it is desired to not hinder this flexibility with inadequate capacity at the terminal. The design volumes used here reflect the upper range of demand estimates. The demand level estimates are given in Table 2.2

Access Modes

The two primary modes served by this station are intercity bus and commuter bus. The additional modes for access or egress are subway, walk, local bus, drop-off/pick-up, and taxi. The design volumes for these modes are given in Tables 2.3 and 2.4.

Table 2.1

Design Dimensions for Intercity and Commuter Buses

Dimension	Commuter (City-Suburban Transit Bus	Intercity Bus[a]
Length of body	43 ft.	45 ft.
Maximum width	9.0 ft.	8.5 ft
Height	11 ft.	13 ft.
Seats	50	45
Standees, easy capacity	10	10
Standees, crush capacity	50	25
Total passengers, easy capacity	60	55
Total passengers, crush capacity	100	70
Total/seated passenger ratio		
easy capacity	1.2	1.22
crush capacity	2.0	1.56
Maximum acceleration/deceleration rate used	3.0 mpg/sec.	3.5 mph/sec.
Maximum speed used[b]	65 mph	75 mph
Loading time per passenger	2.0-4.0 sec.	6.0-8.0 sec.
Unloading time per passenger	1.5-2.5 sec.	4.0-6.0 sec.

[a]would be adjusted for maximum speed limit

[b]taken from Reference 17

Table 2.2

Demand Levels for Design of Central Area Bus Terminal

Disembarking (One-Way Flows in)	Morning Peak Hour	Evening Peak Hour	Daily
Intercity Passengers	1,100	900	11,200
Intercity Buses	24	24	330
Commuter Bus Passengers	6,000	500	15,000
Commuter Buses[a]	136	125	1,111

Embarking (One-Way Flows Out)	Morning Peak Hour	Evening Peak Hour	Daily
Intercity Passengers	900	1,100	11,200
Intercity Buses	24	24	330
Commuter Bus Passengers	700	5,500	15,000
Commuter Buses[a]	136	125	1,111

[a]Commuter buses using the station would operate on maximum of 45 routes

Table 2.3

Central Area Bus Terminal Morning Peak Hour Access and Egress Mode Volumes

Major Mode to Egress Mode Volumes

To		From	
		Intercity Bus	Commuter Bus
intercity bus		405	50
commuter bus		0	0
subway		150	1,400
walk		50	4,300
local bus		20	175
drop-off/pick-up		400	0
taxi		30	75
	Total	1,100	6,000

Access Mode to Major Mode Volumes

To		From	
		Intercity Bus	Commuter Bus
intercity bus		370	50
commuter bus		0	0
subway		125	200
walk		40	400
local bus		15	50
drop-off/pick-up		325	0
taxi		25	0
	Total	900	700

Table 2.4

Central Area Bus Terminal Evening Peak Hour Access and Egress Mode Volumes

Major Mode to Egress Mode Volumes

To	From	
	Intercity Bus	Commuter Bus
intercity bus	370	35
commuter bus	0	0
sbuway	125	145
walk	40	285
local bus	15	35
drop-off/pick-up	325	0
taxi	25	0
Total	900	500

Access Mode to Major Mode Volumes

From	To	
	Intercity Bus	Commuter Bus
intercity bus	450	45
commuter bus	0	0
subway	150	1,280
walk	50	3,945
local bus	20	160
drop-off/pick-up	400	0
taxi	30	70
Total	1,100	5,500

STATION SITE

As stated earlier, the bus terminal will be on the fringe of the CBD, between an Expressway and the CBD core. The expressway has two exclusive bus lanes with a grade separated access to the station. The construction site will include all of the block bounded by D and E Avenues and 20th and 19th streets.

The subway line runs under E Avenue (ease-west). The subway station will interface with the bus terminal. A schematic representation of the station site is shown in Figure 2.1.

The site was previously occupied by an old and dilapidated warehouse. This was torn down as part of an urban renewal project. Presently the site is surrounded by office and retail land use.

OPERATING AGENCY

The primary operating agency involved with this project is a Rapid Transit Authority (RTA). The major goals of RTA with respect to this terminal are:

1. To encourage the use of the transit system,
2. To minimize costs of the system,
3. To provide a high level of service to the elderly and handicapped,
4. To encourage joint development
5. To include provisions for concessions and advertising if financially beneficial
6. To provide for a smooth transition between modes.

DESIGN CRITERIA

RTA representatives and the design consultant have met privately with potential developers and in public meetings with local citizens to develop a set of objectives for the design of this downtown bus terminal. With the assistance of the available objectives-criteria list the objectives to be used here were derived (1).

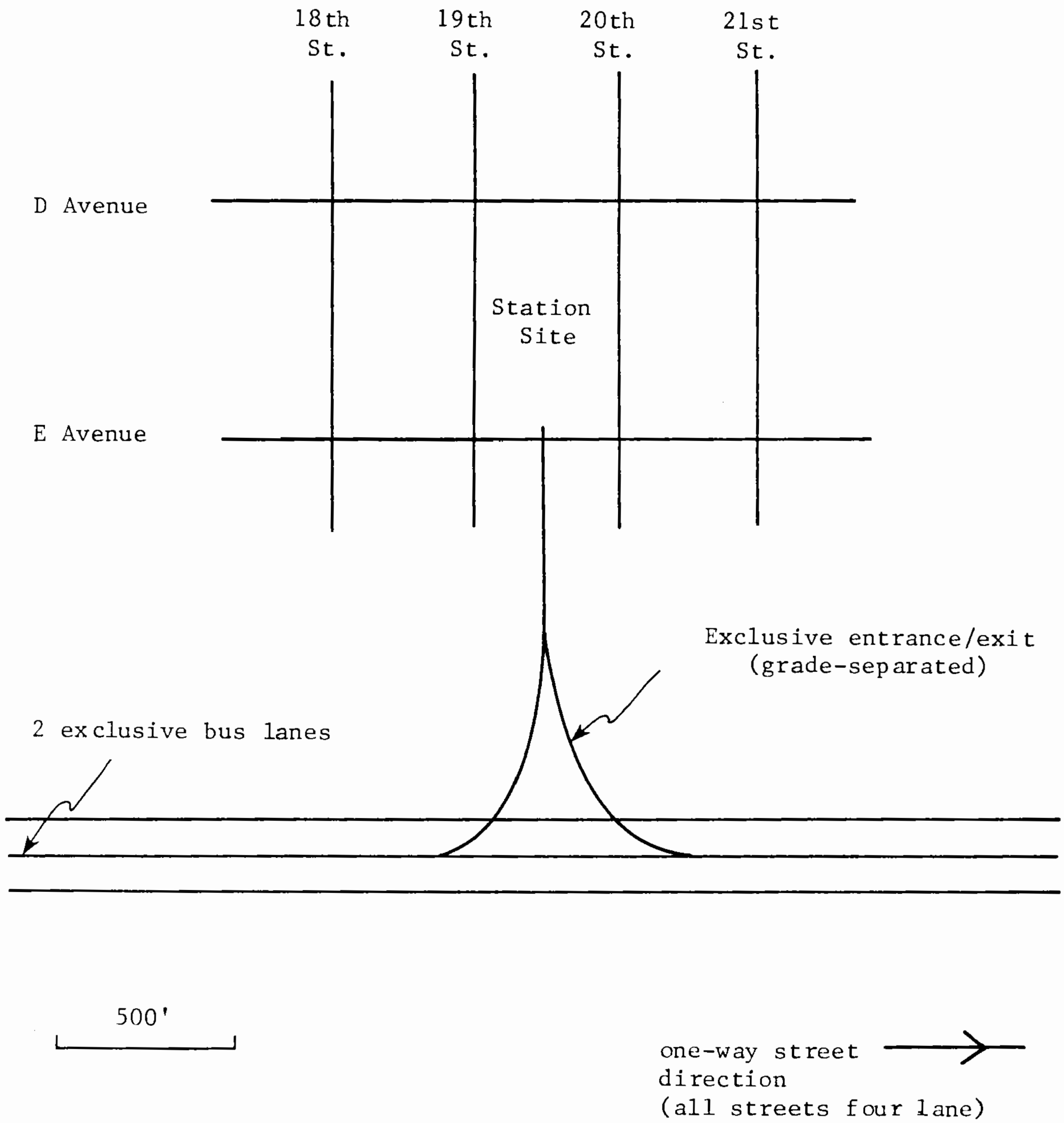


Figure 2.1 Central Area Bus Terminal Site

Intercity User Objectives

Passenger Processing

2. Minimize crowding on links
3. Minimize disorientation
4. Maximize safety
5. Minimize level changes

Environmental

6. Provide comfortable ambient environment
7. Provide adequate lighting
8. Provide for personal comfort
9. Provide clean and pleasant environment
10. Provide supplementary services
11. Provide protection from weather
12. Provide adequate security

Commuter User Objectives

Passenger Processing

13. Minimize travel time in station
2. Minimize crowding on links
4. Maximize safety
14. Provide for efficient fare collection

Environmental

6. Provide comfortable ambient environment
7. Provide adequate lighting
9. Provide clean and pleasant environment
10. Provide supplementary services
12. Provide adequate security

Intercity Special User Objectives

Passenger Processing

1. Minimize walking distance
2. Minimize crowding on links
3. Minimize disorientation
4. Maximize safety
15. Eliminate physical barriers

Environmental

6. Provide comfortable ambient environment
7. Provide adequate lighting

8. Provide for personal comfort
9. Provide clean and pleasant environment
10. Provide supplementary services
11. Provide protection from weather
12. Provide adequate security

<u>Commuter Special User Objectives</u>

Passenger Processing

13. Minimize travel time in station
2. Minimize crowding on links
4. Maximize safety
14. Providw for efficient fare collection
15. Eliminate physical barriers

Environmental

6. Provide comfortable ambient environment
7. Provide adequate lighting
9. Provide for clean and pleasant environment
10. Provide supplementary services
11. Provide protection from weather
12. Provide adequate security

<u>Operator Objectives</u>

Passenger Processing

16. Maximize equipment reliability
17. Provide smooth transition between modes
18. Provide sufficient space

Environmental

19. Provide adequate security for monies received
20. Make provisions for concessions and advertising

Fiscal

21. Provide for joint development potential and value capture
22. Minimize maintenance, cleaning, and replacement costs
23. Minimize operating cost
24. Minimize capital cost
25. Obtain adequate return on incremental investments

The corresponding criteria and performance measures are shown in Table 2.5. These will be used in the evaluation of station designs.

Table 2.5

Central Area Bus Terminal Objectives, Criteria, and Performance Measures

Objectives	Criteria	Performance Measures
1. Minimize walk distance	Average distance	Feet
2. Minimize crowding on link	Level of service	Level of service
3. Minimize disorientation	Connectivity of paths	Connectivity measure
4. Maximize level changes	Presence of design hazards	Subjective rating
5. Minimize level changes	Number of level changes Type of change aids	Number of changes Subjective rating
6. Comfortable enrivonment	Thermal comfort Noise levels	RWI(subj.) HDR(subj.) Subjective rating
7. Adequate lighting	Illumination levels	ft-c
8. Personal comfort	Restrooms	Capacity
9. Clean and Pleasant environment	Finish materials	Subjective rating
10. Supplementary services	Number and type	Subjective rating
11. Weather protection	Time exposed	Minutes
12. Adequate security	Separate spaces % paid area Types of provisions	Number % Subjective rating
13. Minimize travel time	Average time	Minutes
14. Efficient fare collection	Average time	Minutes
15. Eliminate physical barriers	Number and type	Subjective rating
16. Maximum equipment reliability	Back-up facilities	Present or not
17. Smooth modal transition	Compatability	Subjective rating
18. Sufficient space	Station size	Sq. ft.
19. Adequate security for monies received	Avenues of escape Procedures	# of avenues Subjective rating
20. Provisions for concessions and advertising	Advertising provisions Concession provisions	Type, size, location Type, size, location
21. Joint development potential and value capture	Design provisions	Subjective rating
22. Minimize maintenance, cleaning and replacement costs	Cost	$/year
23. Minimize operating cost	Cost	$/year
24. Minimize capital cost	Cost	$
25. Obtain adequate return on operator's investments	Return	Return

POLICY STATEMENTS

The RTA established the following policy statements governing this station.

1. The intercity operation will remain open continuously. The commuter operation will be open 24 hours a day, except on holidays when commuter and local buses are not running.

2. Non-transport activities, such as concessions and advertising, will be operated at a profit.

3. An adequate level-of-service will be provided to the elderly and handicapped (special users).

4. Joint development will be encouraged.

5. Public telephones will be provided to patrons.

6. The information system will include an information booth, a public address system, and signing.

7. Construction materials will be selected for high levels of durability, low maintenance, safety, aesthetics, and low cost.

8. Restrooms will be provided for intercity travelers.

9. In warm weather, station patrons will be at least as comfortable as they would be outdoors.

10. In cold weather, station patrons will not be subjected to a greater heat deficit indoors than they would be subjected to outdoors.

ALTERNATIVE DESIGNS

There are many possible ways for developing transit station designs, but typically initial decisions concerning basic station layout govern many of the subsequent options that are available. Such station layouts reflect the number of levels, location of entry and exit points, location of line haul and public transit occur points, the amount of space allocated for non-transportation purposes and so forth. Accordingly there are many possible ways to create different station designs but usually the experience of the operating agency and the architect are relied upon to initiate the design process with reasonable alternative layouts that reflect the local objectives and design controls.

In this problem three alternative design approaches are established from the literature which share the following characteristics (4).

1. Air rights development
2. Separation of commuter and intercity buses
3. Grade separated bus entry and exit
4. Commuter bus sawtooth platforms
5. Pedestrian connections to other modes

The alternatives are described below; Alternatives 2 and 3 are variations of Alternative 1.

Alternative 1 (Adapted from Ref. 4)

A sketch of Alternative 1 is shown in Figure 2.2. As can be seen, the ground floor contains the commuter concourse, intercity bus lobby, and four areas to be leased. Direct access to the commuter and intercity bus levels is provided by elevators, escalators, and stairs. The commuter bus level (2nd floor) has separate bus loading and unloading areas and the loading area has two parallel platforms with passing lanes for buses. The intercity bus level (3rd floor) contains one large waiting area and a long concourse for access to the buses. The entire structure would be 13 stories, including basement. All additional floors would be rented for office space.

Alternative 2

The layout of this alternative is similar to the first one except that the commuter and intercity bus areas are side-by-side on the second floor (see Figure 2.3). Access to these areas is provided from street level. Intercity passengers will have to travel only one floor height

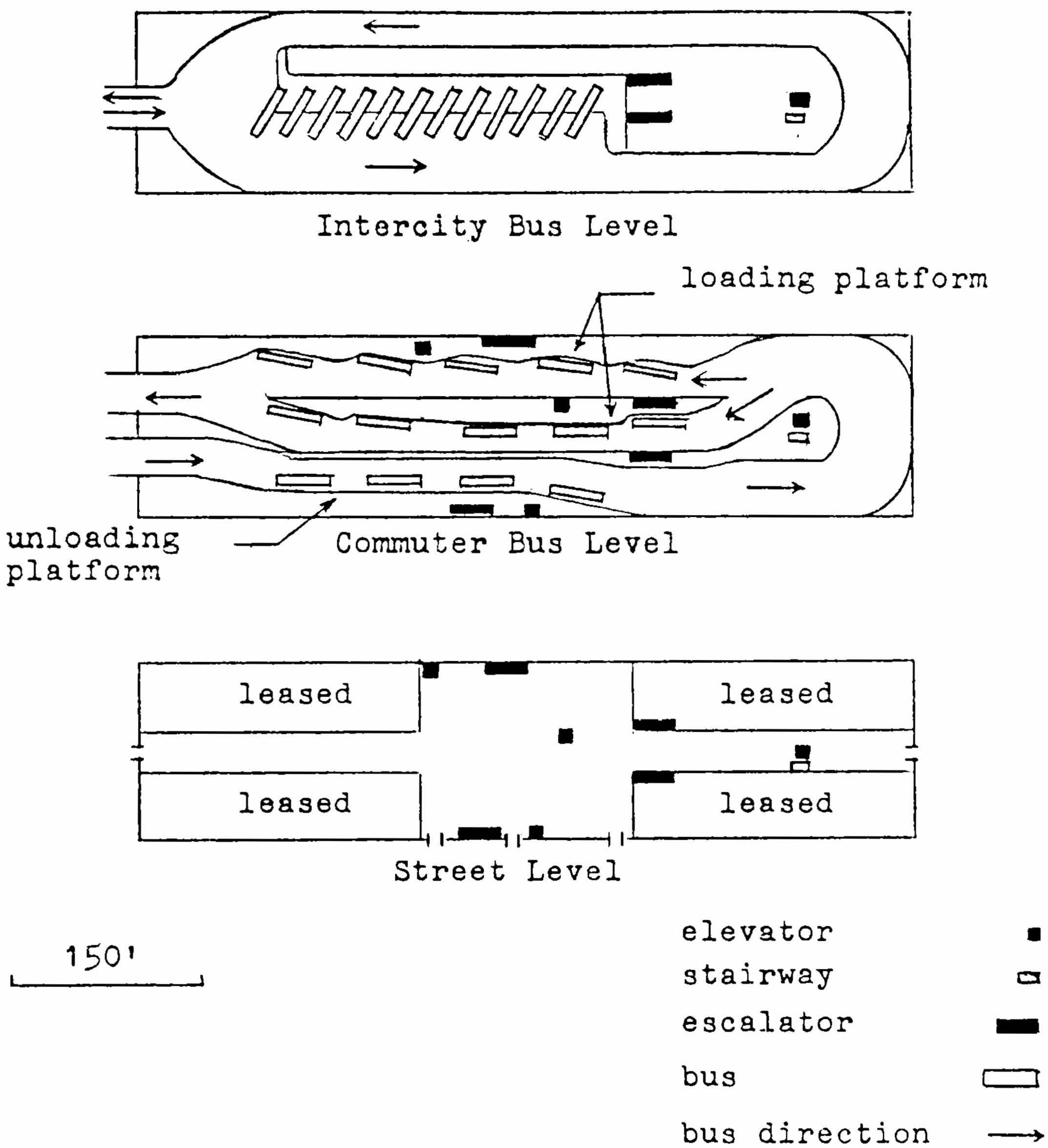


Figure 2.2 Bus Terminal: Alternative 1 (Adapted from Ref. 16)

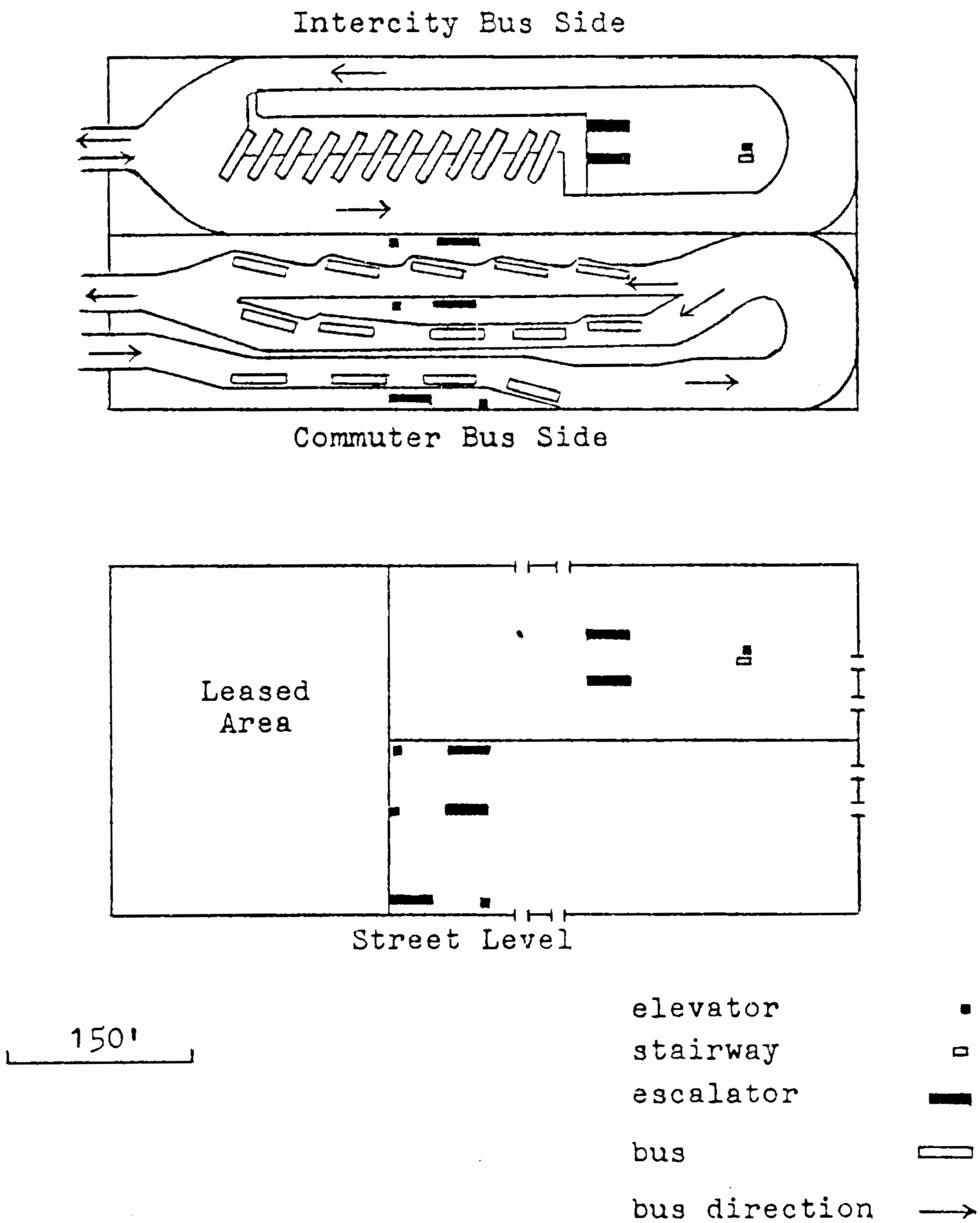


Figure 2.3 Bus Terminal: Alternative 2

instead of two, but the ground area required for the facility is doubled. Direct access to other modes is still provided. The structure would be nine stories including basement, with the additional floors rented for office space.

Alternative 3

Alternative 3 is similar to Alternative 1 except that at the commuter bus level loading and unloading occur from the same central platform (see Figure 2.4). Buses entering this level will be required to cross the paths of exiting vehicles. This layout will not require separate escalators, elevators, and stairs to each of the two bus levels. This structure, like that of Alternative 1, would be 13 stories.

EVALUATION I

The performances of each of the three preliminary alternative designs relative to the criteria are measured. This provides input for evaluating station policy, performance, and cost. It also leads to the selection of one of the alternatives for detailed design. The performance measures used are discussed below.

Intercity User Performance

Average walk distance

This is walking distance within the terminal. As measured from the drawings, all three alternatives have the same average distance of 390 feet.

Level of service on links

These level of service values are derived from Fruin's work and are similar to level of service descriptions for roadway traffic.

Commuter Bus Level

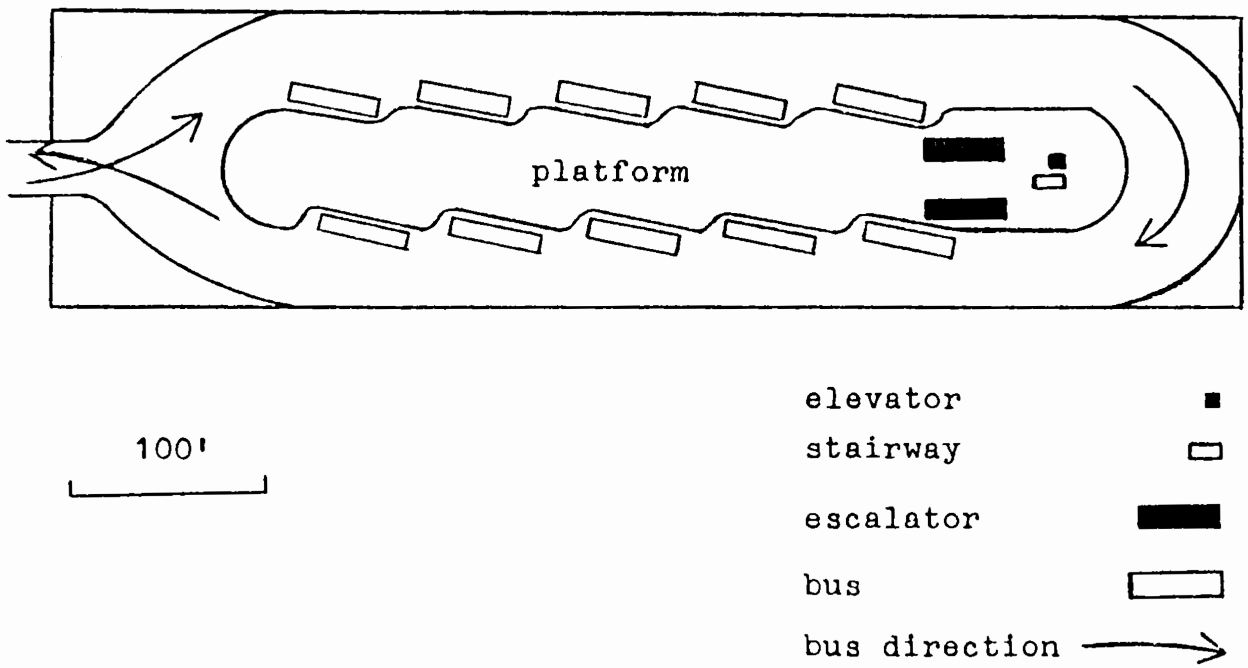


Figure 2.4 Bus Terminal: Alternative 3

Application techniques are shown in Ref. 2, Appendix B. Level of service was measured for walk links in the lobby, on escalators, and on the concourse. A value of 1.25 was assumed to convert pedestrian arrival rates from peak hour volumes to peak 15 minute volumes. An adjustment factor of 1.5 was used to estimate micro-peaks within the 15 minute peak.

Since the concourses in all three alternatives are identical, the levels of service are equivalent. The concourses are 20 feet wide but 18 inches were subtracted on each side, because of the presence of curbs, and 18 inches were subtracted to allow a buffer for the two directions of flow, leaving a total effective width of 15.5 feet. An analysis of pedestrian demand and available travel space showed a flow of 4.0 passengers per foot width per minute (level of service A).

Level of service on escalators was next determined. For Alternatives 1 and 2 two escalators (one in each direction) were used (32 inches at hips, 24 inch treads, 90 feet per minute) with nominal capacities of 3750 persons per hour. Since the micro-peak flow was only 2060 persons per hour, this resulted in Level of Service C. For Alternative 3, one set of escalators serves both the intercity and commuter bus levels, so the micro-peak volume is 12,780 persons per hour. After assuming two escalators serving the major direction of flow with a total of three escalators in service from the first to second floors, and nominal capacities of 8025 persons per hour (5), Level of Service D was determined.

To determine level of service in the lobbies, it was assumed that almost all persons in the intercity part of the lobby were passengers. Effective walkway widths were assumed to be 50 feet and Level of Service A was determined.

Connectivity (directness) of paths

This measure is the ratio of walking distance to straight line distance (2). As this ratio increases, system coherence decreases. In this evaluation, the average of the connectivity measures for the major paths used is the performance measure.

Design hazards

Many factors were considered in evaluating station safety. These included vehicle/pedestrian collisions, vehicle/vehicle collisions, exposure to weather, level changes, walking hazards, platform edges, passenger volumes, and distance to station agent's booth. Because of the similarity of layout among the three alternatives, they performed almost equally well. The only significant difference was that in Alternative 2 only one level change is required, rather than two. However all three designs were rated as being good.

Number of level changes

This criterion was used separately as a measure of passenger inconvenience, rather than as a measure of safety as was discussed directly above. As noted there, Alternative 2 requires one change from street level, while the others require two.

Types of level change aids

The level change aids, primarily escalators (while elevators are present for special users) were rated as being good compared with stairs.

Thermal comfort (relative warmth index)

System policy states that "in warm weather, station patrons will be at least as comfortable as they would be outdoors." An equation is available to determine the difference between outdoor and indoor temperature to achieve the above criterion (6):

$$\left[\frac{M(Icw + I_a) + 1.13(t_o - 95) + RIa}{74.2}\right]_{outdoors} = \left[\frac{M(I_{cw} + I_a) + 1.13(t_s - 95)}{74.2}\right]_{station} \qquad (2.1)$$

where:

M = metabolic rate, Btu per (hr.)(sq.ft.)

I_{cw} = insulation of clothing based on wet cloth assumption, clo.

I_a = insulation effect of air boundary layer, clo.

t_o = outdoor dry bulb air temperature, °F

t_s = station dry bulb air temperature, °F

R = mean incident radiant heat from sources other than walls at room temperature, Btu per (hr.)(sq.ft.)

Assuming the design conditions are:

M = 54 Btu per (hr.)(sq.ft.); walking at 3 mph

I_{cw} = 0.35 clo., walking at 3mph

I_a = 0.22 clo. outdoors, total air velocity = 900 fpm

0.32 clo. in station, total air velocity = 360 fpm

R = 10 Btu per (hr.(sq.ft.); outdoors from sun

then by substitition.

$$\frac{54(0.35 + 0.22) + 1.13(t_o - 95) + 10(0.22)}{74.2}$$

$$= \frac{54(0.35 + 0.32) + 1.13(t_s - 95)}{74.2}$$

$$t_o - t_s = 2.83°F$$

Then, if during warm weather the station temperature is kept 3°F lower than the outdoor temperature, the stated objective will be met. Since this should be possible in all three alternative station designs, all three were rated as fair.

Thermal comfort (heat deficit rate)

System policy for cold weather states that environment control systems will prevent patrons from experiencing a greater heat deficit in the station than they would experience outdoors. Since station patrons will be coming from outdoors, this means that the heat deficit rate must be equal to or less than zero. The equation for heat deficit rate (6) is:

$$HDR = - M - \frac{1.13(t-87)}{I_{cw} + I_a} + 9 \frac{RI_a}{I_{cw} + I_a} \qquad (2.2)$$

Assuming HDR equals zero and the following design conditions:

M = 39 BTU per (hr.)(sq.ft.), an occasional stroll

R = 0 BTU per (hr.)(sq.ft.)

I_a = 0.33 c/o., for total air velocity of 360 fpm

I_{cw} = 1.13 c/0., assuming one dresses for walking 4 mph, with a 15 mph wind, on a 30°F day

and substituting in Eq. 2.1:

$$0 = - 39 - \frac{1.13(t - 87)}{1.13 + 0.33} + 9 \frac{0(0.33)}{1.13 + 0.33}$$

$t = 48.14°F$

the station should be designed to provide a temperature of at least 49°F on cold days. Since all of the alternatives use the same mechanical equipment they all will meet this level, which was rated as "fair".

Noise levels

It is expected that noise levels in all three alternatives will not exceed acceptable levels. Therefore all three were rated as "good".

Illumination levels

All three station designs will meet recommended minimum illumination levels (7). Relevant levels are:

Station Area	Illumination Level (ft.c.)
Platform	15
Fare collection	100
Mezzanine	20
Building entry	10 (night)
Stairs and escalators	25
Elevator (interior)	20
Washrooms	30
Passages	20

In addition, brightness and brightness differences should be within acceptable ranges. Therefore, all three alternatives were rated as "good".

Restrooms

These will be provided in the intercity bus lobbies. It has been estimated that, considering peak hour volumes and user characteristics, that the following facilities are needed.

Women's Restroom	Men's Restroom
6 lavatories	6 lavatories
6 water closets	3 water closets
	3 urinals

All three alternative designs include such provisions.

Finish materials

The materials which are planned to be used in the lobby area are:

(a) floor - synthetic resin tile,

(b) walls - structural glazed facing tile, and

(c) ceiling - perforated cement asbestos panels with wrapped acoustical material.

On bus levels the planned materials are:

(a) floor (concourse and waiting area) - concrete toppings

(b) walls - structural glazed ceiling tile, and

(c) ceiling - perforated cement asbestos panels with wrapped acoustical material.

These materials were rated as "good".

Supplementary services

Planned supplementary services for each of the alternatives include telephones (two), a candy/magazine counter, and a snack bar. Since the station is located near the downtown area, with a wide variety of shops and restaurants nearby, it was not felt that much more than this would be necessary. These services were rated as "fair".

Exposure to weather

There is no exposure to weather after entering the various stations. Since exposure to weather outside the building will be the same, regardless of the design, only the possible exposure inside the building was considered here.

Separate spaces

There are five separate non-interdivisible spaces in Alternatives 1 and 3 (basically these are the first, second, and third floors and restrooms). In Alternative 2 there are only four of these spaces.

Paid area

The percentage of station area (lobby and commuter bus area) which is "paid area" was measured from the drawings. For intercity users the values obtained for 6 iteratives 1, 2 and 3 were 35, 29 and 35% respectively.

Security provisions

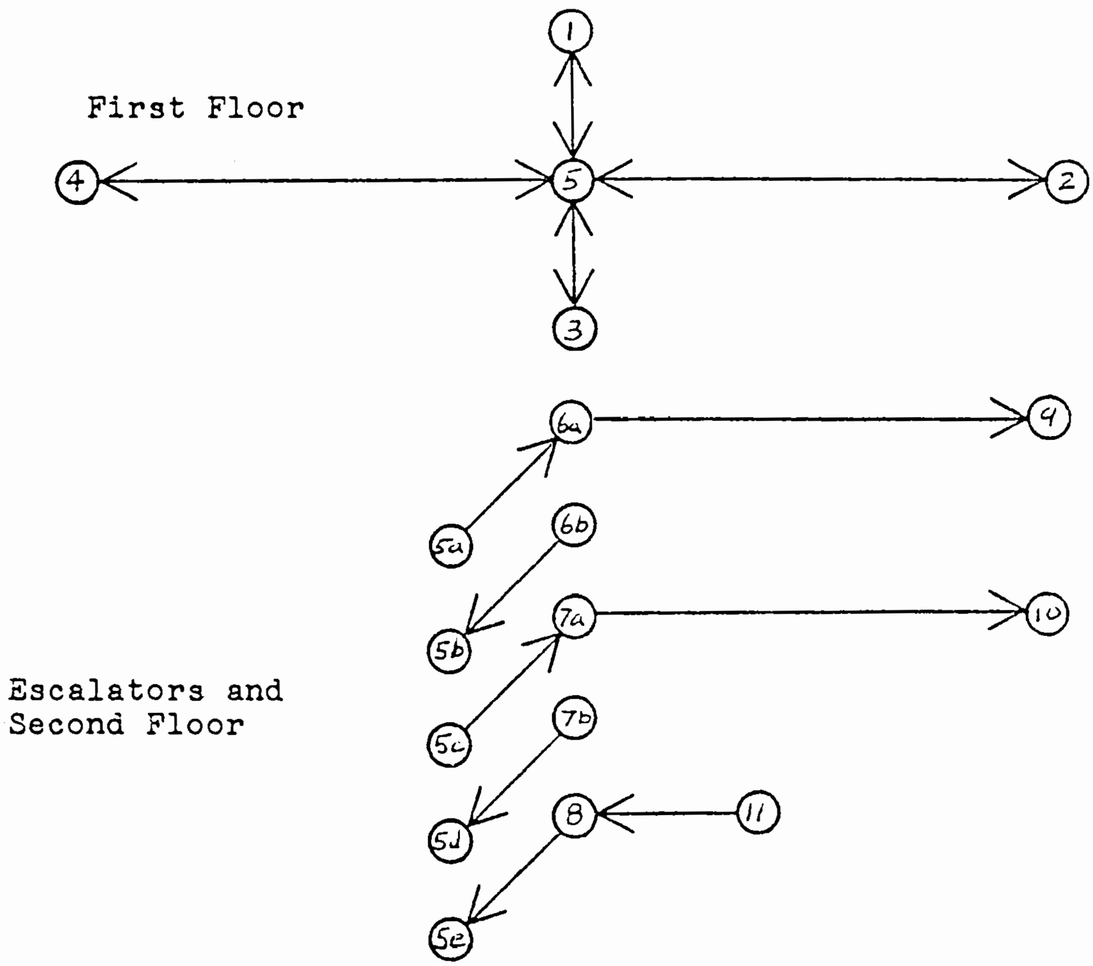
Original plans call for no special security provisions for passengers in any of the station designs. This should be changed in the detailed design phase. At this stage, the designs were rated as "poor" in this regard.

Commuter User Performance

Travel time and level of service in station

The travel time in station measure could be more accurately called "walking time in station" since the waiting time for a bus is not included. The measure was taken during the evening peak period and only outbound travel was measured. The evening peak is the most critical because passengers will be waiting for buses and thereby reducing the effective width of the bus platforms for walkers.

The procedures used here are outlined in Reference 2, Appendix C. A somewhat simplified network representing the major walk links for Alternative 1 is shown in Figure 2.5. The data and calculations required are shown in Table 2.6 which show that, for pedestrians entering the station on the first floor, pedestrian level of service is A. It should be noted that only a fraction of the total effective walkway width was apportioned to transit users while the rest was apportioned to other pedestrians using the building.



Node	Description
1	Entrance from contiguous building
2	E Avenue entrances
3	20th Street entrances
4	F Avenue entrances
5	Bottoms of escalators
6	Tops of escalators at side boarding platform
7	Tops of escalators at center platform
8	Top of escalator at unloading platform
9	Centroid of side boarding area
10	Centroid of center boarding area
11	Centroid of unloading platform

Figure 2.5 Commuter-Pedestrian Network: Alternative 1

Table 2.6

Commuter-Pedestrian Link Characteristics:
Alternate 1

Link	Length	Effective width (ft.)	Micro-Peak Volume (ped./hr.)	PFM[a]	Module (ft^2/ min.)	Speed (ft./ min.)	Level of Service	Average Time (min.)
1-5	90	20	300	0.24	50	270	A	0.33
2-5	300	18	4,000	3.6	50	270	A	1.11
3-5	90	20	3,006	2.5	50	270	A	0.33
4-5	300	18	3,006	2.7	50	270	A	0.11
5a-6a	40	8,025[b]	5,156	0.64	4.84	120	D	0.33
6b-5a[c]	40	8,025[b]	0	0		120	A	-
5c-7a	40	8,025[b]	5,156	0.64	4.84	120	D	0.33
7b-5d[c]	40	8,025[b]	0	0		120	A	-
8-5e[c]	40	8,025[b]	940	0.12	26	120	A	-
6a-9	180	8	5,156	10.74	25	250	B/C	0.72
7a-10	180	8	5,156	10.74	25	250	B/C	0.72
11-8[c]	70	8	940	1.96	50	270	A	-

Average station travel time = 1.87 min.

[a]PFM = pedestrians per foot-width per minute

[b]Nominal escalator capacity of 8,025 persons/hr. incline speed = 120 ft./min., 89 steps per minute width at hips = 48 in.
angle = 30°

[c]Not included in average station travel time computation

Fruin (5) did not give level of service standards for escalators. To estimate level of service on the escalators for Alternative 1, area per pedestrian was found and the standards for waiting areas were used. The level of service on the up-escalators was then found to be D. As a check the volume-to-capacity ratio for the escalators was found and compared to level of service of this same volume-to-capacity ratio for walkways and stairs. Similar results were found by this check.

Level of service at the most critical points in the loading areas for Alternative 1 were on the border-line between levels B and C. It had originally been assumed that pedestrian volumes would be equally split between the two loading platforms since they each serve five bus loading points. Since one of the platforms will probably serve slightly higher volumes than the other, Level of Service C should predominate on one of them, and this will serve as the measure for the loading platforms. The average station travel time during the evening micro-peak is shown in Table 2.6.

For Alternative 2, the passenger flow characteristics would be identical to Alternative 1 on the second floor and the escalators. The area-per-person on the first floor would be the same or slightly higher, resulting in the same free-flow characteristics as in the first alternative (Level of Service A). Since the walk distances are almost exactly the same, the in-station travel time would be roughly equal.

In Alternative 3 the pedestrian level of service and walk speed on the first floor remain the same as in Alternative 1. Two escalators provide upward movement for a micro-peak flow of 12,374 commuter and intercity bus passengers per hour (103 ped./min./esc.).

The horizontal speed of the escalators is 104 ft./min. and the width at hips is 48 in. Therefore, there were 4.03 sq. ft. per pedestrian on the escalators, implying Level of Service D, when Fruin's standards for waiting areas were used.

Speed x Density = Flow

104 ft./min. x Density = 103 ped./min.

Density = 0.99 ped./ft.

since width = 4 ft.,

Density = 0.25 ped./ft.^{2}

or,

Pedestrian density = 4.0 ft.^{2}/ped.

On the second floor, the commuter bus level, an effective platform width of 24 ft. was used. With 10,312 commuters per hour, pedestrian density was 6.87 ped./min./ft., yielding Level of Service A and a speed of 265 ft./min.

Design hazards

Design hazards considered included:

(a) vehicle/vehicle collisions,

(b) vehicle/pedestrian collisions,

(c) exposure to weather,

(d) level changes,

(e) walking hazards,

(f) platform edges,

(g) pedestrian path crossing volumes, and

(h) distance to station agent's booth.

Alternatives 2 and 3 are virtually identical with respect to these potential hazards. Alternative 3 has slightly higher pedestrian path crossing volumes (because of escalators shared with intercity users) and probably a higher chance of vehicle/vehicle collisions (because of path crossings at the bus entrance. All three alternative designs performed close enough so that all were rated as having "fair" performance for design hazards.

Fare collection time

The average fare collection time should be approximately the same for the three alternatives since fare collection will occur on-board. Using the evening peak hour flows (5500 passengers/hr., 125 buses/hr.) and an assumed average boarding time of 3.0 sec./passenger, the average loading time (T) was determined to be:

T = (5500 pass./hr/125 buses/hr)x(3.0 sec./pass)

T = 132 sec./bus

The average fare collection time for a passenger in the boarding lane would be half of this average loading time, or 66 seconds (1.1 minutes).

Environmental criteria

The environmental performance measures for commuter user were determined in the same manner as those for intercity users.

Intercity Special User Performance

Average walk distance

This is walk distance within the terminal, using an elevator rather than an escalator. For all three alternatives the distance was approximately 590 feet.

Level of service on links

The levels of service for special users on the first floor and intercity bus level are the same as for users, Level A, since there are relatively low pedestrian volumes for the walk widths provided. On the elevators (which can be considered as links), level of service was defined as that of a waiting area. Assuming a worse condition (one elevator for both intercity and commuter special users in Alternative 3) round-trip time of 2 minutes for the elevator and an area of seven feet by nine feet, Level of Service A (a minimum of 13 sq. ft. per person) would not be exceeded unless the flow was greater than 145 persons per hour. The number of special users expected to use elevators in any of the alternatives is far below this figure, so Level of Service A can be expected on the elevators.

Connectivity of paths

This ratio of walking distance to straight line distance was determined in the same manner as it was for intercity users.

Design hazards

Because of the similarities of design between the alternatives, they perform about equally well with respect to design hazards. Factors considered were vehicle/pedestrian collisions, vehicle/vehicle collisions, exposure to weather, level changes (by escalator and elevator), movement hazards, platform edges, pedestrian volumes, distance to station agent's booth, and vehicle boarding/deboarding. For all designs, this rating was "good".

Number of level changes

For special users riding elevators, there is only one level change experienced in each of the three alternatives. For those riding escalators, Alternatives 1 and 3 require two such changes compared to one change required in Alternative 2.

Types of level change aids

The level change aids, primarily escalators and elevators, were rated as being good in all three alternatives.

Number of physical barriers

Possible physical barriers to special users which are present include vehicle loading and unloading, level changes directly outside of the building (curbs), and doorways for station entry and exit. These are present in all three designs with about the same severity.

Environmental criteria

In general, the performance measures for the environmental criteria were the same for intercity special users as they were for intercity users. The one major difference was in the number of separate non-intervisible spaces. For intercity users, elevators were not considered as separate spaces, but for special intercity users they were. Therefore, one separate space was added to each alternative.

Commuter Special User Performance

Travel time in station

To determine travel time in the station it was assumed that special users would travel at one-half the speed of other users on links and that elevators would require an average of 30 seconds per floor, including loading and unloading. Therefore the travel time calculations included walking time, elevator riding time, and waiting time for elevator (one-half headway or 30 seconds).

Level of service on links

Similar to the condition for intercity special users, levels of service on walk links were the same as for users. On the elevator links, the worse condition (one elevator for both intercity and commuter special users in Alternative 3) still is at Level of Service A.

Design hazards

The same considerations for design hazards were used here that were used for intercity special users. The performance of all three designs were rated as good.

Fare collection time

This would be the same as that for other commuter users.

Number of physical barriers

The possible physical barriers found were the same as those for intercity special users: vehicle loading and unloading, level changes directly outside of the building (curbs), and doorways for station entry and exit. They are all present and have about the same severity in all three designs.

Environmental criteria

In general, the performance measures for the environmental criteria are the same for commuter special users as for other commuters. The one major difference is the additional number of separate non-intervisible spaces resulting from the use of elevators by commuter special users.

Operator Performance

Back-up facilities

These could conceivably be needed for breakdowns of elevators, escalators, doorways, and vehicles. An elevator breakdown would be most critical for Alternative 3 because only one elevator is used for all intercity and commuter users requiring this.

Smoothness of modal transition

While this is a subjective measure, an objective measure, distance to other modes, is used as an indirect indication of transition smoothness. The total distance from the unloading platform of the commuter bus area to all other major modes (intercity bus + walk + local bus + taxi + subway) was found for

Alternative 1 (750 + 280 + 400 + 400 + 460 = 2290 feet),

Alternative 2 (720 + 280 + 400 + 350 + 500 = 2350 feet),

Alternative 3 (400 + 280 + 400 + 400 + 460 1940 feet).

Since these three measures are fairly close to each other and other aspects are similar, all three alternatives were rated as "good" for smoothness of modal transition.

Sufficiency of space

More than an adequate amount of space is available for all operations at this station. The pedestrian level of service was acceptable in each design. Therefore all three designs were rated as "excellent" for this criterion.

Avenues of escape

Alternatives 1 and 3 provide six basic avenues of escape for fleeing criminals (four sets of exterior doors and the elevator and escalator leading to the subway station). Alternative 2 has 10 avenues of escape (six sets of exterior doors and two elevators and escalators going down to the subway station). The total number of escape avenues was used on the performance measure.

Security of monies received

Commuter bus users must pay the exact fare or use bus tokens or passes. Since the money is then in a locked box, the security of that money is not too great a problem. Intercity bus users must purchase tickets at the intercity bus ticketing area, where money is kept in cash registers. Besides these operating characteristics, relevant station attributes include number of exits, alarm provisions, surveillance, and security patrols.

The number of exits was discussed in the previous section. Presently, there are no provisions for alarms, surveillance, or security patrols. Therefore all three designs were rated as "fair" with respect to security of monies received.

Advertising provision

System policy is directed at providing limited and controlled advertising space with:

(a) a minimum number of locations

(b) standard sizes of displays

(c) no advertising on platforms

(d) advertising which complements station architecture, and

(e) centralized control for the entire transit system.

These provisions were rated as "good" for all three station designs.

Concession provisions

System policy calls for limited and controlled concessions, a minimum number of locations, and centralized control of concessions. Provisions at this station call for a candy/magazine counter and snack bar, and public telephones for the intercity bus lobby. The commuter lobby will also contain public telephones. While these provisions were rated as only "fair" for users commuter and intercity users, they were rated as "good" from the operator's perspective.

Design provisions for joint development

The cost of land is high around the station site (about $15/sq. ft.), partly due to extensive urban renewal activities. There is easy access from all surrounding modes to the building lobby. From the lobby, access to upper floors, planned for office space, is provided by elevators and stairs. Significant interest in air-rights development has been shown by several developers. Their major condition is that the station design be complementary to their needs.

The area which is available to the transit system for the station is approximately 280' x 600'. Alternative 1 requires all of this space. The preliminary design calls for eight stores from the ground level up. Alternatives 1 and 3 (140'x600') call for 12 stories from the ground level up. If Alternative 1 or 3 is selected, the other half of the block will be sold by the city. With respect to design provisions for join development, all three designs were considered as "good".

Maintenance, cleaning, and replacement costs

The itemized estimates of maintenance, cleaning and replacement costs are shown in Table 2.7. It is interesting to note that there is little variation among the three designs for these costs. Also, more than 80% of the cost in each design goes toward the three cleaning employees.

Table 2.7

Central Area Bus Terminal Maintenance, Cleaning and Replacement Costs ($/year)[a]

Items	Alternatives 1	2	3
Maintenance			
lighting	100	120	100
heating, venting, airconditioning	250	300	250
plumbing	100	100	100
electrical	50	50	50
escalators and elevators	300	400	150
contingency (15%)	120	145	100
Cleaning			
employees (3)	33,000	33,000	33,000
materials	300	300	300
equipment	200	200	200
contingency (15%)	75	75	75
Replacement			
lighting	200	200	200
floor covering	600	700	600
painting	450	550	450
seats	200	200	200
roadway repaving	3,000	3,000	3,000
contingency (15%)	670	700	670
Total	39,615	40,040	39,445

[a]General estimates

Operating costs

The estimates for operating costs are shown in Table 2.8 and indicate only a small difference among the three alternatives. The data in this table are limited to operating costs for the bus terminal operations in the building and do not include operating costs that would be paid for by leasers of the intercity bus area and the food and amenities counters (e.g. for their employees, materials, etc.).

Capital costs

The estimates for the basic costs of the buildings and special costs for transportation equipment are shown in Table 2.9. It was assumed here that if the transportation agency only requires one-half of the block (as in Alternatives 1 and 3) the city will pay for one-half of the cost for demolition and disposal of the existing building and then sell the other half of the block.

The size of the building varies with the alternative. Alternatives 1 and 3 call for a building one-half the size of the block with 13 stories, including a basement level. Alternative 2 involves a building, over the entire block, of nine stories including a basement level.

One may note that, for terminal equipment, the cost for the elevator and escalator systems varies highly among the alternatives. This is due to the different requirements for the number of these movement aids for each design.

Return on incremental investment

The incremental investments under study here were:

(a) air rights development,

Table 2.8

Central Area Bus Terminal Operating Costs ($/yr.)[a]

Items	Alternatives 1	2	3
General			
overhead (main office, insurance, etc.)	40,000	40,000	40,000
electricity	24,000	30,000	22,000
heating	3,500	4,000	3,500
water	600	600	600
snow removal (elevated bus lanes)	1,200	1,200	1,200
materials	300	300	300
contingencies (15%)	10,440	11,415	10,140
Total	80,040	87,515	77,740

Other operating costs paid by leasers of the intercity bus area and food and amenities counters

[a]General estimates

Table 2.9

Central Area Bus Terminal Capital Costs ($)

Items (unit cost)[a]	Alternatives 1	2	3
Land ($15/S.F.)[b]	1,620,000	3,240,000	1,620,000
Land Preparation			
demolition ($0.10/C,F,)	432,000	864,000	432,000
disposal of material ($4/C.Y)	640,000	1,280,000	640,000
Land Improvements			
sidewalks ($1.25/S.F.)	12,300	24,600	12,300
curbs ($6.00/L.F.)	4,920	9,840	4,920
fire main ($3,500 ea.)[c]	3,500	3,500	3,500
Building Construction			
architectural trades ($25.26/S.F.)	27,583,920	38,193,120	27,583,920
plumbing ($1.25/S.F.)	1,365,000	1,890,000	1,365,000
heating, venting, a/c ($3.20/S.F.)	3,494,400	4,838,400	3,494,400
electrical ($2.80/S.F.)	3,057,600	4,233,600	3,057,600
floor covering ($0.43/S.F.)	469,560	650,160	469,560
painting ($0.46/S.F.)	502,320	695,520	502,320
elevators, non-terminal ($1.45/S.F.)	1,583,400	2,192,400	1,583,400
Sub-total	40,786,920	58,115,140	40,768,920
Bus Terminal Equipment			
elevators, 3 story ($25,000 ea.)	-	100,000	-
elevators, 4 story ($30,000 ea.)	120,000	-	30,000
escalators ($100,000 ea.)	1,200,000	1,400,000	700,000
interior roadway ($9.45/S.Y)	107,730	107,730	112,450
signs, small ($20 ea.)	500	500	600
signs, large ($50 ea.)	750	750	1,000
seats ($60 ea.)	3,000	3,000	3,000
one-story baggage system ($25,000)	-	25,000	-
two-story baggage system ($35,000)	35,000	-	35,000
intercity ticketing desk ($1,000)	1,000	1,000	1,000
public-address system ($230/speaker)	1,840	1,840	1,840
candy/magazine, counter ($1,000)	1,000	1,000	1,000
snack bar ($45/S.F.)	10,000	10,000	10,000
water fountains ($400 ea.)	1,600	1,600	1,600
employee washroom fixtures ($800 ea.)	800	800	800
lockers ($50 ea.)	2,000	2,000	2,000
Total	42,254,140	59,770,360	41,669,210

[a]unless otherwise noted, cost data is taken from Reference 25 and not adjusted for inflation

[b]Source: rough estimate

[c]Source: Reference 19

(b) rental space on first floor corners,

(c) provisions for commuter buses,

(e) rental space for concessions, and

(f) space for advertising.

These were examined individually.

Air Rights

Significant cost savings (arising basically from the high cost of land), should result from the joint ownership of the building between the transportation authority and a private developer. Land, land preparation, land improvement, and building construction costs can be shared by the transportation authority and the developer based upon the proportion of floor space to used by them. Under this assumption, with Alternatives 1 and 3 the authority will use 23.08% of the floor space and for Alternative 2 it will use 22.22%. The rest of the floor space will be used by the developer. As shown in Table 2.10, the transportation authority's annualized capital cost will be $958,354 for Alternatives 1 and 3 and $1,315,208 for Alternative 2. While the above cost figures do not relate directly to return on incremental investment, they do show the costs of the buildings that result from this form of air rights development.

Rental space

The transportation authority can rent space on the first floor and at the intercity bus level. The rental rate is assumed to be $5.20 per square foot per year. Table 2.11 shows the areas and rents for this rental space on the corners of the first floor, for the intercity bus companies, and for concessions. It also shows expected advertising revenues.

Table 2.10
Land, Preparation, Improvements and Building Construction
Cost Proportions

Items	Alternatives 1 and 3	Alternatives 2
Percentage of floor space (%)		
transportation authority	23.08	22.22
private developer	76.92	77.78
Total	100.00	100.00
Shared capital costs ($)		
transportation authority	9,409,467	12,913,184
private developer	31,359,453	45,201,956
Total	40,768,920	58,115,140
Annualized capical costs (8%, 20 yrs.)[a]		
transportation authority	958,354	1,315,208
private developer	3,193,960	4,603,819
Total	4,152,960	5,919,027

[a]zero resale value assumed

Table 2.11
Rental Space and Rents ($/yr.)

Type of Rental (S.F.)	Rents for Alternatives ($5.20/S.F.) 1	2	3
First floor corners (43,000)	223,600	-	223,600
First floor corners (86,000)	-	447,200	-
Intercity buses (84,420)	438,984	438,984	438,984
Concessions (400)	2,080	2,080	2,080
Sub-total	664,664	888,264	664,664
Advertising, net revenue[a]			
2 sheet size (4'x5'), $153 ea.	765	1,530	765
escalator headers, $1,020 ea.	6,120	7,140	3,060
Total	671,549	896,934	668,489

Source: Reference 8.

Table 2.12
Transportation Authority's Annual Costs and Revenues ($/yr.)

	Alternatives		
Costs	1	2	3
Land and Building	958,354	1,315,208	958,354
Terminal Equipment	151,270	168,585	91,695
Maintenance, Cleaning, and Replacement	39,615	40,040	39,445
Operation	80,040	87,515	77,740
Total	1,229,279	1,611,348	1,167,234
Revenues			
Total Revenues (excluding commuter bus operation)	671,549	896,934	668,489
Difference (deficit)	(577,730)	(714,414)	(498,745)

Table 2.13
Intercity User Evaluation Matrix

Criteria Subsystem/category: Measure	Performance Measures Alternatives 1	 2	 3
Passenger Processing			
Average walk distance (ft.)	390	390	390
Level of service on links (Fruin level)	A,C,A	A,C,A	A,D,A
Connectivity of paths measure	1.17	1.15	1.17
Design hazards (subj.)	3	3	3
Number of level changes (#)	2	1	2
Type of level change aids (subj.)	3	3	3
Environmental			
Thermal comfort (RWI) (subj.)	2	2	2
Thermal comfort (HDR) (subj.)	2	2	2
Noise levels (subj.)	3	3	3
Illumination levels (subj.)	3	3	3
Restrooms (capacity)	sufficient	sufficient	sufficient
Finish materials (subj.)	3	3	3
Supplementary services (subj.)	2	2	2
Exposure to weather (minutes)	0	0	0
Separate spaces (#)	5	4	5
Paid area (%)	35	29	35
Security provisions (subj.)	1	1	1

Subjective Categories:

4 = excellent
3 = good
2 = fair
1 = poor
0 = very poor

Table 2.14
Commuter User Evaluation Matrix

Criteria Subsystem/category: Measure	Performance Measures Alternatives 1	 2	 3
Passenger Processing			
Travel time in station (min.)	1.87	1.87	1.89
Level of service on links (Fruin level)	A,D,C	A,D,C	A,D,A
Design hazards (subj.)	2	2	2
Avg. fare collection time (min.)	1.1	1.1	1.1
Environmental			
Thermal comfort (RWI) (subj.)	2	2	2
Thermal comfort (HDR) (subj.)	2	2	2
Noise levels (subj.)	3	3	3
Illumination Levels (subj.)	3	3	3
Finish materials (subj.)	3	3	3
Supplementary services (subj.)	2	2	2
Exposure to weather (min.)	0	0	0
Separate spaces (#)	2	2	2
Paid area (%)	38%	32%	41%
Security provisions (subj.)	1	1	1

Subjective Categories:

4 = excellent
3 = good
2 = fair
1 = poor
0 = very poor

Table 2.15
Intercity Special User Evaluation Matrix

Criteria Subsystem/category: Measure	Performance Measures Alternatives 1	 2	 3
Passenger Processing			
Average walk distance (ft.)	590	590	590
Level of service on links (Fruin level)	A,A,A	A,A,A	A,A,A
Connectivity of paths measure	1.16	1.14	1.16
Design hazards (subj.)	3	3	3
Number of level changes (#)	2/1	1/1	2/1
Type of level change aids (subj.)	3	3	3
Number of physical barriers (#)	3	3	3
Environmental			
Thermal comfort (RWI) (subj.)	2	2	2
Thermal comofrt (HDR) (subj.)	2	2	2
Noise levels (subj.)	3	3	3
Illumination levels (subj.)	3	3	3
Restrooms (capacity)	sufficient	sufficient	sufficient
Finish materials (subj.)	3	3	3
Supplementary services (subj.)	2	2	2
Exposure to weather (min.)	0	0	0
Separate spaces (#)	6	5	6
Paid area (%)	35	29	35
Security provisions (subj.)	1	1	1

Subjective Categories:
- 4 = excellent
- 3 = good
- 2 = fair
- 1 = poor
- 0 = very poor

Table 2.16
Commuter Special User Evaluation Matrix

Criteria Subsystem/category: Measure	Performance Measures 1	Alternatives 2	 3
Passenger Processing			
Travel time in station (min.)	3.89	3.89	4.00
Level of service on links (Fruin level)	A,A,C	A,A,C	A,A,A
Design hazards (subj.)	3	3	3
Fare collection time (min.)	1.1	1.1	1.1
Number of physical barriers (#)			
Environmental			
Thermal comfort (RWI) (subj.)	2	2	2
Thermal comfort (HDR) (subj.)	2	2	2
Noise levels (subj.)	3	3	3
Illumination levels (subj.)	3	3	3
Finish materials (subj.)	3	3	3
Supplementary services (subj.)	2	2	2
Exposure to weather (min.)	0	0	0
Separate spaces (#)	5	5	3
Paid area (%)	38	32	41
Security provisions (subj.)	1	1	1

Subjective Categories:
- 4 = excellent
- 3 = good
- 2 = fair
- 1 = poor
- 0 = very poor

Table 2.17
Bus Terminal Operator Evaluation Matrix

Criteria Subsystem/category: Measure	Performance Measures Alternatives 1	 2	 3
Passenger Processing			
Back-up facilities (subj.)	2	2	2
Smoothness of modal transition (subj.)	3	3	3
Sufficiency of space (subj.)	4	4	4
Environmental			
Avenues of escape (#)	6	10	6
Security of monies received (subj.)	2	2	2
Advertising provisions (subj.)	3	3	3
Concession provisions (subj.)	2	2	2
Fiscal			
Design provisions for joint development (subj.)	3	3	3
Maintenance, cleaning, and replacement costs ($/yr.)	39,615	40,040	39,445
Operating cost ($/yr.)	80,040	87,515	77,740
Capital cost ($)	42,254,140	59,770,360	41,669,210
Return on incremental investments			
Operator's total annual cost ($)	1,229,279	1,611,348	1,167,234
Operator's total annual revenue ($) exclusive of commuter bus	671,549	896,934	668,489
Difference (dificit, $)	(557,730)	(714,414)	(498,745)

Table 2.18
Criteria Having Differing Performance Measures

Interest Group Criteria	Performance Measures Alternatives 1	2	3
Intercity User			
Level of service on links	A,C,A	A,D,A	A,D,A
Connectivity of paths measure	1.17	1.15	1.17
Number of level changes	2	1	2
Separate spaces (#)	5	4	5
Paid area (%)	35	29	35
Commuter User			
Travel time in station	1.87	1.87	1.89
Level of service on links	A,D,C	A,D,C	A,D,A
Paid area (%)	38	32	41
Intercity Special User			
Connectivity of paths measure	1.16	1.14	1.16
Number of level changes	2/1	1/1	2/1
Separate spaces (#)	6	5	6
Paid area (%)	35	29	35
Commuter Special User			
Travel time in station	3.98	3.98	4.00
Level of service on links	A,A,C	A,A,C	A,A,A
Paid area (%)	38	32	41
Operator			
Avenues of escape (#)	6	10	6
Maint., clean., replace. cost ($/yr.)	39,615	40.040	39,445
Operating cost ($/yr.)	80,040	87,515	77,740
Capital cost ($), total	42,254,140	59,770,360	41,669,210
Return on operator's investments			
- total cost ($/yr.)	1,229,279	1,611,348	1,167,234
- total revenue ($/yr.) excluding commuter bus	671,549	896,934	668,489
- Difference (deficit)	(557,730)	(714,414)	(498,745)

Table 2.12 shows the annual cost and the net deficit a transportation authority should expect from each alternative. Since the major concern of the transportation authority is, of course, transportation, this net deficit could be described as the net cost of providing the downtown bus terminal. Because of the relevance of the operator's cost, revenue, and deficit, these figures are included in the operator's evaluation matrix (Table 2.17). It could be asserted that, because these annual total cost, revenue, and deficit figures are present in the evaluation matrix, the individual figures for maintenance, cleaning, and replacement costs, operating cost, and capital cost are not needed. However, the magnitude of these costs, especially capital cost, are important for the decision-making process, if only for financing and risk reasons.

Design Alternative Selection

The purpose of this section is to select the most suitable preliminary alternative design and to evaluate the effectiveness of policy. To determine the most suitable design, an effectiveness analysis framework using the data from Tables 2.13 through 2.17 was employed.

As can be noted from these tables, many of the performance measures for the three alternative designs are identical. Of the 78 performance measures, only 23 differ for the three alternatives. These differences are shown in Table 2.18. Since Alternative 1 and 3 are the two least cost alternatives, they are compared first.

Comparing Alternatives 1 and 3

For intercity users the only difference between 1 and 3 is in "level of service on links". It appears that, overall, there is little difference in user performance between the two alternatives.

There is, however, a significant difference in performance from the operator's perspective. Alternative 3 has slightly lower maintenance/cleaning/replacement and operating costs and a considerably lower capital cost than Alternative 1. The yearly deficit for Alternative 3 is almost $59,000 lower than that for Alternative 1. The above analysis indicates that Alternative 3 is superior to Alternative 1.

Comparing Alternatives 3 and 2

For intercity users and intercity special users Alternative 2 performs slightly better than 3 for "level of service on links" and "number of separate spaces" and much better for "number of level changes." On the other hand, Alternative 3 is slightly superior for "percentage of area that is in paid area". It would seem that these two groups would prefer Alternative 2. Commuter users and commuter special users would probably prefer Alternative 3 because it performs slightly better for them in "level of service on links" and "percentage area that is paid area."

Again there is a major difference in performance from the operator's perspective. Alternative 3 has fewer avenues of escape, a significantly lower operating cost (by almost $10,000/year), and a much lower capital cost (by over $18,000,000). The yearly deficity for Alternative 3 is more than $215,000 lower than that for Alternative 2. The above analysis indicates that Alternative 3 is superior to Alternative 2, mainly on the basis of the operator's costs. Therefore Alternative 3 was selected as a basis for more detailed design.

Policy

A review of the policy statements in light of the results of this first-round evaluation was made. It was determined that no changes in policy are warranted.

DESIGN IMPROVEMENTS

The development and testing of possible improvements to the chosen design (Alternative 3) is now discussed. These design changes are directed at improving upon weaknesses in the basic design and the changes are evaluated in terms of their direct and indirect effects.

Strategies for Improving Station Performance

The preliminary evaluation suggested eight station design features for possible improvement:

(1) level of service on links,

(2) presence of design hazards,

(3) provisions for station patron security,

(4) intercity special user walk distance,

(5) special user movement barriers,

(6) number of separate, non-intervisible spaces,

(7) system reliability, and

(8) security of monies received.

Fifteen design and operation strategies are investigated to improving upon the station design for the 8 features stated above.

1. Level of service on links

The pedestrian level of service provided for in the design is excellent except on the escalators between the first and second floors. Two strategies were considered for improving upon the level of service between the two floors. The first strategy provided an additional escalator between the first and second floors. The second strategy provided a wide stairway, parallel to the escalators, to serve part of the level change flow.

2. Design hazards

A set of strategies are considered for improving station safety concerning the bus path crossing on the commuter bus level and the presence of platform edges. One strategy suggests the use of a traffic signal at the bus path crossing to control flow. Another calls for the commuter buses to operate on the "wrong" side (left) at the bus entrance/exit and then to cross to the "correct" side (right) outside of the terminal building, where visibility would be less of a problem. Commuter buses exiting the station can simply yield the right of way to incoming buses to provide a further improvement. Another strategy calls for platform edges to be painted a bright color to aid passengers in recognizing platform edges. Finally the use of texturized concrete on the platform edges could further enhance safety.

3. Station user security

The present design includes no provisions for surveillance. Two strategies were proposed that were expected to directly increase the security of station patrons. The first strategy involves the use of security guards jointly with the subway station. The second strategy calls for security cameras to be used to scan the terminal.

4. Walk distance

In order to decrease the walk distance required of special users, short-term parking for the handicapped is provided beside the northern building entrance.

5. Physical barriers

Two strategies were considered for reducing barriers to special users. One provided ramps at the curbs directly outside the station building. The other provided a set of automatically opening doors on each side of the building.

6. Separate spaces

To reduce the number of separate, non-intervisible spaces encountered by special users it was suggested that the elevators used could have transparent sides.

7. System reliability

To improve system reliability for special users it was proposed that an additional elevator be provided.

8. Security of monies received

To improve the security of monies received, it was suggested that alarm provisions be installed in the intercity bus counter area.

Summary

The 8 objectives, 15 strategies, and expected direct and indirect effects are summarized in Table 2.19. The analyses of the different proposals are described below.

Analyses

Analyses were conducted to determine the direct and indirect effects of the 15 proposed design and operation improvement strategies. The results are evaluated to recommend whether a strategy should be accepted or rejected.

1. Provide an additional escalator

The strategy calls for an additional escalator to be used to help carry the major flow between the first and second floors. Presently two escalators provide for the maximum flow of 206 pedestrians per minute. Since the horizontal speed of these units is 104 feet per minute and the width at hips is 48 inches, there are 4.03 sq. ft. per pedestrian (Level of Service D for queueing areas, from Ref. 2). One additional escalator would increase the area per pedestrian to 6.05 sq. ft. (still Level of Service D).

It was estimated that the initial cost of the escalator would be $100,000 (from Ref. 9), annual operating cost would be $1,000 and annual maintenance cost would be $30.

In the case of an escalator breakdown, the presence of the additional escalator would help to maintain pedestrian flow. Only two escalators are needed to meet demand from the major direction of flow.

2. Provide a wide stairway

If 42% (87 ped./min) of the major direction flow on the present two escalators could be diverted to a parallel stairway, the escalators would operate at no worse than Level of Service C (7 sq. ft./ped). A 12 foot-wide stairway could carry this load of 87 ped./min., also at Level of Service C.

Table 2.19
Strategies for Improving Central Area Bus Terminal

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
1. Improve level of service on links	A. Provide an additional escalator (for major direction of flow) between first and second floors	Reduce density of pedestrian on escalators in major direction of flow	1. Increase system reliability for users and some special users 2. Increase capital cost 3. Increase operating cost 4. Increase maintenance cost
	B. Provide a wide stairway, parallel to escalators, to serve part of the level change flow	Reduce pedestrian density on level change aids	1. Increase system reliability for users and some special users 2. Change safety characteristics
II. Remove design hazards	A. Provide signalization for vehicle path crossing on commuter bus level	Increase safety for commuter bus	1. Change travel time in vehicle 2. Increase system reliability 3. Increase capital cost 4. Increase maintenance cost

Table 2.19 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
	B. Have buses operate on opposite sides (drive on left) at commuter bus level entrance/exit	1. Increase safety for people in vehicles at present crossing 2. Decrease safety for people in vehicles where crossing will occur	1. Change travel time in vehicles 2. Change system reliability 3. Slightly increase capital cost
	C. Have buses exiting station yield right of way to incoming buses	Increase safety for people in vehicles	1. Change travel time in vehicles 2. Increase system reliability
	D. Paint platform edges a bright color to aid passengers in recognizing platform edges	Warn users of edge	1. Increase capital cost 2. Increase maintenance cost 3. Change visual aesthetics
	E. Use texturized concrete on platform edges	Warn users of edge	Increase capital cost
III. Improve station user security	A. Provide security patrols jointly with subway station	Increase security of patrons	1. Decrease disorientation if guards are to answer patrons directional questions

Table 2.19 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
			2. Increase safety by warning users of hazards and aiding injured patrons 3. Increase security of monies received 4. Increase operating cost
	B. Provide security cameras with console in subway station agent's booth	Increase security of patrons	1. Increase safety by monitoring possible hazardous situations and aiding injured patrons 2. Increase security of monies received 3. Increase capital cost 4. Increase maintenance cost
IV. Decrease walk distance for intercity special users	Provide short-term parking for handicapped beside northern building entrance	Reduce walk distance for those who can use reserved parking	1. Slightly increase walk time for others 2. Increase safety for those who use the spaces 3. Reduce barriers.for those who use spaces

Table 2.19 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
V. Reduce physical barriers to special users	A. Provide ramps at curbs outside station building	Reduce barriers to those using wheel-chairs, walkers and crutches	Increase capital cost
	B. Provide a set of auto-matic doors on each side of building	Reduce barriers to special users	1. Increase convenience to users 2. Increase capital cost 3. Increase maintenance cost 4. Increase operating cost
VI. Reduce number of separate, non-intervisible spaces	Use elevators with transparent sides	Decrease number of separate, non-intervisible spaces for special users	1. Decrease disorientation for special users 2. Increase system reliability by making elevator malfunctions more visible 3. Increase capital cost 4. Change aesthetics
VII. Improve system reliability	Provide an additional elevator	Increase system reliability for special users	1. Increase level of service for those using elevators

Table 2.19 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
			2. Increase capital cost 3. Increase operating cost 4. Increase maintenance cost
VIII. Improve security of monies received	Include alarm provisions for intercity bus counter areas	Increase security intercity bus counter areas	Increase capital cost

The maximum capacity of a 12 foot-wide stairway would be approximately 200 ped./min. (2) If all of the escalators serving the major direction of flow were to fail, the stairs could handle most all of the major flow.

The presence of a wide stairway could change both the true safety and the perceived safety of the terminal. Accident frequency and severity would probably be different from stairway and escalators. A few people fear both escalators and elevators. The presence of stairs would at least offer users another option for the level change operation.

The initial cost of the 12 foot-wide stairway was estimated to be $2,000.

3. Bus path signalization

Two traffic signals (one for each bus path) which are semi-actuated (one vehicle sensor to activate the signal) could be used at the bus path crossing. The signalization could increase safety by controlling the bus movements but would cause slight delays for travelers in the buses. The additional capital cost was estimated to be $12,000 (from Ref. 9) and the additional maintenance cost was estimated to be $50 per year.

4. Wrong-side operation

By having buses operate on the left of the roadway rather than the right at the entrance/exit, safety should be enhanced at the present crossing and reduced at the point where vehicle crossings will occur. There would probably be little in-vehicle travel time change, since the crossing must eventually occur. System reliability would probably not change since the conflict point would be moved rather than eliminated. Additional signing would cause a slight increase in capital cost.

This strategy could have adverse psychological effects on riders since they might fear riding on the "wrong" side of the road. A lack of concentration on the part of bus drivers could greatly increase accident risk.

5. Yield right of way

This strategy calls for commuter buses exiting the terminal to yield the right of way to incoming buses. Providing this simple operational rule could increase the safety of people in the vehicles, increase system reliability, and cause little change for in-vehicle travel time. The only problem would occur when bus drivers violate the right of way provisions.

6. Paint platform edges

This strategy calls for platform edges to be painted a bright color (one foot wide) to aid passengers in recognizing the edges. It was estimated that doing this would increase capital cost by $300 (Ref. 9) and maintenance cost by $90 per year. An additional consideration is that the bright color may add or detract from the interior aesthetics.

7. Texturized concrete

This strategy calls for an 18 inch border of texturized concrete to be used on platform edges. The direct effect would be to warn users of the edges and the indirect effect would be an increase in capital cost of about $1500 ($0.50/sq.ft/, from Ref. 9).

8. Security patrols

The present design includes no provision for security patrols or surveillance. This strategy would provide the equivalent of four full-time security guards (one guard in building at any one time) to patrol the terminal facilities. The guards would be part of the security patrol for the city's subway system.

The strategy would increase station security. Since there are three levels of the bus terminal facility, the entire area of the operation could not be covered at any one time by the guard on duty. However, the presence of the guard in the terminal area should benefit security.

The presence of a security guard should aid some station users who are "lost", if the guard answers people's directional questions. It should also increase safety, by providing someone who might spot potentially hazardous situations, warn users of it, and aid injured persons. The security of monies received would also be enhanced.

The equivalent of four full-time security guards was estimated to increase the station operating cost by about $50,000 annually.

9. Security cameras

The use of security cameras, with viewing console in the subway station agent's booth, would increase the security of patrons in the bus terminal. As with security guards, the camera presence would increase safety by helping to monitor potentially hazardous situations, helping to aid injured patrons, and increasing the security of monies received.

Seven camera stations could cover virtually the entire terminal area. The added capital cost of this system was estimated to be $3600 (Ref 9) and the added maintenance cost was estimated to be $150 annually.

10. Parking for the handicapped

Short-term parking directly outside the station entrance, would benefit some special users who would drive or be driven to the station. It would reduce walk-distance on the ground floor by an average of 100 feet. The decrease in walk distance outside the station building would be must greater.

This strategy would slightly increase the walk time for other users. The safety and freedom from barriers would be increased for those using the reserved spaces because their walking distance outside the terminal would be decreased.

It was felt that few special users would benefit from the reserved spaces because the bus mode does not serve the mobile handicapped well. However the number of reserved spaces would be flexible to meet the demand of those special users who would benefit from the spaces.

11. Ramps at curbs

This strategy would reduce barriers to those using wheelchairs, walkers, crutches, and other movement aids by providing ramps at the curbs on the block around the terminal building. The indirect effect would be an increase in capital cost of about $400. Again it is important to point out that most people using these movement aids could not easily use buses. Also, if similar ramps are not made available on other walkways in the area around the terminal, the benefits of these few ramps would be minimal.

12. Automatic doors

Providing one pair of automatic doors for each side of the building would reduce one of the barriers to special users and add to the convenience of other users. The additional capital cost was estimated to be $4000 ($500 per door, Ref. 9). The additional maintenance cost was estimated to be $200 per year. The additional operating cost would be small.

13. Elevators with transparent sides

The purpose of this strategy is to decrease the number of separate, non-intervisible spaces for special users by using elevators with transparent sides. Since there is presently one elevator, the number of these spaces would be reduced by one for special users. Because people in the elevators would have a constant view of the terminal, the transparent sides would slightly decrease disorientation. Since the presence of special users inside the elevator would be evident to those outside the elevator, a malfunction of the elevator would be more apparent to others, leading to more rapid repair.

The additional capital cost of the transparent sides for the elevators was estimated to be $500. Any change in station aesthetics caused by the elevator sides was expected to be slightly positive.

14. Additional elevator

The direct effect of providing an additional elevator would be to increase system reliability for special users. For instance, if the probability of an elevator not being operable at any one time was 4%, the probability that neither one of two elevators would be operable at any one time would be 0.16% (assuming that the probability of a breakdown by one elevator is independent of a breakdown by the other).

An additional elevator was estimated to initially cost $30,000 (from Ref. 9), or $30,500 if transparent sides are used. The increase in annual operating cost was estimated to be $400 and the increase in annual maintenance cost was estimated to be $100.

The provision of an additional elevator could improve the level of service provided to special users by decreasing walk distance, waiting time, and person density on the elevators. The average walk distance would be decreased by as much as 250 feet if the elevators were placed far apart. The average waiting time for an elevator would be decreased if the elevators were close together. The average number of people per elevator would be cut by half.

15. Alarm provisions

The security of the intercity bus area would be improved by including silent alarm provisions for the area. The estimated additional capital cost was $250 (Ref. 9).

After the potential benefits and adverse effects of each strategy were reviewed, the following strategies were selected for implementation.

1. Provide a wide stairway parallel to escalators.

2. Have buses exiting station yield right of way to incoming buses.

3. Paint platform edges a bright color.

4. Provide security cameras with console in subway station agent's kiosk.

5. Provide short-term parking for handicapped beside northern building entrance.

6. Provide ramps at curbs outside station building.

7. Provide a set of automatic doors on each side of building.

8. Use elevator with transparent sides.

9. Include alarm provisions for intercity bus counter areas.

SUMMARY

This central area bus terminal design problem was concerned with a facility located on the fringe of the CBD of a large city next to a subway station and near an expressway having two exclusive bus lanes with grade-separated access to the station. The daily demand for intercity bus service was estimated to be 11,200 and the daily demand for commuter bus service was estimated to be 15,000. The major line-haul, access and egress modes were intercity bus, commuter bus, subway, walk, local bus, drop-off/pick-up, and taxi.

The criteria used for evaluation were based upon the viewpoints of users, special users, and the station operator. Considerations for joint development were included. The types of performance measures used in the evaluation process dealt with passenger processing, environmental, and fiscal concern in station design. The resulting station design is shown by Figure 2.6.

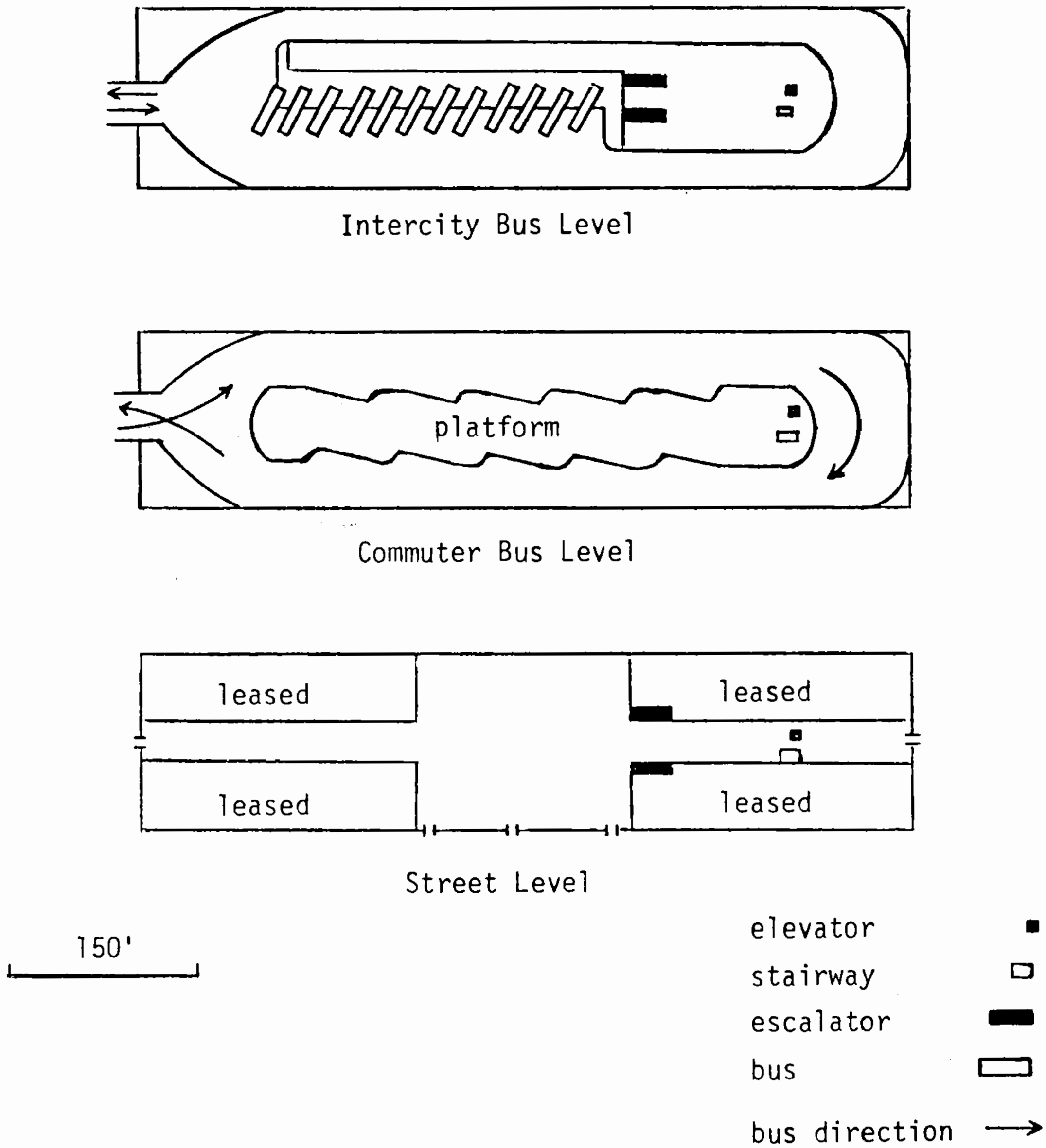


Figure 2.6 Bus Terminal Plan

CHAPTER 3

RAIL RAPID TRANSIT STATION

Rail rapid transit stations are elevated, at grade, or underground, depending upon the elevation of the lines adjacent to them. Underground stations are generally located in areas of high land use intensity and, because rail rapid transit lines generally cross in high intensity areas, are the most likely stations to serve more than one line (i.e. be a transfer point). The subway station studied here is an underground transfer terminal.

INVENTORY

The subway station is located within the central business district (CBD) of a large city. The city is assumed to have an SMSA population of 3,000,000 and a CBD work force of 280,000. Automobile congestion in the area is a serious problem, but it is partially alleviated by an extensive bus system. Sections of the city's subway system are assumed to be either presently under construction, proposed but not finally approved, or completed and providing service.

Station Site

The station is to be located near the middle of the CBD, at the intersection of First Street and E Avenue (see Figure 3.1). It will serve two rail lines, one running north/south and the other running east/west.

The buildings on the corners of the intersection are the Excelsior Building, the Universal Department Store, the King Edward Building, and the Hotel Epsilon. The owners of the Excelsior Building (a large office building) and the Universial Department Store have agreed to provide long term leases on space on the corners of their buildings. These spaces will be used for street-level access to the station.

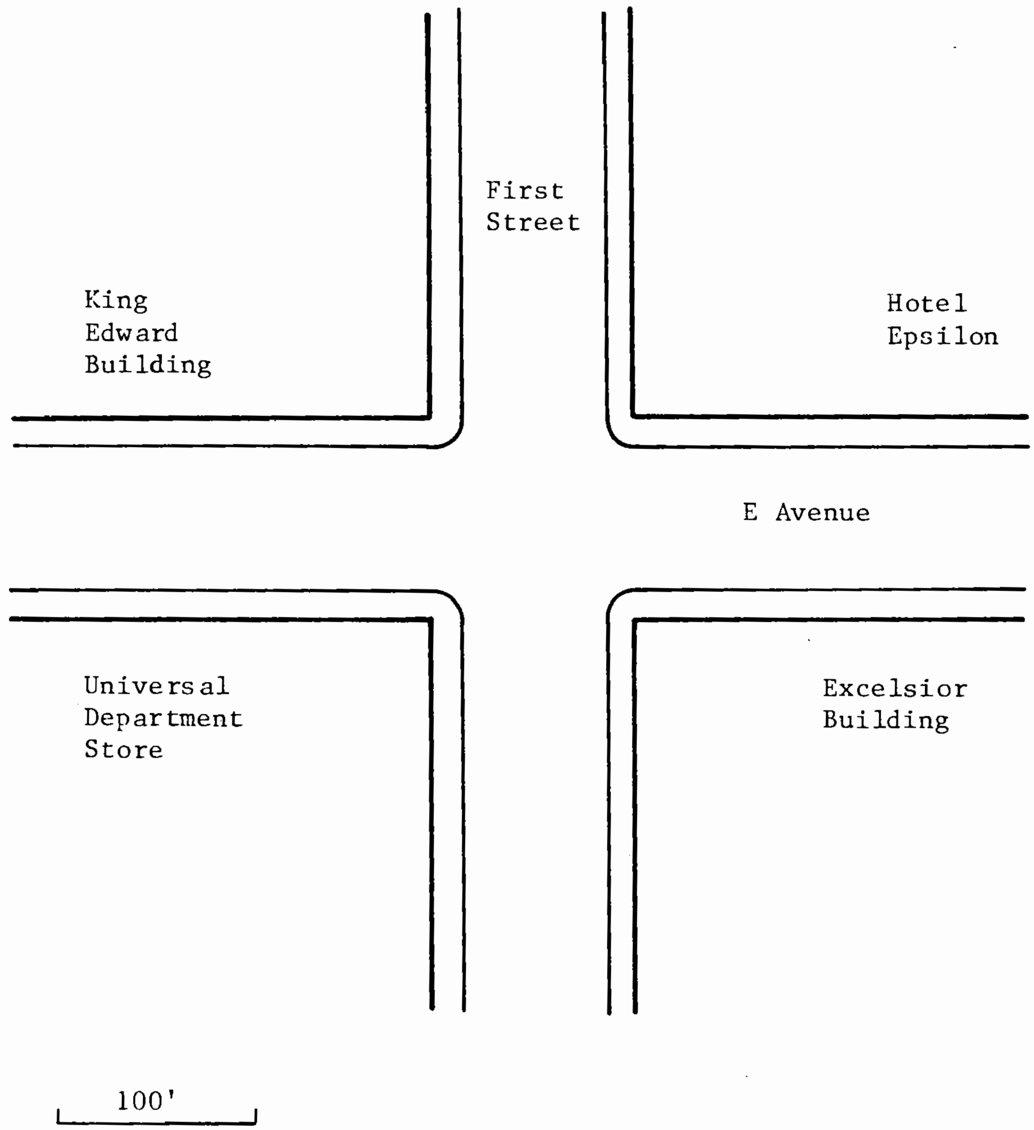


Figure 3.1 Subway Station Site

Surrounding Land Use

The land use surrounding the station is assumed to be typical of city CBD's. It includes large and small retail establishments, banks, business offices, and government offices.

System Vehicles

The relevant characteristics of the conventional transit cars used are shown below:(10)

Length of body	70 ft. (21m)
Width, maximum	10.5 ft.(3.2 in)
Height, wheels to roof inclusive	10.5 ft.(3.2 in)
Seats	72
Standees, easy capacity	60
Standees, crush capacity	156
Total passengers, easy capacity	132
Total passengers, crush capacity	228
Cars per train, maximum	10
Total passengers per	
maximum train easy capacity	1320
crush capacity	2280
Maximum acceleration/deceleration	
rate used	3.0 mph/sec (4.6 kph/sec)
Maximum speed used	70 mph
Loading time per passenger	2.2 sec
Unloading time per passenger	2.0 sec.
Doorway clear width, per passenger lane	27.0 in (69cm)
Doorways per side	2
Lanes per door	2

Demand Levels

On weekdays in the design year it is expected that 41,000 people will enter the station from the street level, 39,000 will leave at street level, and 10,000 people will use the station to transfer from one train line to another. The estimated passenger flow rate in the station for the morning and evening peak 15 minute periods are shown in Tables 3.1 and 3.2.

Table 3.1
Subway Station Predicted Morning Peak Demand Levels
(Hourly rate for peak 15 minute period)

Entering station:	Hourly Rate	Pass./min.
northbound	49	0.82
southbound	44	0.73
eastbound	43	0.72
westbound	44	0.73
Total	180	3.0

(access modes: 91% walk, 9% local bus)

Exiting station:	Hourly Rate	Pass./min.
from north	1700	28.3
from south	1800	30.0
from east	1600	26.7
from west	2000	33.3
Total	7100	118.3

(egress modes: 95% walk, 5% local bus)

Transferring within station	Hourly Rate	Pass./min.
Northbound to eastbound	100	1.7
northbound to westbound	200	3.3
southbound to eastbound	175	2.9
southbound to westbound	170	2.8
eastbound to northbound	120	2.0
eastbound to southbound	230	3.8
westbound to northbound	205	3.4
westbound to southbound	200	3.3
Total	1400	23.3

Through volumes	Hourly Rate	Pass./min.
northbound	825	13.8
southbound	725	12.1
eastbound	750	12.5
westbound	700	11.7
Total	3000	50.0

Totals	Hourly Rate	Pass./min.
entering station	180	3.0
exiting station	7,100	118.3
tranferring	1,400	23.3
through	3,000	50.0
Total	11,680	194.7

Table 3.2
Subway Station Predicted Evening Peak Demand Levels
(Hourly rate for peak 15 minute period)

Entering station:	Hourly Rate	Pass./min.
northbound	2,000	33.3
southbound	1,900	31.7
eastbound	1,900	31.7
westbound	2,200	36.7
Total	8,000	133.3

(access modes: 93% walk, 7% local bus)

Exiting station:	Hourly Rate	Pass./min.
from north	400	6.7
from south	450	7.5
from east	500	8.3
from west	350	5.8
Total	1,700	28.3

(egress modes: 96% walk, 5% local bus)

Transferring within station	Hourly Rate	Pass./min.
northbound to eastbound	90	1.5
northbound to westbound	120	2.0
southbound to eastbound	200	3.3
southbound to westbound	90	1.5
eastbound to northbound	100	1.7
eastbound to southbound	150	2.5
westbound to northbound	150	2.5
westbound to southbound	100	1.7
Total	1,000	16.7

Through volumes	Hourly Rate	Pass./min.
northbound	750	12.5
southbound	600	10.0
eastbound	550	9.2
westbound	600	10.0
Total	2,500	41.7

Totals	Hourly Rate	Pass./min.
entering station	8,000	133.3
exiting station	1,700	28.3
transferring	1,000	16.7
through	2,500	41.7
Total	13,200	220.0

Access Modes

The only two major access (and egress) modes are walking and local bus. As stated in the section on demand levels, the morning peak period modal splits are:

(a)	entering station	91% walking 9% local bus
(b)	exiting station	95% walking 5% local bus

The evening peak period modal splits for access and egress modes are:

(a)	entering station	93% walking 7% local bus
(b)	exiting station	95% walking 5% local bus

The local buses are to be accomodated on the streets beside the station.

Design Objectives

The operating agency responsible for this station is the Rapid Transit Authority (RTA). The major goals of RTA associated with this terminal are:

1. To encourage the use of the transit system.
2. To provide a high level of service for the elderly and handicapped.
3. To provide for concessions and advertising, if financially feasible.
4. To provide proper amenities.
5. To encourage joint development with nearby businesses.

The design objectives that were established by local users, special users, and the operator are shown in Table 3.3. The corresponding criteria and performance measures that derive from these objectives are shown in Table 3.4.

Table 3.3
Design Objectives

Station User Objectives

Passenger Processing

1. Minimize walking time within station
2. Minimize crowding on links
3. Minimize time spent in queues
4. Minimize crowding in waiting areas
5. Minimize disorientation
6. Minimize level changes
7. Maximize safety

Environmental

8. Provide a comfortable ambient environment
9. Provide adequate lighting
10. Provide for amenities
11. Provide for concessions
12. Provide adequate security

Special User Objectives

Passenger Processing

same as 1 through 7 plus:

13. Minimize barriers to use

Environmental

same as 8 through 12

Operator Objectives

Passenger Processing

14. Control entry efficiently

Environmental

15. Provide adequate security for fares paid

Fiscal

16. Receive adequate income from non-transport activities
17. Exploit joint development potential
18. Minimize costs

Table 3.4
Design Objectives, Criteria, and Performance Measures

Objectives	Criteria	Performance Measures
1. Minimize walking time in station	Walk time	Minutes
2. Minimize link crowding	Area per person	Level of service
3. Minimize queueing time	Queueing time	Minutes
4. Minimize queue crowding	Area per person	Level of service
5. Minimize disorientation	Connectivity of paths	Connectivity measure
6. Minimize level changes	Level changes	Number and type
7. Maximize safety	Design hazards	Number and type
8. Provide comfortable ambient environment	Thermal comfort	RWI and HDR
9. Provide adequate lighting	Illumination levels	Foot-candles
	Glare	Brightness and brightness differences
10. Provide amenities	Amenities	Number and type
11. Provide concessions	Concessions	Types
12. Provide adequate security	Separate spaces	Number
	Paid area	% of all area
	Tactical measures	(Subjective)
13. Minimize barriers	Barriers present	Number and type
14. Control entry efficiently	Tactical measures	(Subjective)
15. Provide security for fares paid	Attraction to robbery	Type of collection Safeguards
16. Receive adequate income from non-transport activities	Cost vs. income	$/year
17. Exploit joint development potential	Accessibility to local businesses	Minutes
	Compatability of use	(Subjective)

POLICY

RTA has developed the following policy specifically related to subway stations.

1. Stations will be in operation continuously (24 hours a day).

2. Concessions and advertising will be encouraged where they do not adversely affect the transportation and aesthetic goals of the system.

3. A sufficient number of telephones will be available to the public.

4. Restrooms will not be available to the public.

5. Construction materials will be selected for high durability, low maintenance, high safety, and low cost.

6. The elderly and the handicapped will be provided with aids enabling them to use the system safely and conveniently.

7. Lighting will conform with Institute for Rapid Transit standards.

8. Whenever feasible, joint development will be encouraged.

9. In warm weather, station patrons will be at least as comfortable as they would be outdoors.

<u>Alternative Design Concepts</u>

It was desired to develop a wide range of station types for preliminary screening (Evaluation I). Seven basic station layouts, representing the range of solutions available, have been described by Robert S. O'Neil et al. in "Study of Subway Design and Construction". These are:

1. Cut-and-cover box structure
   Mezzanines separate from trainroom and at street level
   Side platform

2. Cut-and-cover box structure
   Mezzanines separate from trainroom and at platform level
   Side platforms

3. Cut-and-cover box structure
   Mezzanine separate from trainroom and above platform level
   Side platform

4. Cut-and-cover box structure
   Mezzanine separate from trainroom and above platform levels
   Stacked platforms

5. Cut-and-cover structure
   Mezzanine within trainroom and above platform level
   Center platform

6. Mined single arch
   Mezzanine separate from trainroom and above platform level
   Center platform

7. Mined twin tubes
   Mezzanine separate from trainroom and above platform level
   Center platform and concourse

If the soil conditions around the station are basically earth rather than rock, the first five station types (cut-and-cover) would be superior to the last two (mined) in cost. The operating agency is assumed to have already determined that the construction's disruption of surface traffic and utilities, as well as other drawbacks of open cut excavation, are outweighed by the cost savings of the open cut excavation over mined excavation.

Since the station will serve as a transfer point for two subway lines, a large number of levels is undesirable. Station type 4 would require a separate level for the mezzanine and 4 separate track levels, due to its stacked platforms. For this reason it is dropped from consideration. The remaining four station types (1,2,3 and 5), after being adapted to serve as transfer stations, will be evaluated as the preliminary alternative designs concepts.

Alternative 1

Alternative 1 illustrates the characteristics of a shallow cut-and-cover station with mezzanines and fare collection facilities at street level. Volume of excavation is relatively small, but passenger circulation and economy of operation can be problem areas (11) (see Figure 3.2).

The station has 6 feet of earth cover, but this could be much greater. Two primary entrances and two elevators are present. Each platform is served by one or both of the elevators and entrances; platform access is from street level.

Alternative 2

Alternative 2 is similar to 1 except that the mezzanines are located beside the upper level platforms. Passenger circulation and personnel control problems are still present (11). Street level space is minimal. Vertical circulation is similar to A (see Figure 3.3).

Alternative 3

Alternative 3's most important characteristic is the single mezzanine, separate from the trainroom. A major asset is that the control point is centralized on a separate level (see Figure 3.4).

The escalator/elevator arrangement for this station is similar to 1 and 2. The major difference is that passengers may have to exit the vertical circulation subsystem to purchase and submit tickets.

Alternative 5

Alternative 5 has the advantage of center platform operation, reducing vertical circulation needs. On the other hand, depth of excavation may be increased for the subway system, because the full height trainroom can become a profile control for the system. The geometry, excavation, and construction cost of the line sections at station ends may also be affected (11) (see Figure 3.5).

EVALUATION 1

User Performance

Travel time in station

The only station component sizes that have been established are platform size, mezzanine area, ceiling height, platform area ceiling

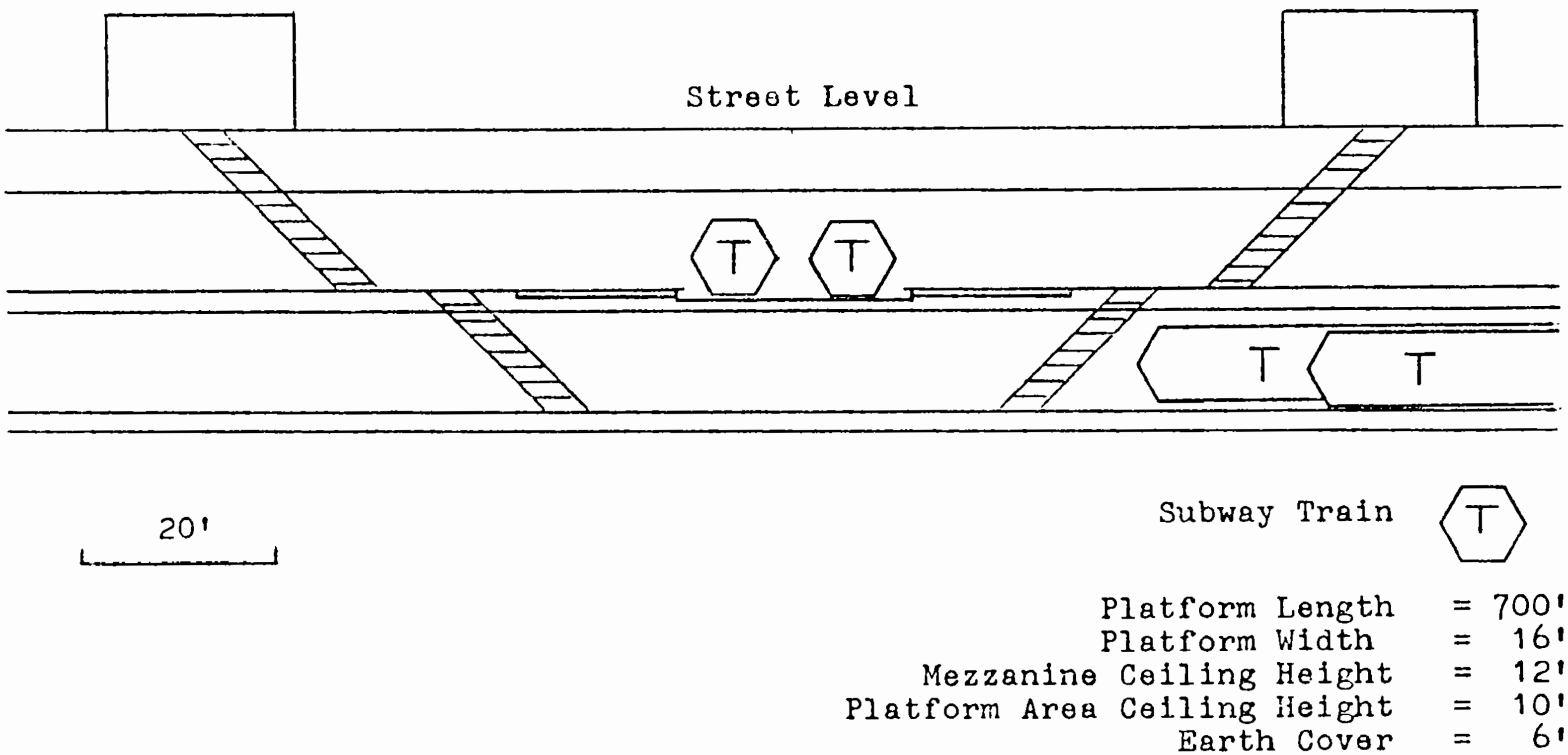
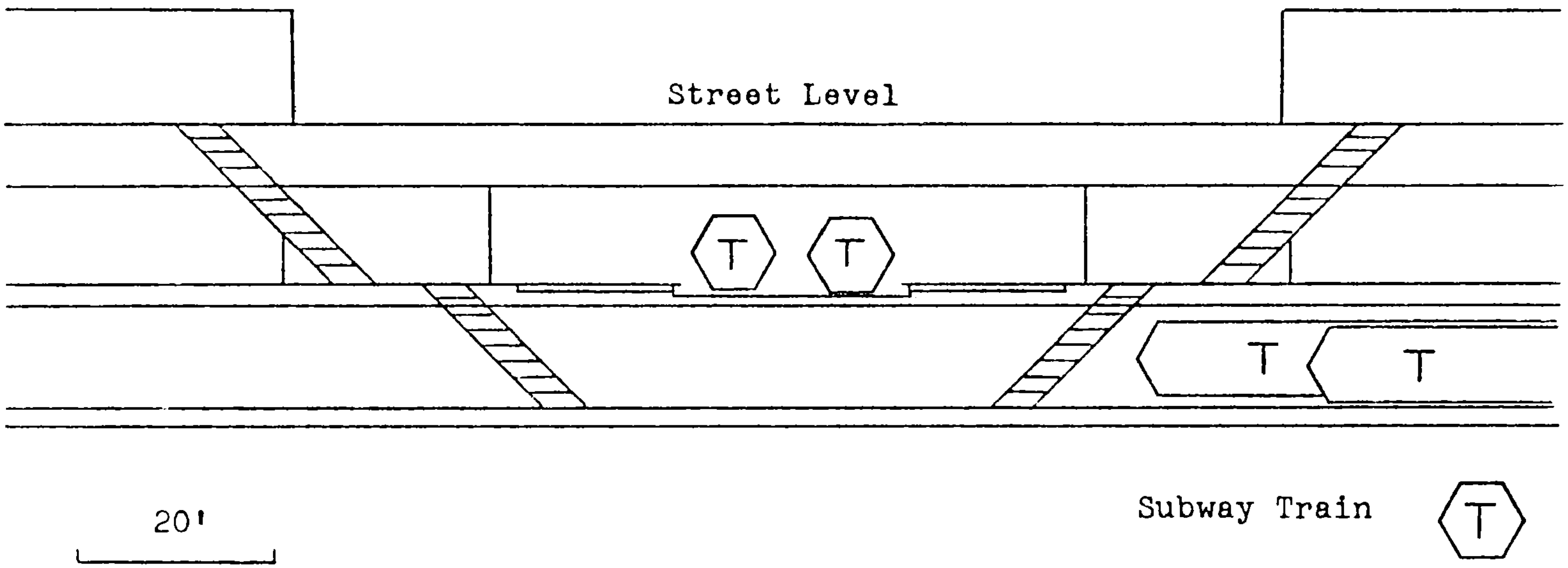


Figure 3.2 Alternative 1: Mezzanine Separate from Trainroom and at Street Level, Side Platform



Platform Length = 700'
Platform Width = 16'
Mezzanine Ceiling Height = 12'
Platform Area Ceiling Height = 10'
Earth Cover = 6'

Figure 3.3 Alternative 2: Mezzanines Separate from Trainroom and at Platform Level, Side Platform

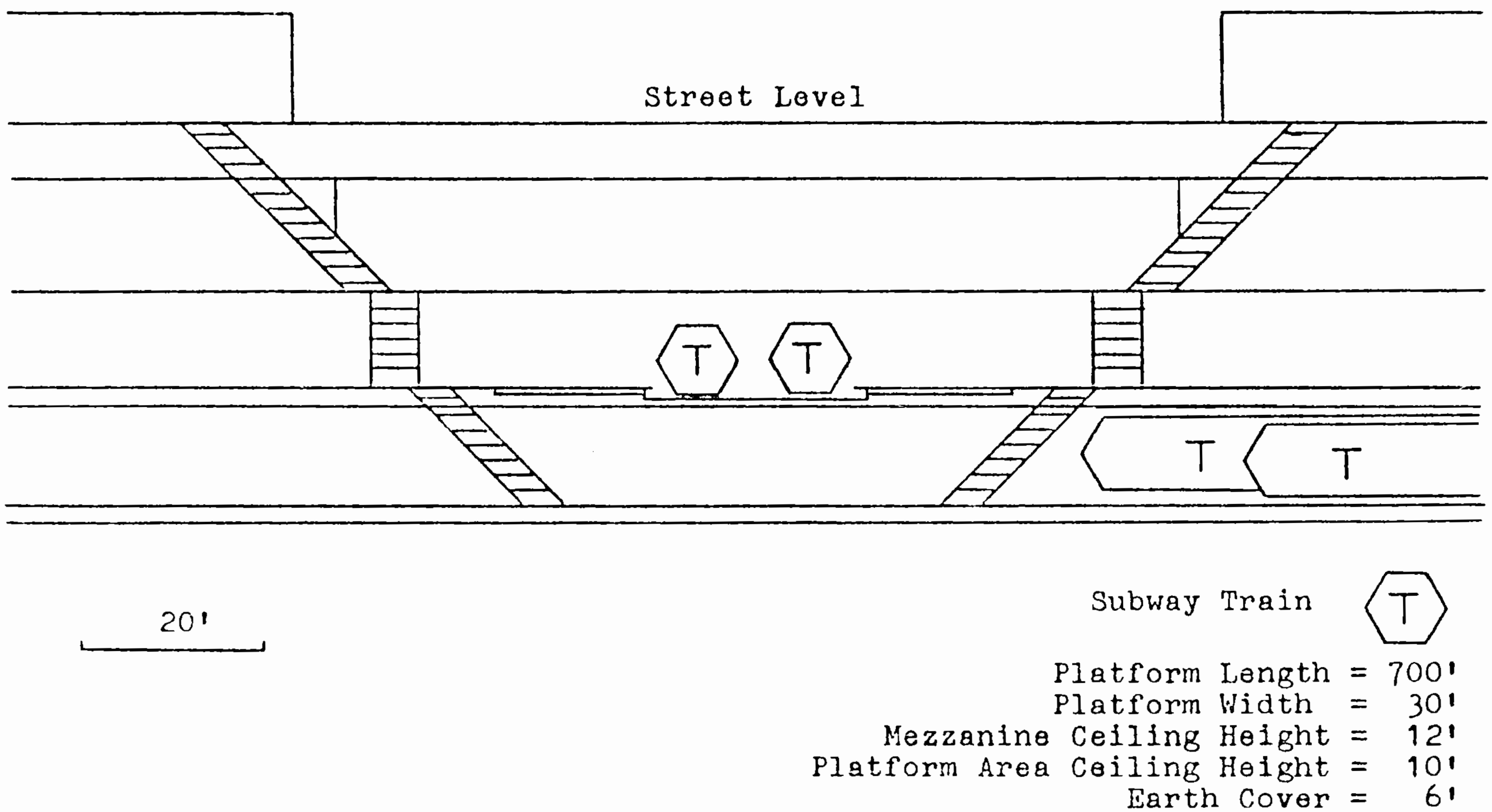
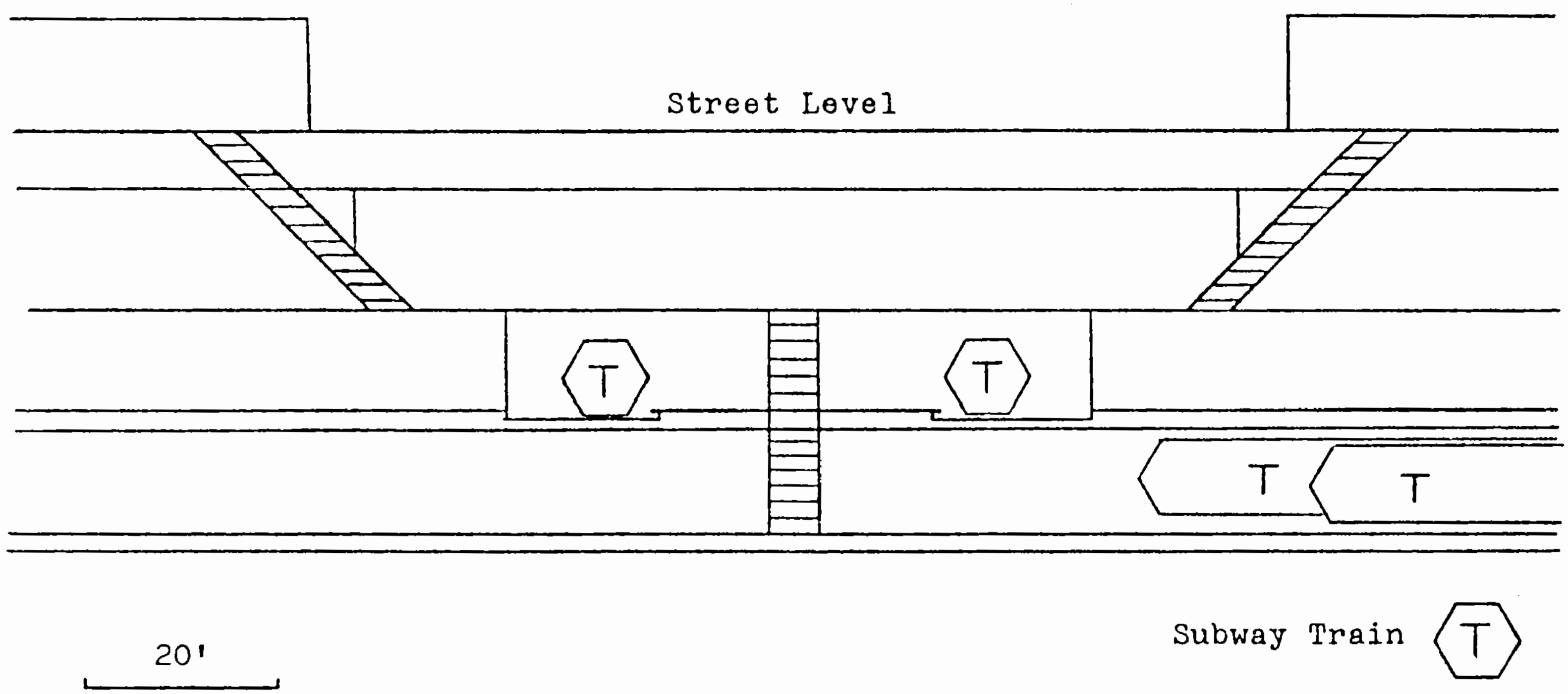


Figure 3.4 Mezzanine Separate From Trainroom and Above Platform Level, Side Platform Alternative 3



Platform Length = 700'
Platform Width = 16'
Mezzanine Ceiling Height = 12'
Platform Area Ceiling Height = 10'
Earth Cover = 6'

Figure 3.5 Alternative 5: Mezzanine Within Trainroom and Above Platform Level, Center Platforms height, and depth of earth cover (see Figures 3.2, 3.3, 3.4, and 3.5). Platform size and ceiling heights are controlled by system policy. The earth cover depth used is assumed to be the minimum required at this site for utility relocation.

The sizes of links and queueing areas have not yet been determined. The approach used here is to draw the link-node network, load the expected number of passengers (for the peak 15 minute period) on to the network, and determine the required sizes of links for Fruin Level of Service C (5). For the queueing analyses it was assumed that a certain number of devices (service channels) had been assigned for each queueing system.

The peak period passenger loadings are shown in Table 3.5. These data are for the evening peak 15 minute demand and are in the units of passengers per minute. This period was used because it has the highest volumes of usage and should have the most critical demand on links and queueing systems. The passengers were loaded onto the link-node pedestrian networks according to the following assumptions. In Alternatives 1 and 2:

(a) patrons will use the western entrance/exit when going to or exiting from the southbound platform,

(b) patrons will use the eastern entrance/exit when going to or exiting from the northbound platform,

(c) 60% of the patrons will use the western entrance/exit when going to or exiting from the eastbound and westbound platforms, and

(d) transferring passengers will use the minimum path available to them.

Table 3.5
Subway Station Evening Peak Demand
(Passengers/Minute)

Entering Station

northbound =	33.3
southbound =	31.7
eastbound =	31.7
westbound =	36.7
Total	133.3

Exiting Station

from north =	6.7
from south =	7.5
from east =	8.3
from west =	5.8
Total	28.3

Transferring Within Station

northbound to eastbound =	1.5
northbound to westbound =	2.0
southbound to eastbound =	3.3
southbound to westbound =	1.5
eastbound to northbound =	1.7
eastbound to southbound =	2.5
westbound to northbound =	2.5
westbound to southbound =	1.7
Total	16.7

Through Volumes

northbound =	12.5
southbound =	10.0
eastbound =	9.2
westbound =	10.0

Totals

Entering Station =	133.3
Exiting Station =	28.3
Transferring =	16.7
Through =	41.7
Total	220.0

In Alternatives 3 and 5 it was assumed that:

(a) 60% of all entering and exiting passengers will use the western entrance/exit,

(b) the entrance or exit used is independent of the platform a passenger uses, and

(c) transferring passengers will use the minimum path available to them.

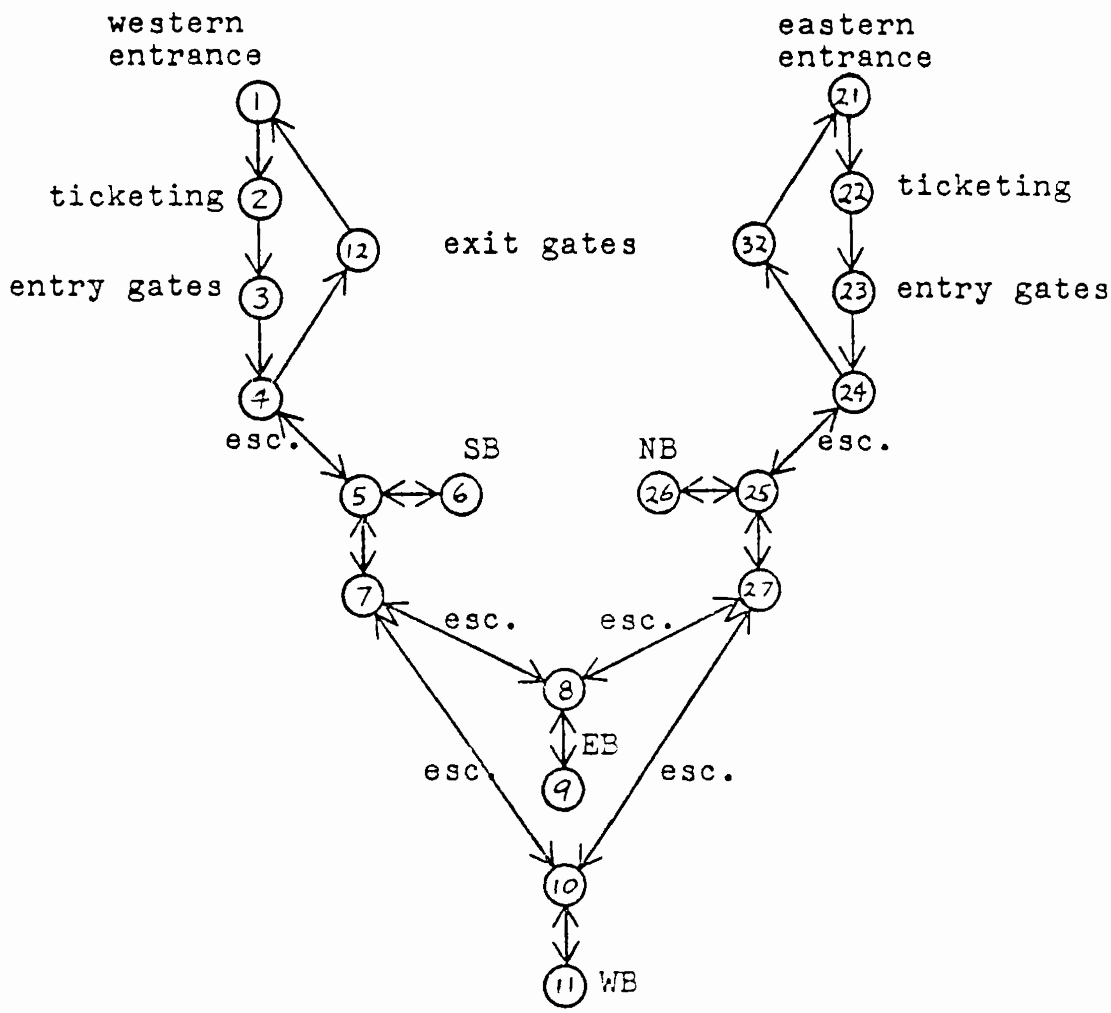
The assumption of the 60/40 split between western and eastern entrances and exits was used to reflect the probable condition that the flows through these entrances and exits will not be balanced. In this case, it was assumed that during the peak period 50% more people will use the western entrance/exit than will use the eastern entrance/exit.

The link-node networks for the four alternatives are shown in Figures 3.6, 3.7, 3.8, and 3.9. The relevant link characteristics are displayed in Tables 3.6, 3.7, 3.8, and 3.9. The information needed to determine time spent walking and waiting in queues for each user path is provided in these tables.

There are four basic queueing operations which take place in the terminals.

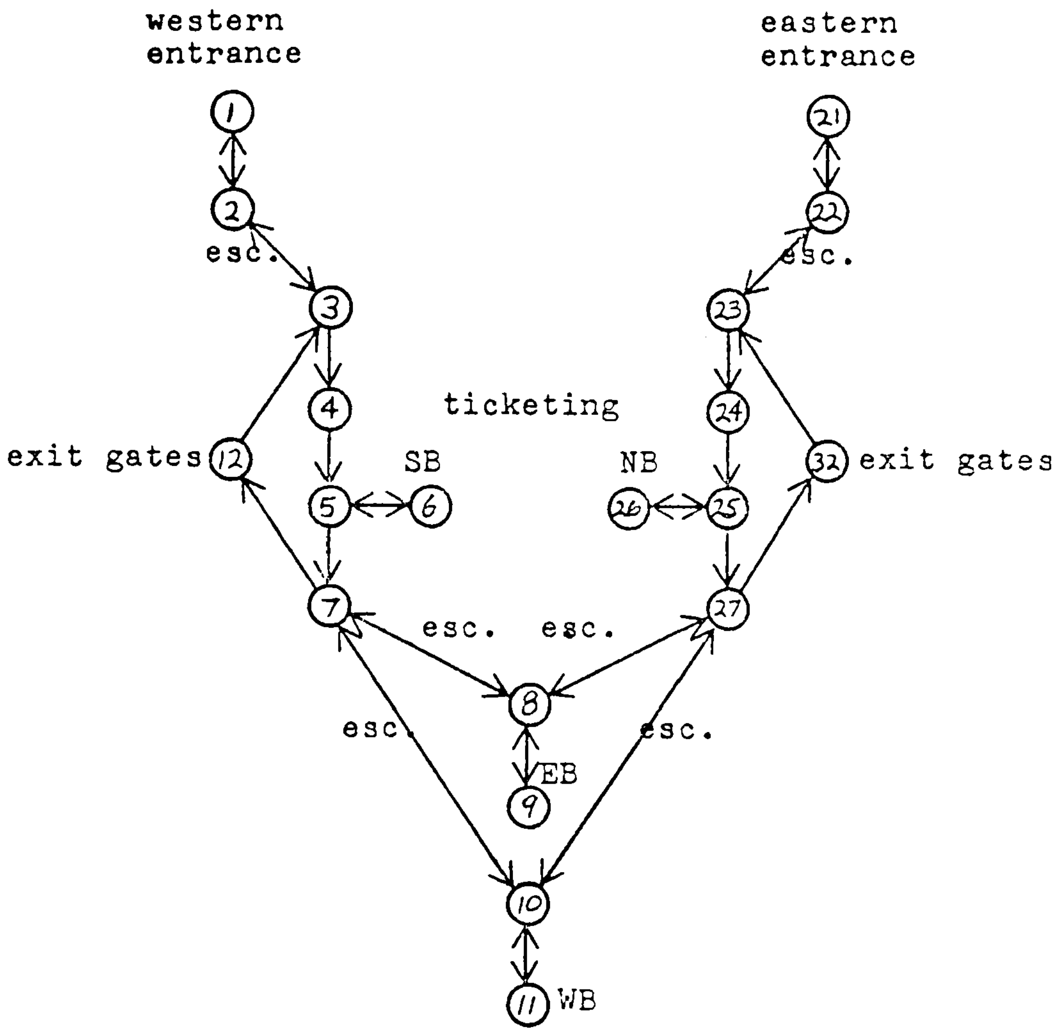
1. Entry (at entry gates)
2. Ticketing (at ticketing machines)
3. Exit (at exit gates)
4. Waiting for trains (on platforms)

For the first three operations, some basic queueing formulations were used for the analysis. For the fourth, waiting for trains, it was assumed that the waiting time will be the same for each alternative, so this time was not included in the queueing analyses.



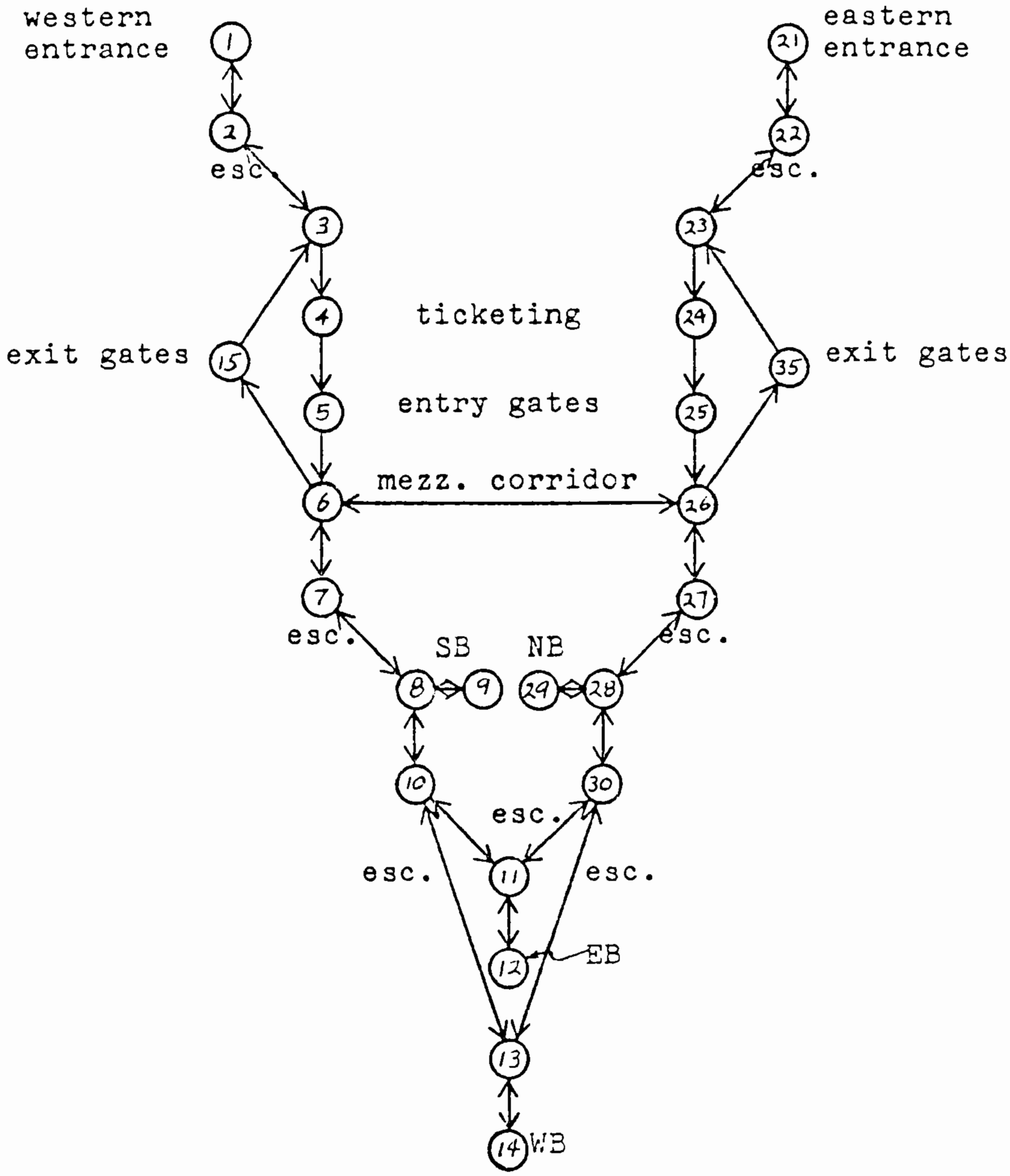
esc. - escalator
NB - northbound platform
SB - southbound platform
EB - eastbound platform
WB - westbound platform

Figure 3.6 Alternative A Link-Node Network



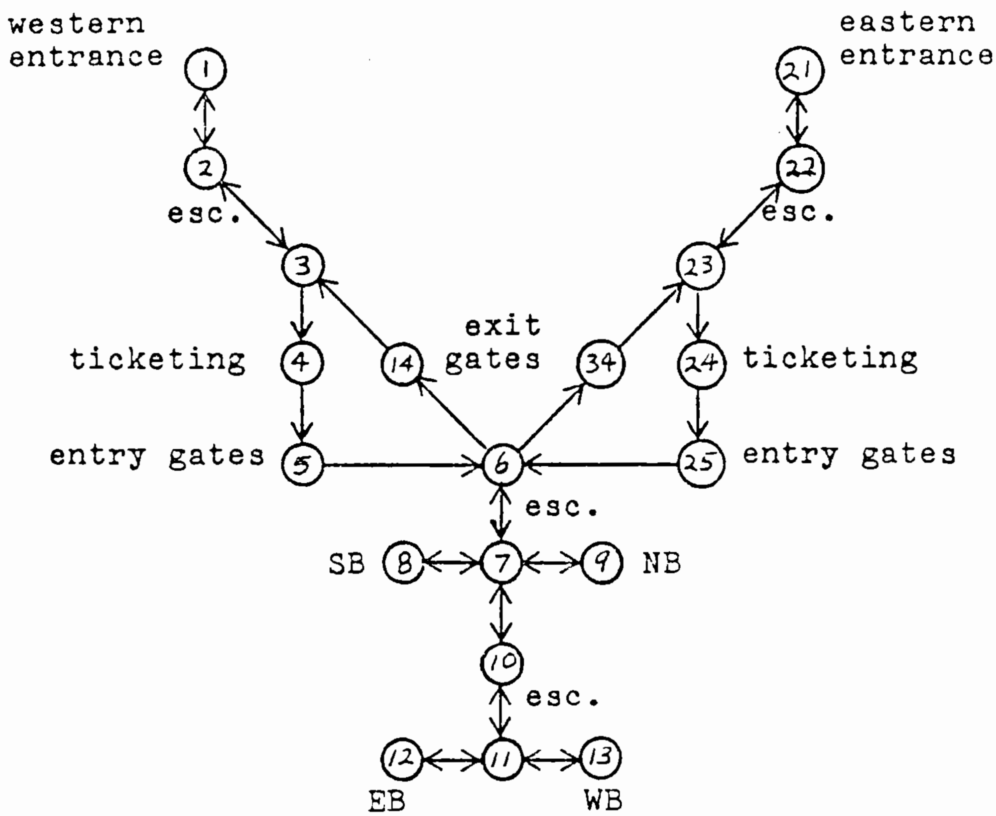
esc. - escalator
NB - northbound platform
SB - southbound platform
EB - eastbound platform
WB - westbound platform

Figure 3.7 Alternative B Link-Node Network



esc. - escalator
NB - northbound platform
SB - southbound platform
EB - eastbound platform
WB - westbound platform

Figure 3.8 Alternative C Link-Node Network



esc. - escalator
NB - northbound platform
SB - southbound platform
EB - eastbound platform
WB - westbound platform

Figure 3.9 Alternative D Link-Node Network

Table 3.6
Alternative 1 Walk Link Characteristics

Link	1-way or 2-way	Volume (ped./ min.)	Required* Flow (PFM)	Required Width (ft.)	Average Speed ft./min.	Estimated Length (ft.)	Time on Link (min.)	Person minutes on link
1-2	1	72.7	12.5	6	245	30	.12	8.7
2-3	1	72.7	12.5	6	245	40	.16	11.6
3-4	1	72.7	12.5	6	245	20	.08	5.8
4-5	1	72.7	**	-	104	36	.35	25.4
5-7	1	45.8	12.5	4	245	40	.16	7.3
7-8	1	22.3	**	-	104	26	.25	5.6
7-10	1	23.5	**	-	104	26	.25	5.9
10-7	1	5.2	**	-	104	26	.25	1.3
8-7	1	7.5	**	-	104	26	.25	1.9
7-5	1	12.7	12.5	1	245	40	.16	2.0
5-4	1	16.0	**	-	104	36	.35	5.6
4-12	1	16.0	12.5	2	245	30	.12	1.9
12-1	1	16.0	12.5	2	245	40	.16	2.6
21-22	1	60.7	12.5	5	245	30	.12	7.3
22-23	1	60.7	12.5	5	245	40	.16	9.7
23-24	1	60.7	12.5	5	245	20	.08	4.9
24-25	1	60.7	**	-	104	36	.35	21.2
25-27	1	30.9	12.5	3	245	40	.16	4.9
27-8	1	14.2	**	-	104	26	.25	3.5
27-10	1	16.7	**	-	104	26	.25	4.2
10-27	1	4.8	**	-	104	26	.25	1.2
8-27	1	5.0	**	-	104	26	.25	1.3
27-25	1	9.8	12.5	1	245	40	.16	1.6
25-24	1	12.3	**	-	104	36	.35	4.3
24-32	1	12.3	12.5	1	245	30	.12	1.5
32-21	1	12.3	12.5	1	245	40	.16	2.0
5-6	2	48.2	12.0	4	245	150	.61	29.4
25-26	2	47.7	12.0	4	245	150	.61	29.1
8-9	2	49.0	12.5	5	245	150	.61	29.9
10-11	2	50.2	12.0	5	245	150	.61	30.6
							Total	272.2

*Required flow for Level of Service C (pedestrians per foot-width per minute)

**Assumes escalator with nominal capacity of 8,025 persons/hour (133.75 per minute) with incline speed of 120 ft./min.

Table 3.7
Alternative 2 Walk Link Characteristics

	1-way or 2-way	Volume (ped./ min.)	Required* Flow (PFM)	Required Width (ft.)	Average Speed ft./min.	Estimated Length (ft.)	Time on Link (min.)	Person Minutes on link
1-2	2	88.7	12.0	8	245	30	.12	10.6
2-3	1	72.7	**	-	104	36	.35	25.4
3-4	1	72.7	12.5	6	245	30	.12	8.7
4-5	1	72.7	12.5	6	245	40	.16	11.6
5-7	2	45.8	12.0	4	245	40	.16	7.3
7-8	1	22.3	**	-	104	26	.25	5.6
7-10	1	23.5	**	-	104	26	.25	5.9
10-7	1	5.2	**	-	104	26	.25	1.3
8-7	1	7.5	**	-	104	26	.25	1.9
7-12	1	16.0	12.5	2	245	30	.12	1.9
12-3	1	16.0	12.5	2	245	40	.16	2.6
3-2	1	16.0	**	-	104	36	.35	5.6
21-22	2	73.0	12.0	7	245	30	.12	8.8
22-23	1	60.7	**	-	104	36	.25	15.2
23-24	1	60.0	12.5	5	245	30	.12	7.3
24-25	1	60.7	12.5	5	245	40	.16	9.7
25-27	2	30.9	12.0	3	245	40	.16	4.9
27-8	1	14.2	**	-	104	26	.25	3.6
27-10	1	16.7	**	-	104	26	.25	4.2
10-27	1	4.8	**	-	104	26	.25	1.2
8-27	1	5.0	**	-	104	26	.25	1.3
27-32	1	12.3	12.5	1	245	30	.12	15.
32-23	1	12.3	12.5	1	245	40	.16	2.0
23-22	1	12.3	**	-	104	36	.25	3.1
5-6	2	48.2	12.0	4	245	150	.61	29.4
25-26	2	47.7	12.0	4	245	150	.61	29.1
8-9	2	49.0	12.0	5	245	150	.61	29.9
10-11	2	50.2	12.0	5	245	150	.61	30.6
							Total	270.1

*Required flow for Level of Service C (pedestrians per foot-width per minute)
**Assumes escalator with nominal capacity of 8,025 persons/hour (133.75 per minute) with incline speed of 120 ft./min.

Table 3.8
Alternative 3 Walk Link Characteristics

	1-way or 2-way	Volume (ped./ min.)	Required* Flow (PFM)	Required Width (ft.)	Average Speed ft./min.)	Estimated Length (ft.)	Time on Link (min.)	Person miniutes on link
1-2	2	97.0	12.0	9	245	30	.12	11.6
2-3	1	80.0	**	-	104	36	.35	28.0
3-4	1	80.0	12.5	7	245	30	.12	9.6
4-5	1	80.0	12.5	7	245	40	.16	12.8
5-6	1	80.0	12.5	7	245	20	.08	6.4
6-7	1	72.7	12.5	6	245	20	.08	5.8
7-8	1	72.7	**	-	104	26	.25	18.2
8-10	1	45.8	12.5	4	245	30	.12	5.5
10-11	1	22.3	**	-	104	26	.25	5.6
10-13	1	23.5	**	-	104	26	.25	5.9
13-10	1	5.2	**	-	104	26	.25	1.3
11-10	1	7.5	**	-	104	26	.25	1.9
10-8	1	12.7	12.5	2	245	30	.12	1.5
8-7	1	16.0	**	-	104	26	.25	4.0
7-6	1	16.0	12.5	2	245	20	.08	1.3
6-15	1	17.0	12.5	2	245	30	.12	2.0
15-3	1	17.0	12.5	2	245	40	.16	2.7
3-2	1	17.0	**	-	104	36	.35	5.9
6-26	2	39.7	12.0	4	245	136	.53	21.0
21-22	2	64.6	12.0	6	245	30	.12	7.8
22-23	1	53.3	**	-	104	36	.35	18.7
23-24	1	53.3	12.5	5	245	30	.12	6.4
24-25	1	53.3	12.5	5	245	40	.16	8.5
25-26	1	53.3	12.5	5	245	20	.08	4.3
26-27	1	60.7	12.5	5	245	20	.08	4.9
27-28	1	60.7	**	-	104	26	.25	15.2
28-30	1	30.9	12.5	3	245	30	.12	3.7
30-11	1	14.2	**	-	104	26	.25	3.6
30-13	1	16.7	**	-	104	26	.25	4.2

Table 3.8 (continued)

	1-way or 2-way	Volume (ped./ min.)	Required* Flow (PFM)	Required Width (ft.)	Average Speed (ft./min.)	Estimated Length (ft.)	Time on Link (min.)	Person minutes on link
13-30	1	4.8	**	-	104	26	.25	1.2
11-30	1	5.0	**	-	104	26	.25	1.3
30-28	1	9.8	12.5	1	245	30	.12	1.3
28-27	1	12.3	**	-	104	26	.25	3.1
27-26	1	12.3	12.5	1	245	20	.08	2.0
26-35	1	11.3	12.5	1	245	30	.12	1.4
35-23	1	11.3	12.5	1	245	40	.16	1.8
23-22	1	11.3	**	-	104	36	.35	4.0
8-9	2	48.2	12.0	4	245	150	.61	29.4
28-29	2	47.7	12.0	4	245	150	.61	29.1
11-12	2	49.0	12.0	5	245	150	.61	29.9
13-14	2	50.2	12.0	5	245	150	.61	30.6
							Total	362.0

*Required flow for Level of Service C (pedestrians per foot-width per minute)
**Assumes escalator with nominal capacity of 8,025 persons/hour (133.75 per minute) with incline speed of 120 ft./min.

Table 3.9
Alternative 5 Walk Link Characteristics

Link	1-way or 2-way	Volume (ped./ min.)	Required* Flow (PFM)	Required Width (ft.)	Average Speed ft./min.)	Estimated Length (ft.)	Time on Link (min.)	Person minutes on link
1-2	2	97.0	12.0	9	245	30	.12	11.64
2-3	1	80.0	**	-	104	36	.35	28.00
3-4	1	80.0	12.5	7	245	30	.12	9.60
4-5	1	80.0	12.5	7	245	40	.16	12.80
5-6	1	80.0	12.5	7	245	65	.27	21.60
6-7	1	133.3	**	-	104	26	.25	33.33
7-8	2	48.2	12.0	4	245	150	.61	29.40
7-9	2	47.7	12.0	4	245	150	.61	29.10
7-10	1	76.7	12.5	7	245	30	.12	9.20
10-11	1	76.7	**	-	104	26	.25	19.17
11-12	2	49.0	12.0	5	245	150	.61	29.89
11-13	2	51.9	12.0	5	245	150	.61	31.66
11-10	1	36.7	**	-	104	26	.25	9.17
10-7	1	36.7	12.5	3	245	30	.12	4.40
7-6	1	28.3	**	-	104	26	.25	7.08
6-14	1	17.0	12.5	2	245	60	.24	4.08
14-3	1	17.0	12.5	2	245	20	.08	1.36
3-2	1	17.0	**	-	104	36	.35	5.95
21-22	2	64.6	12.0	6	245	30	.12	7.75
22-23	1	53.3	**	-	104	36	.35	18.66
23-24	1	53.3	12.5	5	245	30	.12	6.40
24-25	1	53.3	12.5	5	245	40	.16	8.53
25-6	1	53.3	12.5	5	245	65	.27	14.39
6-34	1	11.3	12.5	1	245	60	.24	2.71
34-23	1	11.3	12.5	1	245	20	.08	0.90
23-22	1	11.3	**	-	104	36	.35	3.95
							Total	360.72

*Required flow for Level of Service C (persons per foot-width per minute)
**Assumes escalator with nominal capacity of 8025 persons/hour (133.75 per./min.) with incline speed of 120 ft./min.

The equations used for calculating the expected time in a queueing system, W, and the expected number in a queue, L(q), are (14):

$$W = \frac{\mu\ (\lambda/\mu)^{k} Po}{(k-1)!\,(k\mu\ -\ \lambda)^{2}} + \frac{1}{\mu} \qquad (3.1)$$

and

$$L(q)\ = \frac{\lambda\mu(\lambda/\mu)^{k} Po}{(k-1)!\,(k\mu-\lambda)^{2}} \qquad (3.2)$$

where: λ = arrival rate (personse per minute),

μ = service rate of a single channel (persons per minute),

κ = number of service channels, and

$$Po\ = \frac{1}{\left[\sum_{n=0}^{n=k-1} \frac{1}{n!} \left(\frac{\lambda}{\mu}\right)^{n} + \frac{1}{k!} \left(\frac{\lambda}{\mu}\right)^{k} \frac{k\partial}{k\mu-\lambda}\ \right]} \qquad (3.3)$$

These equations are used subject to the assumption that the arrival and service rates are randomly distributed according to the Poisson distribution. This assumption is reasonable for the service rates and for the arrival rates at the entrance gates and the ticketing machines. The arrival patterns at the exit gates, however, would probably reflect the bulk-arrival nature of subway operations (i.e. many people would exit a subway train during a relatively short interval and this group would not be completely dispersed when the members arrive at the exit gates). Since there are four tracks served by the stations and, during the peak hour, train headways will be low, the assumption of random and Poisson distributed arrival rates for the exit gates was assumed to be suitable.

In analyzing the ticketing machines it was assumed that 25% of the passengers entering the station from street level would already have a valid fare card (a magnetic card with sufficient credit on it for the trip to be made) and would not use the ticketing machines. Further, none of the passengers exiting the subway trains would turn in fare cards at these machines to receive cash for the credit remaining on the card. The results of the queueing analyses for Alternatives 1 and 2 and for Alternatives 3 and 4 are shown in Tables 3.10 and 3.11.

The travel time on each path within each station are shown in Tables 3.12, 3.13, 3.14, and 3.15. The averages of the times of entering paths, exiting paths, and transferring paths are shown in Table 3.15. These are the averages of paths, not averages of individuals.

One important fact does not show up in Table 3.16. Entering and exiting passengers using the northbound or southbound platforms are limited to one entrance or exit in Alternatives 1 and 2. Some of them must therefore make one street crossing more than they would in Alternatives 3 and 5.

Level of service in queues

The expected number of people in each queue during the evening peak was shown in Tables 3.10 and 3.11. Area sizes of 200 sq. ft. for each entry and exit queue and 300 sq. ft. for each ticketing queue can easily be provided. Even if the expected size of each queue were tripled, the Level of Service in any queue would be no worse than "C". This performance should be satisfactory.

Table 3.10
Queueing for Alternatives 1 and 2

Queue	Arrival Rate (per./min.)	Service Rate (per./min.)	Number of Channels	Expected Time in Queueing System	Expected Number in Queue
Entrance					
eastern	60.7	24.0	4	0.05	0.57
western	72.3	24.0	4	0.06	1.57
Ticketing					
eastern	45.5	3.0	22	0.34	0.16
western	54.2	3.0	22	0.36	1.31
Exit					
eastern	16.0	24.0	4	0.05	0.01
western	12.3	24.0	4	0.05	0.01

Table 3.11
Queueing for Alternatives 3 and 5

Queue	Arrival Rate (per./min.)	Service Rate (per./min.)	Number of Channels	Expected Time in Queueing System (min.)	Expected Number in Queue
Entrance					
eastern	53.3	24.0	4	0.05	0.29
western	80.0	24.0	4	0.08	3.29
Ticketing					
eastern	40.0	3.0	22	0.33	0.03
western	60.0	3.0	22	0.43	5.68
Exit					
eastern	11.3	24.0	4	0.05	0.01
western	17.0	24.0	4	0.05	0.01

Table 3.12
Travel Time on Paths of Alternatives A: Evening Peak (minutes)

Paths	Walking	Queueing Entry	Queueing Ticketing	Queueing Exit	Total
Entering station from:					
East ent. to N.M. platform	1.32	0.05	0.34	-	1.71
East ent. to S.B. platform	-	-	-	-	-
East ent. to E.B. platform	1.73	0.05	0.34	-	2.12
East ent. to W.B. platform	1.73	0.05	0.34	-	2.12
West ent. to N.M. platform	-	-	-	-	-
West ent. to S.B. platform	1.32	0.06	0.36	-	1.74
West ent. to E.B. platform	1.73	0.06	0.36	-	2.15
West ent. to W.B. platform	1.73	0.06	0.36	-	2.15
Exiting station from:					
N.B. platform to east exit	1.20	-	-	0.05	1.25
S.B. platform to east exit	-	-	-	-	-
E.B. platform to east exit	1.65	-	-	0.05	1.70
W.B. platform to east exit	1.65	-	-	0.05	1.70
N.B. platform to west exit	-	-	-	-	-
S.B. platform to west exit	1.20	-	-	0.05	1.25
E.B. platform to west exit	1.65	-	-	0.05	1.70
W.B. platform to west exit	1.65	-	-	0.05	1.70
Transferring from:					
N.B. to E.B.	1.63	-	-	-	1.63
N.B. to W.B.	1.63	-	-	-	1.63
S.B. to E.B.	1.63	-	-	-	1.63
S.B. to W.B.	1.63	-	-	-	1.63
E.B. to N.B.	1.63	-	-	-	1.63
E.B. to S.B.	1.63	-	-	-	1.63
W.B. to N.B.	1.63	-	-	-	1.63
W.B. to S.B.	1.63	-	-	-	1.63

Table 3.13
Travel Times on Paths of Alternative B: Evening Peak (minutes)

Paths	Walking	Queueing Entry	Queueing Ticketing	Queueing Exit	Total
Entering station from:					
East ent. to N.B. platform	1.26	0.05	0.34	-	1.65
East ent. to S.B. platform	-	-	-	-	-
Ease ent. to E.B. platform	1.76	0.05	0.34	-	2.06
East ent. to W.B. platform	1.76	0.05	0.34	-	2.06
West ent. to N.B. platform	-	-	-	-	-
West ent. to S.B. platform	1.26	0.06	0.36	-	1.68
West ent. to E.B. platform	1.67	0.06	0.36	-	2.09
West ent. to W.B. platform	1.67	0.06	0.36	-	2.09
Exiting station from:					
N.B. platform to east exit	1.42	-	-	0.05	1.47
S.B. platform to east exit	-	-	-	-	-
E.B. platform to east exit	1.51	-	-	0.05	1.56
W.B. platform to east exit	1.51	-	-	0.05	1.56
N.B. platform to west exit	-	-	-	-	-
S.B. platform to west exit	1.42	-	-	0.05	1.47
E.B. platform to west exit	1.51	-	-	0.05	1.56
W.B. platform to west exit	1.51	-	-	0.05	1.56
Transferring from:					
N.B. to E.B.	1.63	-	-	-	1.63
N.B. to W.B.	1.63	-	-	-	1.63
S.B. to E.B.	1.63	-	-	-	1.63
S.B. to W.B.	1.63	-	-	-	1.63
E.B. to N.B.	1.63	-	-	-	1.63
E.B. to S.B.	1.63	-	-	-	1.63
W.B. to N.B.	1.63	-	-	-	1.63
W.B. to S.B.	1.63	-	-	-	1.63

Table 3.14
Travel Times on Paths of Alternative C: Evening Peak (minutes)

Paths	Walking	Queueing Entry	Queueing Ticketing	Queueing Exit	Total
<u>Entering station from:</u>					
East ent. to N.M. platform	1.77	0.05	0.33	-	2.15
East ent. to S.B. platform	2.30	0.05	0.33	-	2.68
East ent. to E.B. platform	2.14	0.05	0.33	-	2.25
East ent. to W.B. platform	2.14	0.05	0.33	-	2.25
West ent. to N.B. platform	2.30	0.08	0.43	-	2.81
West ent. to S.B. platform	1.77	0.08	0.43	-	2.28
West ent. to E.B. platform	2.14	0.08	0.43	-	2.65
West ent. to W.B. platform	2.41	0.08	0.43	-	2.65
<u>Exiting station from:</u>					
N.B. platform to east exit	1.69	-	-	0.05	1.74
S.B. platform to east exit	2.22	-	-	0.05	2.27
E.B. platform to east exit	2.06	-	-	0.05	2.11
W.B. platform to east exit	2.06	-	-	0.05	2.11
N.B. platform to west exit	2.22	-	-	0.05	2.27
S.B. platform to west exit	1.69	-	-	0.05	1.74
E.B. platform to west exit	2.06	-	-	0.05	2.11
W.B. platform to westexit	2.06	-	-	0.05	2.11
<u>Transferring from:</u>					
N.B. to E.B.	1.59	-	-	-	1.59
N.B. to W.B.	1.59	-	-	-	1.59
S.B. to E.B.	1.59	-	-	-	1.59
S.B. to W.B.	1.59	-	-	-	1.59
E.B. to N.B.	1.59	-	-	-	1.59
E.B. to S.B.	1.59	-	-	-	1.59
W.B. to N.B.	1.59	-	-	-	1.59
W.B. to S.B.	1.59	-	-	-	1.59

Table 3.15
Travel Times on Paths of Alternative D: Evening Peak (minutes)

Paths	Walking	Queueing Entry	Queueing Ticketing	Queueing Exit	Total
Entering station from:					
East ent. to N.B. platform	1.88	0.05	0.33	-	2.26
East ent. to S.B. platform	1.88	0.05	0.33	-	2.26
East ent. to E.B. platform	2.25	0.05	0.33	-	2.63
East ent. to W.B. platform	2.25	0.05	0.33	-	2.63
West ent. to N.B. platform	1.88	0.08	0.43	-	2.39
West ent. to S.B. platform	1.88	0.08	0.43	-	2.39
West ent. to E.B. platform	2.25	0.08	0.43	-	2.76
West ent. to W.B. platform	2.25	0.08	0.43	-	2.76
Exiting station from:					
N.B. platform to east exit	1.65	-	-	0.05	1.70
S.B. platform to east exit	1.65	-	-	0.05	1.70
E.B. platform to east exit	2.02	-	-	0.05	2.07
W.B. platform to east exit	2.02	-	-	0.05	2.07
N.B. platform to west exit	1.65	-	-	0.05	1.70
S.B. platform to west exit	1.65	-	-	0.05	1.70
E.B. platform to west exit	2.02	-	-	0.05	2.07
W.B. platform to west exit	2.02	-	-	0.05	2.07
Transferring from:					
N.B. to E.B.	1.59	-	-	-	1.59
N.B. to W.B.	1.59	-	-	-	1.59
S.B. to E.B.	1.59	-	-	-	1.59
S.B. to N.B.	1.59	-	-	-	1.59
E.B. to N.B.	1.59	-	-	-	1.59
E.B. to S.B.	1.59	-	-	-	1.59
W.B. to N.B.	1.59	-	-	-	1.59
W.B. to S.B.	1.59	-	-	-	1.59

Table 3.16
Comparison of In-Station Travel Times
(Average of Travel Times of Available Paths, Evening Peak)

Movement	Unweighted Average Time (min.) A	B	C	D
Entering Station	1.98[a]	1.94[a]	2.53	2.51
Exiting Station	1.55[a]	1.53[a]	2.06	1.89
Transferring	1.63	1.63	1.59	1.59

[a]Does not include time required to cross a street (about one minute) for approximately one-fourth of all entering passengers (who must do so to reach their proper entrance) or for approximately one-fourth of all exiting passengers (who could otherwise exit the station closer to their final destination if they were not limited to one exit.)

Directional information

There are four basic groups that the directional information system will serve: passengers entering the station; passengers exiting the station; passengers transferring within the station; and passengers passing through the station in subway cars. There are five basic types of information that are important to the above four groups:

(1) identification of the station by name,

(2) description of the area surrounding the station,

(3) description of the transit system to aid passenger in selecting proper platform,

(4) directions to reach proper platform or exit, and

(5) component labeling (e.g. for entry gates, exit gates, ticketing machines, transfer machines, platforms, restrooms, etc.).

For entering passengers the important information types are identification of the station, description of the transit system, directions to proper platform, and component labeling. For exiting passengers the important types are identification of the station, description of the area surrounding the station, directions to reach proper exit, and component labeling.

For transferring passengers, types (1), (3), (4), and (5) are needed. Passengers passing through the station would benefit from some identification of the station.

The above concepts would be included in each alternative design, at a moderate level such that each receives a fair rating regarding directional information.

Hazards present

Potential hazards which were considered included:

(1) walking hazards in station,

(2) level changes

(3) pedestrian/vehicle collisions,

(4) exposure to weather, and

(5) platform edges.

Few walking hazards would be expected within any of the station designs. In Alternatives 3 and 5 entering and exiting passengers must make one more level change than they would in Alternatives 1 and 2. Transferring passengers must make the same number of level changes in all the alternatives.

In Alternatives 1 and 2 some entering and exiting passengers must make one more street crossing than would be required of them in Alternatives 3 and 5. The first two alternatives would therefore increase the chances of pedestrian/vehicle collisions and increase the exposure to weather for some station users.

In general, the presence of side platforms in Alternatives 1, 2, and 3 vs. the center platforms in Alternative 5 does not present any drastic difference in hazard presence. Side platforms expose a passenger to only one platform edge but center platforms are more flexible during rush periods to handle crowds.

For the above reasons all of the alternatives were rated as "fair" with respect to hazards present.

Level changes

Passengers entering or exiting the station must make either one or two level changes in Alternatives 1 and 2 and two or three in Alternatives 3 and 5. Transferring passengers must make one level change in all of the alternatives. The major means for making level changes is by escalators, but elevators are provided for special users. These level change aids are rated here as "good".

Thermal comfort (relative warmth index)

System policy states that "in warm weather, station patrons will be at least as comfortable as they would be outdoors." The Subway Environmental Design Handbook provides an equation to determine the difference between outdoor and indoor temperature to achieve the above criterion:

$$\left[\frac{M(I_{cw} + I_a) + 1.13(t_o - 95) + RI_a}{74.2}\right]_{\text{outdoors}} = \left[\frac{M(I_{cw} + I_a) + 1.13(t_s - 95)}{74.2}\right]_{\text{station}} \quad (3.4)$$

where:

M = metabolic rate, BTU per (hr.)(sq.ft.)

I_{cw} = insulation of clothing based on wet cloth assumption, clo.

I_a = insulation effect of air boundary layer, clo.

t_o = outdoor dry bulb air temperature, ^oF

t_s = station dry bulb air temperature, ^oF

R = mean incident radiant heat from sources other than walls at room temperature, Btu per (hr.)(sq.ft.)

From an example in the design handbook, assuming the design conditions are:

M = 54 Btu per (hr.)(sq.ft.); walking at 3 mph

I_{cw} = 0.35 clo., walking at 3 mph

I_a = 0.22 clo. outdoors, total air velocity = 900 fpm

0.32 clo. in station, total air velocity = 360 fpm

R = 10 Btu per (hr.)(sq.ft.); outdoors from sun

then by substitution:

$$\frac{54(0.35 + 0.22) + 1.13(t_o - 95) + 10(0.22)}{74.2}$$

$$= \frac{54(0.35 + 0.32) + 1.13(t_s - 95)}{74.2}$$

$$t_o - t_s = 2.83°F$$

Then, if during warm weather the station temperature is kept 3°F lower than the outdoor temperature, the stated objective will be met. Since this should be possible in all four alternative station designs, all four were rated as fair.

Thermal comfort (heat deficit rate)

System policy for cold weather state that environment control systems will prevent patrons from experiencing a greater heat deficit in the station thay they would experience outdoors. Since station patrons will be coming from outdoors, this means that the heat deficit rate must be equal to or less than zero. The equation for heat deficit rate (6) is:

$$HDR = - M - \frac{1.13(t-87)}{I_{cw} + I_a} + 9 - \frac{RI_a}{I_{cw} + I_a} \qquad (3.5)$$

(see Eq. 3.4 for meanings of variables)

Assuming HDR equals zero and the following design conditions:

M = 39 BTU per (hr.)(sq.ft.), an occasional stroll R = 0 Btu per (hr.)(sq.ft.)

I_a = 0.33 clo., for total air velocity of 360 fpm

I_{cw} = 1.13 clo., assuming one dresses for walking 4 mph, with a 15 mph wind, on a 30^{o}F day

and substituting into Eq. 3.5:

$$0 = -39 - \frac{1.13(t-87)}{1.13 + 0.33} + 9 - \frac{0(0.33}{1.13 + 0.33}$$

$t = 48.14°F$

the station should be designed to provide a temperature of at least 49^{o}F on cold days. It is assumed that all of the alternatives meet this level, which was rated as "fair".

Illumination

Illumination in each station design will conform with Institute for Rapid Transit Guidelines (7). This performance was rated as "good".

Personal comfort

None of the present designs include provisions for rest areas. The performance in this regard was therefore rated as "very poor". Since such provisions could be included in all of the designs, they are investigated subsequently in the detailed design phase.

Supplementary services

The present designs include no provisions for either advertising or concessions. The performance for all four designs with respect to advertising was rated as "very poor". Since advertising provisions can be added, they too are investigated in the detailed design phase.

The performance of the designs was rated slightly differently for concessions. Since Alternatives 3 and 5 each have one central mezzanine, they would have greater potential for concessions than would Alternatives 1 and 2, which each have two separate mezzanines. Alternatives 1 and 2 were rated as "poor" while Alternatives 3 and 5 were rated as "very poor". Possible provisions for concessions are investigated in the detailed design work.

Security

In Alternative 1 there are six separate, non-intervisible spaces: mezzanines (two) and platforms (four). In Alternative 2 there are eight such spaces: station entrances (two), mezzanines (two), and platforms (four). Alternative 3 has seven such spaces: station entrances (two), a mezzanine, and platforms (four). Alternative 5 has five separate, non-intervisible spaces: station entrances (two), a mezzanine, and platforms (two).

The "paid area" performance measure used here is the fraction of the separate, non-intervisible spaces which are entirely part of the "paid area". In Alternative 1 the two mezzanines are not part of the paid area. In Alternatives 2, 3, and 5 the station entrances (3) and the mezzanines (either 1 or 2) are not part of the paid area.

Special User Performance

Travel time in station

The components of the special user average in-station travel time for each alternative are shown in Table 3.14. For the walking time

Table 3.17
Special User Average in Station Travel Times[a] (minutes)

Alternative	Walk Time	Entry Queueing	Exit Queueing	Ticket Machine Queueing	Elevator Queueing	Elevator Riding Time	Total
Alternative A							
entry	2.15	0.05	-	0.35	1.0	0.75	4.30
exit	1.97	-	0.05	-	1.0	0.75	3.77
transfer	2.76	-	-	-	1.0	0.50	4.26
Alternative B							
entry	2.03	0.05	-	0.35	0.75	0.75	3.93
exit	1.93	-	0.05	-	0.75	0.75	3.48
transfer	2.76	-	-	-	0.50	0.50	3.76
Alternative C							
entry	2.72	-	-	0.38	1.5	1.25	5.91
exit	2.56	0.05	0.05	-	1.5	1.25	5.36
transfer	2.68	-	-	-	1.0	0.50	4.12
Alternative D							
entry	2.68	-	-	0.38	1.5	1.25	5.87
exit	2.22	0.05	0.05	-	1.5	1.25	5.02
transfer	2.68	-	-	-	1.0	0.50	4.18

[a]Averages of major paths

calculations it was assumed that special users would walk the same total distance as users, but would do so at one-half the speed (about 122 ft./min) of the users. Special users were assigned the same "time spent in queueing system" in the entry, exit, and ticket machine queues that had been determined for users.

For elevator riding time it was assumed that the average time for a trip from one floor to the next was 0.5 minutes. For elevator queueing time it was assumed that wait time for an elevator was one-half the elevator round trip time.

Level of service in queues

The level of service in entrance, exit, and ticketing machine queues should be the same as for users (i.e. not worse than Level C). Since few people will be using any of the elevators at any one time, the queues outside elevator doors should not create problems.

Directional information

The performance of the designs relative to directional information should be the same for special users as for users (i.e., "fair").

Hazards present

The hazards considered for special users were similar to those considered for users:

(1) walking hazards in station,

(2) level changes,

(3) pedestrian/vehicle collisions,

(4) exposure to weather, and

(5) platform edges.

Walking hazards within the stations should be minimal within all the station designs, mainly because all walking should be on flat surfaces. Since special users have access to the elevators, level changes should not be hazardous. Alternatives 1 and 2 require some entering and exiting passengers to make one more street crossing than would be required of them in Alternatives 3 and 5. Accordingly, the probability of pedestrian/vehicle collisions would be slightly greater in the first two designs, as would be the exposure to weather. The presence of center platforms in Alternative 5 vs. side platforms in the first three alternatives should not cause any large difference in exposure to hazards. For the above reasons, all four alternatives were rated as "fair" with respect to hazards present.

Level changes

When using elevators, entering and exiting passengers must make one level change operation in Alternative 1, one or two level changes in Alternative 2, and two level changes in Alternatives 3 and 5. Transferring passengers must make only one level change in all four alternatives. The types of level change aids available, elevators and escalators, were rated as "good".

Movement barriers

Potential movement barriers include entry gates, exit gates, level changes, station doors, and vehicle doors. Special users who are not capable of using the standard entry and exit gates may use a larger channel located by and controlled from the station agent's kiosk. Level changes are well accomodated by elevators. Station and vehicle doors should be large enough for all special users and are opened automatically. Therefore the performances of all four designs were rated as "good" with respect to movement barriers.

Environmental performance measures

The performance measures for thermal comfort, illumination, personal comfort, and supplementary services were the same for special users as they were for users. Because of the use of elevators by special users, the number of separate spaces is larger for this group. Alternative 1 includes two elevators, both of which are within the paid area. Alternative 2 includes four elevators, two of which are within the paid area. Alternative 3 has four of its six elevators in the paid area. Alternative 5 includes only three elevators, one of which is within the paid area.

The "paid area" performance measure used here is the number of separate, non-interdivisible spaces divided into the number of these spaces which are totally within the paid area.

Operator Performance

Entry control

The entry control procedures are the same in each of the alternatives. The major components of concern are the entry gates. It was assumed that the type to be used would require passengers to insert a magnetic fare card (with a record of the remaining monetary value on it), pass through a mechanical device normally preventing entry, and pick up the fare card from the machine. The exit gates would work in a manner similar to the entry gates, but deduct the appropriate fare from the card before returning it to the passenger.

Some special users (e.g., those in wheelchairs, on crutches, etc.) would be allowed to bypass the entry and exit gates by going through a wider channel next to the station agent's kiosk.

Security of fares paid

All monetary transactions at the station occur at the ticketing machines. This type of collection was rated as "good". The major safeguard for the fares paid was to have the machines in full view of the station agent's booth. The performance for safeguards was rated as "fair".

Income from non-transport activities

As stated earlier, none of the alternatives include provisions for concessions or advertising at the station. These possibilities are investigated in the detailed design work.

Total cost

The total cost of the station is composed of capital cost and operation and maintenance costs. The estimated capital cost for the four alternatives is shown in Table 3.18 and the estimated operation and maintenance costs are shown in Table 3.19.

The capital cost is composed of costs for construction disturbances, land preparation, land improvements, station construction, mechanical equipment, and the passenger management system. The costs for construction disturbances and land improvements were the same for each alternative. This is because the length and width of the cut-and-cover operation will be about the same in each alternative.

The differences in cost for land preparation are basically due to the different requirements for excavation, hauling, dumping of exca-

Table 3.18
Subway Station Capital Cost Elements ($)[a]

Cost Elements				
1. Construction Distrubances				
Rerouting vehicular traffic	10,000	10,000	10,000	10,000
Rerouting pedestrian traffic	4,000	4,000	4,000	4,000
Relocation of utilities	200,000	200,000	200,000	200,000
Contingencies (15%)	32,100	32,100	32,100	32,100
Sub-total	246,100	246,100	246,100	246,100
2. Land Preparation				
Sidewalk removal ($2.75/S.Y.)	2,600	2,600	2,600	2,600
Curb removal ($2.05/L.F.)	5,000	5,000	5,000	5,000
Pavement removal ($2.30/S.Y.)	4,950	4,950	4,950	4,950
Excavation ($1.05/C.Y.)	94,500	96,750	151,450	159,550
Hauling ($1.15/C.Y.)	113,850	116,550	182,500	192,250
Dump charges ($2.50/C.Y.)	225,050	230,350	360,600	379,950
Sheeting and bracing				
15'-22' deep ($13.50/S.F.)	396,900	400,000	-	-
23'-35' deep ($15.00/S.F.)	-	-	693,000	693,000
36'-45' deep ($17.50/S.F.)	961,400	961,400	1,281,850	1,278,500
Shoring building ($850/MFBM)	300,000	300,000	300,000	300,000
Underpining foundation				
5'-16' below grade ($500/C.Y.)	50,000	50,000	50,000	50,000
16'-25' below grade ($550/C.Y.)	200,000	200,000	200,000	200,000
26'-40' below grade (600/C.Y.)	150,000	150,000	150,000	150,000
Dewatering ($245/day)	44,000	44,000	50,000	50,000
Backfill ($1.00/C.Y.)	41,000	41,000	97,350	103,000
Contingencies (15%)	388,400	390,400	529,400	535,300
Sub-total	2,977,600	2,993,000	4,058,700	4,104,100

[a] Most unit cost data from Building Construction Cost Data: 1977, e. Robert Godfrey

Table 3.18 (continued)

Cost Elements	Alternatives A	B	C	D
3. Land Improvements				
Sidewalks ($1.40/S.F.)	35,750	35,750	35,750	35,750
Curbing ($2.05/L.F.)	4,900	4,900	4,900	4,900
Paving ($11.70/S.Y.)	58,050	58,050	58,050	58,050
Contingencies (15%)	14,800	14,800	14,800	14,800
Subtotal	113,500	113,500	113,500	113,500
4. Station Construction				
Architectural trades ($13.00/S.F.)[b]	1,300,000	1,255,800	1,430,000	1,430,000
Structural steel (3.46/S.F.)[b]	346,000	334,250	380,600	380,600
Heating, venting, and air-conditioning ($7.80/S.F.)[b]	780,000	753,500	858,000	858,000
Plumbing ($0.85/S.F.)	85,000	82,100	93,500	93,500
Electrical $2.55/S.F.)	255,000	246,350	280,500	280,500
Contingencies (15%)	414,900	400,800	456,390	456,390
Subtotal	3,180,900	3,072,800	3,499,000	3,499,000
5. Mechanical Equipment				
Elevators				
2-story ($25,000 ea.)	-	100,000	50,000	50,000
3-story ($30,000 ea.)	60,000	-	120,000	30,000
Escalators ($64,000 ea.)	768,000	768,000	1,024,000	512,000
Contingencies (15%)	124,200	130,200	179,100	88,800
Subtotal	952,200	998,200	1,373,100	680,800
6. Passenger Management System				
Ticketing machines ($12,000 ea.)[b]	576,000	576,000	552,000	552,000
Entry gates ($12,000 ea.)[b]	96,000	96,000	96,000	96,000

[b] Source: "Cost Parametric Analysis: Dual Mode Transit System," General Motors Systems Division

Table 3.18 (continued)

Cost Elements	Alternatives			
	A	B	C	D
Exit gates ($12,000 ea.)[b]	96,000	96,000	96,000	96,000
Service gates ($15,000 ea.)[c]	30,000	30,000	30,000	30,000
Emergency exit gates ($2,000 ea.)[c]	4,000	4,000	4,000	4,000
Station agent's kiosk ($3,000 ea.)[c]	6,000	6,000	6,000	6,000
Contingencies (15%)	121,200	121,200	117,150	117,150
Subtotal	929,200	929,200	898,150	898,150
Total	8,399,500	8,352,800	10,188,550	9,541,650

[b]Source: "Cost Parametric Analysis: Dual Mode Transit System," General Motors Systems Division

[c]Source: Estimate

Table 3.19
Subway Station Annual Operation and Maintenance Costs ($)

Cost Elements	Alternatives A	B	C	D
1. Rental of street-level space ($6.00/ft^2)	28,800	4,800	4,800	4,800
2. Utilities				
Air conditioning	10,000	10,000	12,000	12,000
Heating	5,000	5,000	6,000	6,000
Ventilating	2,000	2,000	2,400	2,400
Lighting	7,000	7,000	8,400	8,400
Other electrical	6,000	6,000	6,000	6,000
Water	1,000	1,000	1,000	1,000
Subtotal	31,000	31,000	35,800	35,800
3. Maintenance of passenger management and movement equipment				
4. Personnel				
Station agents ($13,000/yr.)	112,300	112,300	56,150	56,150
Janitors ($4.50/hr.)	20,200	20,200	20,200	20,200
Subtotal	132,500	132,500	76,350	76,350
5. Consumable supplies	15,000	15,000	15,000	15,000
6. Other maintenance	2,000	2,000	2,000	2,000
7. Contingencies (15%)	28,000	28,000	20,250	20,100
Total	243,300	219,300	160,200	159,050

vated material, sheeting and bracing, and backfill. The differences reflect the various depths of excavation for the four station, the additional depths of excavation for the tracks outside Alternatives 3 and 5 (assuming a grade of 4%) and the additional width of trackway excavation required by Alternative 5 (assuming a 1000 foot radius of horizontal curvature).

The different costs for station construction are due to the differences in floor area among the alternatives. The different costs for mechanical equipment and the passenger management system are due to the different number of devices required in each alternative.

The largest differences in operation and maintenance cost among the alternatives are due to the number of employees required and the amount of street level space rented. Alternatives 1 and 2 require two station agents to be on duty at all times while Alternatives 3 and 5 require only one. Alternative 1 requires 28,800 sq. ft. of street level space compared to 4,800 sq. ft. for the others.

The annual equivalent of the capital cost is shown in Table 3.20. The sum of annual capital, operation, and maintenance cost is also shown.

Joint development potential

The accessibility of the station to local businesses was rated as "fair" for Alternatives 1 and 2 and as "good" for Alternatives 3 and 5. Alternatives 1 and 2 had lower ratings because some patrons are required to use one particular entrance or exit while in Alternatives 3 and 5 a patron can use any entrance or exit.

Table 3.20
Total Subway Station Costs

	Alternatives 1	2	3	5
Total Capital Cost ($)	8,399,500	8,352,800	10,188,550	9,541,650
Annualized Capical Cost ($/yr.): Assuming 8% rate of return and 30 year life	746,150	742,000	905,050	847,600
Annual Operation and Maintenance Cost ($/yr.)	243,300	219,300	160,200	159,050
Annual Capital, Operation, and Maintenance Cost ($/yr.)	989,450	961,300	1,065,250	1,006,650

The compatability of use for all four designs was rated as "good". The designs lend themselves well to joint development.

Comparing Alternative Designs

The selection of the basic station design is done by comparing two alternatives at a time until all the designs have been compared with the leading candidate design.

Comparing Alternatives 1 and 2

As can be seen from the evaluation matrices (Tables 3.21, 3.22 and 3.23), Alternative 1 is superior to 2 for number of separate spaces, number of areas that are paid areas, and number of level changes for special users. Alternative 2 is superior to 1 for special user travel time and total cost. All other performance measures are equal. From the above considerations, Alternative 2 was judged to be superior to Alternatives 1.

Comparing Alternatives 2 and 3

The evaluation has shown that Alternative 2 is superior to Alternative 3 in the following ways.

1. It has lower travel times for both users and special users.

2. It has significantly fewer level changes for both users and special users.

3. It is lower in cost by more than $100,000 per year.

On the other hand, Alternative 3 is superior to Alternative 2 in the following ways.

1. It has one fewer separate, non-intervisible space for both users and special users.

2. It has a slightly higher ratio of paid areas to total number of separate areas.

3. It does not require some of its users to make an extra street crossing because they are required to use one particular entrance or exit.

4. It provides better accessibility to local businesses.

5. It provides one central mezzanine for potential concessions.

Subjective interpretation of the above findings relative to the stated design objectives led to the selection of Alternative 3 as superior to Alternative 2. This decision is somewhat arbitrary since all measures are not reduced to a common matrix nor are relative weights available for each criteria.

Comparing Alternatives 3 and 5

The evaluation matrices show that Alternative 5 is superior to 3 in the following ways.

1. It has lower travel times for both users and special users.

2. It has fewer separate, non-intervisible spaces for both users and special users.

3. It is lower in cost by almost $60,000 per year.

Alternative 3 did not perform better than Alternative 5 in any of the criteria categories. For these reasons, Alternative 5 was selected as being the "best" design and it was chosen to be the basis for detailed designs.

Evaluating Policy

After reviewing the present policy statements in view of the results of the preliminary evaluation, the potential benefits and costs of concessions and advertising were investigated and the opportunities for joint development exploited. This is accomplished in the next section on detailed design.

DESIGN IMPROVEMENTS

The development and testing of proposed improvements to the basic station layout are considered here. The strategies were evaluated for their direct and indirect effects.

Table 3.21
Subway Station User Performance

Criteria	Performance Measures Alternatives 1	2	3	5
Subsystem/category: Measure				
Passenger Processing				
Travel time (min.) entering				
entering station	1.98	1.94	2.53	2.51
exiting station	1.55	1.53	2.06	1.89
transferring	1.63	1.63	1.59	1.59
Level of service in queues	C	C	C	C
Directional information				
location (subj.)	2	2	2	2
type (subj.)	2	2	2	2
Hazards present	2	2	2	2
Level changes				
number	1, 2:1	1, 2:1	2, 3:1	2, 3:1
type (subj.)	3	3	3	3
Environmental				
Thermal comfort				
RWI (subj.)	2	2	2	2
HDR (subj.)	2	2	2	2
Illumination (subj.)	3	3	3	3
Personal comfort	0	0	0	0
Supplementary services				
advertising (subj.)	0	0	0	0
concessions (subj.)	0	0	1	1
Security				
separate spaces	6	8	7	5
paid area	4/6	4/8	4/7	2/5

Subjective rating:
- 4 = excellent
- 3 = good
- 2 = fair
- 1 = poor
- 0 = very poor

Table 3.22
Subway Station Special User Performance

Criteria Subsystem/category: Measure	Performance Measures Alternatives 1	2	3	5
Passenger Processing				
Travel time (min.)				
entering station	4.30	3.93	5.91	5.87
exiting station	3.77	3.48	5.36	5.02
transferring	4.26	3.76	4.12	4.18
Level of service in queues	C	C	C	C
Directional information				
location (subj.)	2	2	2	2
type (subj.)	2	2	2	2
Hazards present	2	2	2	2
Level changes				
number	1, 1:1	1, 2:1	2, 2:1	2, 2:1
type (subj.)	3	3	3	3
Movement barriers (subj.)	3	3	3	3
Environmental				
Thermal comfort				
RWI (subj.)	2	2	2	2
HDR (subj.)	2	2	2	2
Illumination (subj.)	3	3	3	3
Personal comfort	0	0	0	0
Supplementary services				
advertising (subj.)	0	0	0	0
concessions (subj.)	0	0	1	1
Security				
separate spaces	8	12	1	1
paid area	6/8	6/12	8/13	3/8

Subjective rating:
- 4 = excellent
- 3 = good
- 2 = fair
- 1 = poor
- 0 = very poor

Table 3.23
Subway Station Operator Performance

Criteria Subsystem/category: Measure	Performance Measures Alternatives 1	2	3	5
Passenger Processing				
Entry control (subj.)	3	3	3	3
Environmental				
Secutiry of fares paid				
type of collection (subj.)	3	3	3	3
safeguards (subj.)	2	2	2	2
Fiscal				
Income, non-transport				
incremental cost ($/yr.)	0	0	0	0
income ($/yr.)	0	0	0	0
difference ($/yr.)	0	0	0	0
Total cost ($/yr.	989,450	961,300	1,065,250	1,006,650
Joint development				
potential accessibility to local business (subj.)	2	2	3	3
compatability of use (subj.)	3	3	3	3

Subjective rating:
- 4 = excellent
- 3 = good
- 2 = fair
- 1 = poor
- 0 = very poor

Strategies for Improving Station Performance

Six station characteristics were identified as needing improvement:

(1) hazards present to users and special users,

(2) services available to users and special users,

(3) security of users and special users,

(4) movement barriers to special users,

(5) system reliability for special users, and

(6) security of fares paid.

Ten design and operation strategies were proposed for improving upon these characteristics. These strategies, along with their potential direct and indirect effects, are summarized in Table 3.24.

Flashing lights

Under this strategy, flashing lights are installed along platform edges. The lights can be activated when a train approaches the platform and remain in a flashing (alternating between on and off) mode until after the train leaves.

The direct effect of this strategy is to warn sighted users that a train was approaching. The indirect effects are limited to cost.

The increase in capital cost from this strategy was roughly estimated to be $4,800. The light control system was estimated to comprise $2,000 of this cost and the flashing light elements were estimated to make up the remaining $2,800 (400 lights at $7.00 each). The increase in annual operating cost was estimated to be $1,750 (160 kilowatt-hours per day at $0.03/killowatt-hour).

An additional consideration is that the lights could act as an "announcer" of an imminent train arrival. The knowledge that one's

Table 3.24
Strategies for Improving Subway Station

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
I. Reduce hazards present to users and special users	Provide flashing lights along platform edges to warn of approaching trains	Visually warn those on platform of approaching trains	1. Increase capital cost 2. Increase maintenance cost
II. Improve upon services to users and special users	A. Provide space for advertising	Provide users and special users with advertised information	1. Increase disorientation 2. Increase capital cost 3. Increase operating cost 4. Increase maintenance cost 5. Increase revenues
	B. Provide concessions for users and special users	Improve amenities for users and special users	1. Decrease pedestrian level of service 2. Increase disorientation 3. Decrease security 4. Increase capital cost 5. Increase operating cost 6. Increase maintenance cost 7. Increase revenues 8. Affect station aesthetics

Table 3.24 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
III. Increase security of users and special users	A. Provide surveillance cameras with console in station agent's kiosk	Increase surveillance of passengers in terminal	1. Increase safety 2. Increase capital cost 3. Increase maintenance 4. Increase security
	B. Provide extra security patrols within station	Increase security of users and special users	1. Decrease disorientation 2. Increase safety 3. Increase operating cost 4. Increase security of monies received
	C. Use elevators with transparent sides	Reduce number of separate non-intervisible spaces	1. Increase capital cost 2. Decrease disorientation for special users 3. Increase system reliability
IV. Reduce movement barriers to special users	Provide ramps at curbs outside station entrances	Reduce barriers to those using movement aids	Increase capital cost
V. Increase system reliability for special users	A. Provide two elevators between mezzanine and platforms	Increase system reliability for those requiring use of elevators	1. Increase level of service for those using elevators 2. Increase capital cost 3. Increase operating cost 4. Increase maintenance cost

Table 3.24 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
VI. Increase security of fares paid	Provide alarm mechanisms to activate from tampering with ticketing machines	Decrease potential for theft from machines	Increase capital cost

train will soon be at the platform may slightly decrease one's perceived waiting time or decrease the disutility of that waiting time.

Advertising

As stated in the chapter dealing with the central area bus terminal, the Rapid Transit Authority seeks to include advertising within its transportation terminals while:

(1) minimizing the number of advertisement locations,

(2) using standard sizes of displays,

(3) having no advertising on platforms,

(4) having advertising which complements station architecture, and

(5) having centralized control of advertising for the entire transit system.

While provisions for advertising are more closely associated with the operator's goals, advertising has been included here under a user objective. This was done to emphasize that the display of advertising can add to the passenger's information, thereby providing a service to him. The direct effect of this strategy is, therefore, the provision of the advertised information to users and special users.

The constraints that the transit authority has placed on advertising led to the following suggested design. The design calls for 2-sheet size (4 ft. x 6 ft.) advertisements with twelve such ads in the mezzanine and eight such ads beside mezzanine/ground level escalators. The design includes the use of ads on escalator headers, but only on upward (out-bound) escalators between the mezzanine and ground level.

Since the number, types, and locations of advertisements are limited, there should be little interference or confusion between the advertisements and directional aids. The indirect effect of increasing disorientation should not be a serious problem.

The 20 two-sheet size advertisements were expected to generate an annual net revenue of $3060 and the two headers were expected to generate an annual net revenue of $2040 totaling $5100 per year (8).

Concessions

The provision of concessions, much like that of advertising, can be seen as satisfying an operator as well as a user objective. System policy states that concessions will be encouraged where they do not adversely affect the transportation and aesthetic goals of the system. Since the provision of concessions has been proposed under a user objective, the direct effect would be the amenities provided to users and special users. The indirect effects are described below.

It was assumed that the concessions would be kept separate from pedestrian paths and off to one side of the mezzanine level. Because of this, detrimental effects to pedestrian level of service and level of disorientation were estimated to be small. It was also estimated that this strategy would have a somewhat detrimental effect on security, partly because of its addition of another separate, non-interdivisible space.

This strategy was expected to have no effect upon capital cost for construction disturbance, land preparation, land improvements, mechanical equipment, or the passenger management system. However the station construction cost was expected to be increased by $31.81 per square foot of concession area. Since this area was expected to be about 60' x 40', (18'm x 12'm) the capital cost would be increased by $76,340.

The only increase in annual operation and maintenance was expected to be for utilities. An increase of 5%, or $2050, was estimated.

The provision of concessions could be expected to increase system revenues. An 8% rate-of-return and a 30 year life were assumed for the concession area, with no resale value. For the increase capital and opearting costs, a yearly rent of $8,880 or $3.70 per sq. ft., would be needed for break-even operation.

The effect upon station aesthetics was expected to be minimal.

Surveillance cameras

The provision of security cameras would have the direct effect of providing surveillance, from the station agent's kiosk, of virtually all parts of the terminal, including station entrances, mezzanine, and platforms. The surveillance would also increase safety, to a limited extent, by the monitoring of potentially hazardous situations and by helping to aid injured patrons.

It was estimated that nine cameras would be required, calling for an additional capital cost of $4500 (from Ref. 9). The additional maintenance cost was roughly estimated to be $190 per year. An additional consideration was that the presence of security cameras might bring some slight increase to the security of monies received.

Security patrols

It was assumed that the transit system has its own security force to patrol the subway system. This strategy would provide for four additional full-time security guards (one guard in the station at any one time) to patrol the station.

This strategy would increase station security. However, since the station has three levels (four including street-level entrances) the station could not be completely covered by one guard at any one time.

The presence of a security guard could have the indirect effect of decreasing user disorientation if the guard would answer people's directional questions. The guard could also increase safety by noticing potentially hazardous situations, warning users of hazards, and aiding injured patrons. The security of monies received would also be improved.

The equivalent of four full-time security guards was estimated to increase annual station operating cost by $50,000.

Elevators with transparent sides

By using elevators with transparent sides, the number of separate, non-intervisible spaces encountered by special users can be reduced from eight to five. The increased capital cost of this strategy was roughly estimated to be $1500. The disorientation of special users would be reduced because those using the elevators would have a constant view of their surroundings. The system reliability for special users would be increased because the presence of people in a disabled elevator would be readily apparent to others in the station.

Ramps at curbs

By providing ramps at the curbs around the station entrances, the number of barriers to the special users requiring movement aids (e.g., wheelchairs, crutches, etc.) would be reduced. The effectiveness of this strategy would be limited, however, if similar ramps are not available at other street crossings in the area served by the station.

For eight ramps to be built at the intersection where the station entrances are located, the increased capital cost was roughly estimated to be \$400.

Additional mezzanine/platform elevator

System reliability for those special users requiring the use of elevators could be increased by providing two elevators between the mezzanine and the platforms instead of the present one elevator. The probability of both elevators being inoperable at one time is much smaller than the probability of one elevator being inoperable.

Providing two elevators, side-by-side, could greatly reduce the expected wait time for an elevator and could reduce the pedestrian density on elevators by 50%. From Reference 9, the increased capital cost was estimated to be \$30,000 (\$30,500 if transparent sides are used). The increased annual operation and maintenance costs were roughly estimated to be \$400 and \$100, respectively.

Additional entrance/mezzanine elevators

Providing two elevators at each of the two station entrances would improve the system reliability for special users in the same way as the previous strategy. The major difference is that for the present situation (one elevator for each entrance), if one of the elevators does not function, those who need to use an elevator can use the elevator at the other entrance. The only adverse effects of this situation are a slightly increased walk distance (about 200 ft.) and an additional street crossing.

The additional capital cost of this strategy was estimated, from Reference 9, at \$60,000 (\$61,000 if transparent sides are used).

The increased annual operation and maintenance costs were roughly estimated to be $600 and $200, respectively.

Alarm mechanisms

This strategy calls for alarm mechanisms to activate from tampering with ticketing machines. The alarms would notify the station agent of the tampering. The station agent could then notify police and the transit security force from his kiosk. The direct effect of this strategy would be to increase the security of monies received by decreasing the potential for theft from the ticketing machines. The increased capital cost of this strategy was roughly estimated to be $6050 (from Ref. 9). The additional annual maintenance cost was roughly estimated to be $50.

Improvement Strategies Selected

After the potential benefits and adverse effects of each strategy were compared, the following strategies were approved for use.

1. Provide flashing lights along platform edges to warn of approaching trains.

2. Provide space for advertising.

3. Provide space for concessions.

4. Provide surveillance cameras with console in station agent's kiosk.

5. Use elevators with transparent sides.

6. Provide ramps at curbs outside station entrances.

7. Provide two elevators between mezzanine and platforms.

8. Provide alarm mechanisms to activate from tampering with ticketing machines.

The above strategies were employed to modify the initial design for the subway station in order to better serve the established design goals. The recommended station design is shown in Figures 3.10 and 3.11.

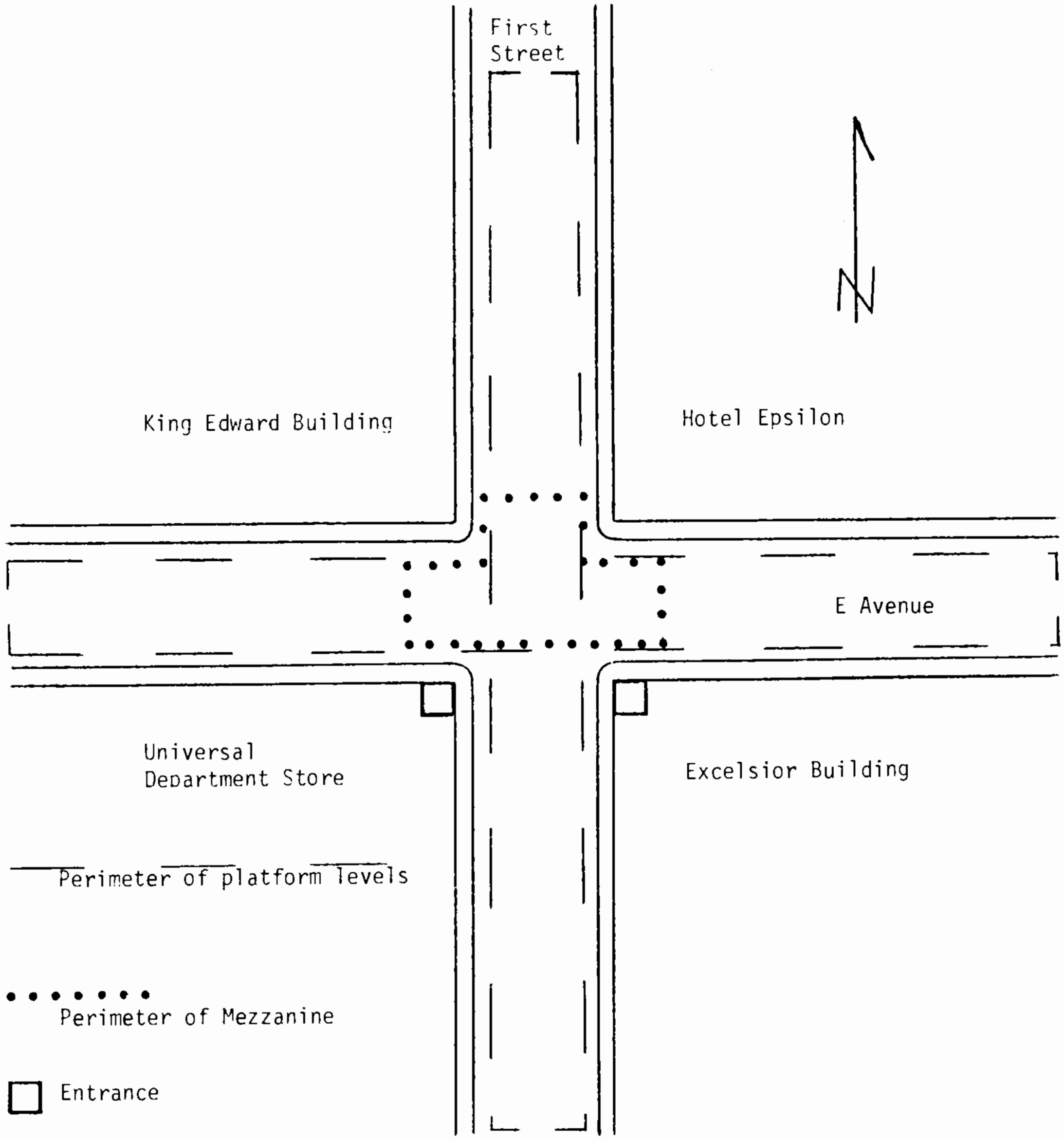
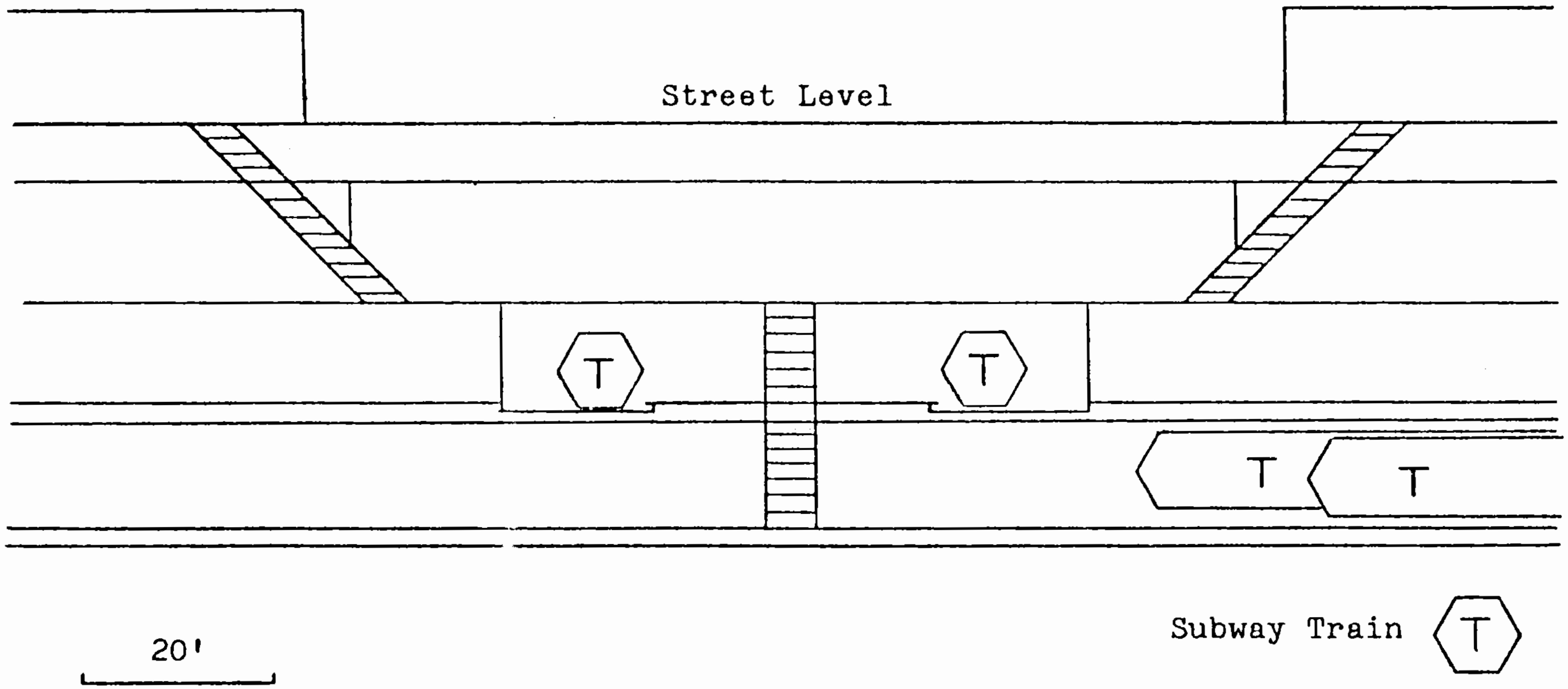


Figure 3.10 Plan of Final Subway Station Design



Platform Length = 700'
Platform Width = 30'
Mezzanine Ceiling Height = 12'
Platform Area Ceiling Height = 10'
Earth Cover = 6'

Figure 3.11 Elevation of Final Subway Station Design

CHAPTER 4

SUPPLEMENTARY EXAMPLES

In order to supply more information for developing generalized guidelines for application of the transit station design methodology and rules of practice, two additional case studies were conducted and are summarized here.

EXPRESS BUS PARK AND RIDE STATION

Express bus park and ride operations can be developed with a wide range of line haul and system access facilities. The prototype station analyzed here falls in the mid range of line haul capacity and system access supply. The specific service originates 8 miles from the CBD and provides an exclusive lot for bus patrons, and two exclusive freeway lanes for high occupancy vehicles (buses and carpools) are available. The following policies have been established regarding the service.

1. The station will be in operation only during the morning and evening peak travel periods.
2. No concessions or advertising will be permitted in the station area.
3. No restrooms will be available to the public.
4. If feasible, a first aid station will be available.
5. Public telephones will be provided.
6. Construction materials should be selected for high levels of durability, low maintenance.

The summary of the objectives, criteria and performance measures for this situation is given in Table 4.1.

The station site is rectangular, approximately 522' x 626' (7.5 acres). Four alternative design concepts were proposed for this station.

Table 4.1
Express Bus Station Objectives, Criteria, and Performance Measures

Objectives	Criteria	Performance Measures
1. Minimize travel	Average travel time	Minutes
2. Maximize safety	Presence of design hazards	(subjective)
3. Provide for efficient fare collection	Inconvenience to user due to method	Minutes required for buying ticket, making change, queueing, fare collection
4. Provide room for cars	Parking area available	Number of spaces
5. Provide comfortable ambient environment	Thermal comfort	Relative comfort Index
6. Provide adequate lighting	Adequacy of lighting	foot-candles
7. Provide clean and pleasant surroundings	Station finish materials	(subjective)
8. Provide adequate weather protection	Passenger exposure to weather	Time exposed
9. Provide adequate passenger security	Number of separate non-intervisible spaces	Number of separate non-intervisible spaces
10. Provide adequate vehicle security	Visibility of lot from terminal	Visibility
11. Eliminate physical barriers	Number of barriers to special users	Number of barriers to special users
12. Maximize equipment reliability	Back-up facilities in case of breakdown	Present or not present
13. Provide adequate space for operation	Station size	Square feet
14. Provide proper security for fares paid	Attraction to robbery	Type of collection
15. Minimize adverse impacts on neighborhood	Outdoor lighting intensity	Illumination levels at station area perimeter
16. Minimize maintenance, cleaning, and replacement needs	Estimated cost	Dollars/year
17. Minimize operating cost	Estimated cost	Dollars/year
18. Minimize capital cost	Estimated cost	Dollars

1. Basic Lot

This alternative provide parking space for park-and-ride and kiss-and-ride operations. A bus loading and unloading area is set aside for the mode transfer operations. In the preliminary design, there are 480 P&R spaces, 76 K&R spaces next to the loading area, space for 40 bicycles, and a bus loop with five bus loading spaces for a sawtooth design. The loading area, having a curb by the bus stops, is a semicircle. This is shown in Figure 4.1.

2. Basic Lot with Shelters

This alternative is identical to the Basic Lot except that bus shelters are provided at each bus loading space.

3. Basic Lot with Platform

This alternative is identical to the Basic Lot with Shelters except that the loading areas are raised to the level of the lowest step of the buses. In addition, steps are provided to access and leave this platform.

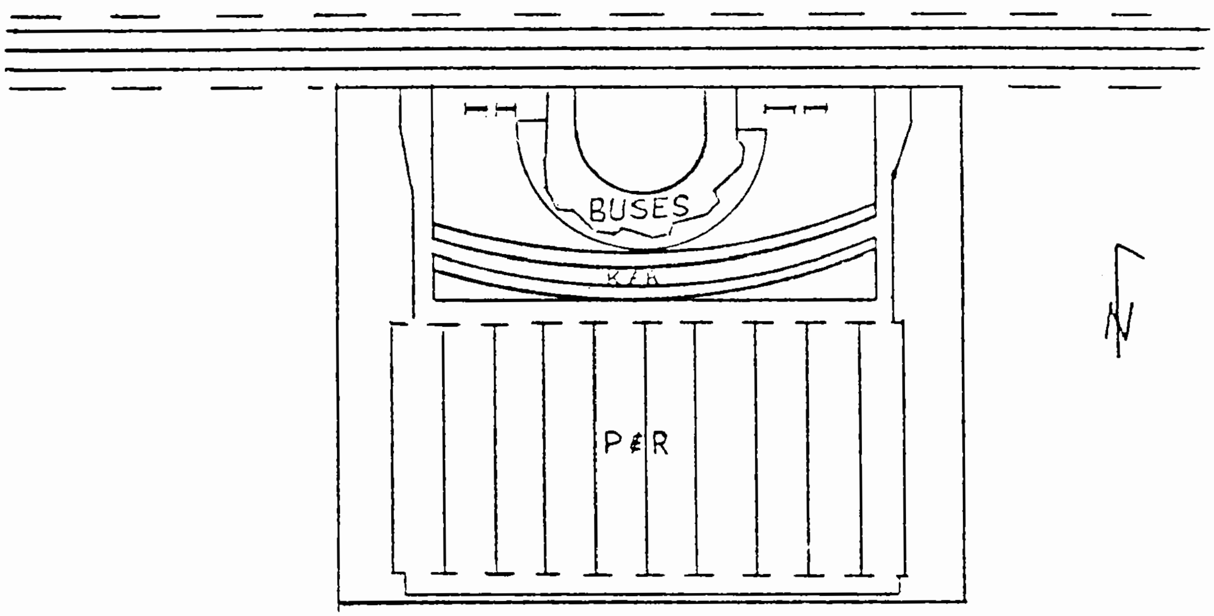
4. Station Building

This alternative is similar to the above ones, but a station building is provided with provision for fare collection and change-making (see Figure 4.2). This building also provides increased weather protection and stairs for access to and from the loading platform.

EVALUATION I

These express bus park-and-ride station designs were evaluated similar to the bus and rapid transit stations described in the earlier text. The preliminary evaluation of policy effectiveness, performance and cost is summarized in Tables 4.2, 4.3 and 4.4. To determine the most suitable design, the effectiveness analysis framework was employed (1).

The effectiveness analysis framework uses a display of performance measures, disaggregated by interest group, and trade-off analysis to determine the "best" alternative. Objective data provides the basis for a subjective selection of this "best" alternative. Among the four design alternatives, Alternatives 2 and 3 are the most similar, so the comparisons begin there.



200'

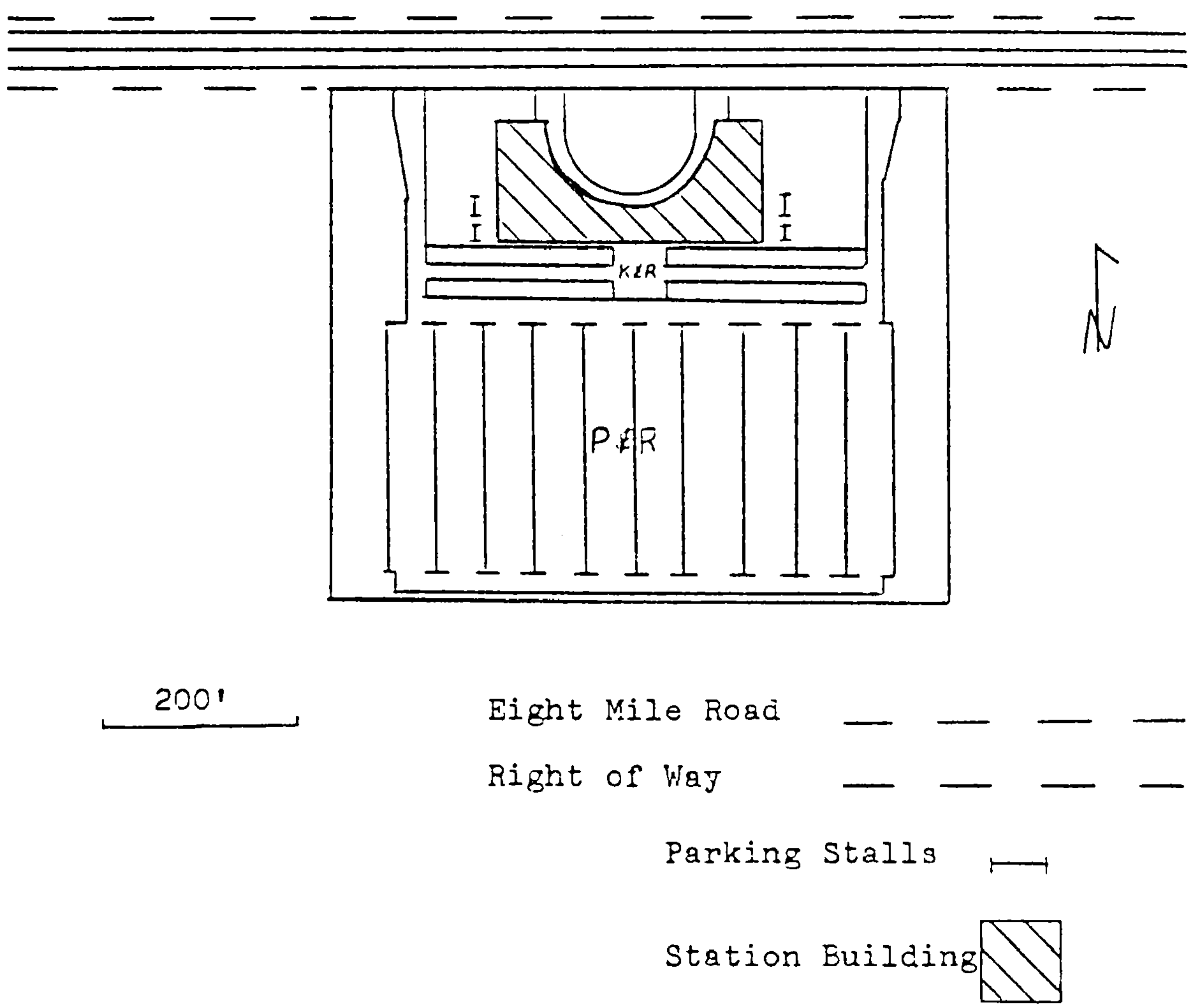
Eight Mile Road

Right of Way

Parking Stalls

K & R = Kiss-and-ride
P & R = Park-and-ride
9 ft. wide stalls
60^{o} parking

Figure 4.1 Alternative B1: Basic Lot



K & R = Kiss-and-ride
P & R = Park-and-ride
9 ft. wide stalls
60° parking

Figure 4.2 Alternative B4: Station Building

Table 4.2
Express Bus Station User Evaluation Matrix

Criteria Subsystem/Category: Measure	Performance Measures Alternatives 1	2	3	5
<u>Passenger Processing</u>				
Avg. travel time peak period characteristics (min).	3.1	3.1	3.1	3.3
Presence of design hazards (subj.)	2	2	2	3
Fare collection and boarding inconvenience (min.)	0.96	0.96	0.96	0.97
Parking area available (# spaces)	556	556	556	566
<u>Environmental</u>				
Thermal comfort (RWI)	0.56	0.56	0.56	0.53
(HDR)	23.6	21.4	21.4	13.1
Adequate lighting (ft.c.)	standard	standard	standard	standard
Finish materials (subj.)	3	3	3	3
Time exposed to weather (min.)	11.2	1.2	1.2	1.0
Non-intervisible spaces (#)	0	0	0	1
Visibility of lot from terminal (%)	100	100	100	30

Subjective categories:

Numerical Value	Quality
4	excellent
3	good
2	fair
1	poor
0	very poor

Table 4.3
Express Bus Station Special User Evaluation Matrix

Criteria Subsystem/category: Measure	Performance Measures Alternatives 1	2	3	5
<u>Passenger Processing</u>				
Avg. travel time (min.)	4.3	4.3	4.3	5.0
Presence of design hazards (subj.)	1	1	1	2
Fare collection inconvenience (min.)	0.96	0.96	0.96	0.97
Barriers (#)	2	2	3	4
<u>Environmental</u>				
Thermal comfort (RWI)	0.56	0.56	0.56	0.53
(HDR)	23.6	21.4	21.4	13.1
Adequate lighting (ft.c.)	standard	standard	standard	standard
Finish materials (subj.)	3	3	3	3
Time exposed to weather (min.)	12.4	2.4	2.4	2.0
Non-intervisible spaces (#)	0	0	0	1
Visibility of lot from terminal (%)	100	100	100	30

Subjective categories:

Value	Quality
4	excellent
3	good
2	fair
1	poor
0	very poor

Table 4.4
Express Bus Station Operator Evaluation Matrix

Criteria Subsystem/category: Measure	Performance Measures Alternatives 1	2	3	5
Passenger Processing				
Back-up facilities (present or not)	present	present	present	present
Station size (sq. ft.)	suitable	suitable	suitable	suitable
Environmental				
Attraction to robbery (subj.)	3	3	3	3
Outdoor lighting				
Outdoor lighting intensity (ft.c.)	2	2	2	2
Fiscal				
Main./Clean./Replace: Cost ($/yr.)	2,500	3,100	3,111	14,250
Operating cost ($/yr.)	470	470	470	15,120
Capital Cost ($)	462,150	472,150	480,150	595,850
Yearly capital cost, 8%, 20 yrs.	35,610	36,630	37,450	49,230
Total yearly cost	38,580	40,200	41,020	64,600

Subjective categories:

Numerical value	Quality
4	excellent
3	good
2	fair
1	poor
0	very poor

It can be seen that the evaluation measures for 2 and 3 are identical except for:

(a) number of special user barriers, and

(b) capital cost.

In this instance it is assumed that the decision-makers have determined that the benefits of having fewer special user barriers outweigh the additional capital cost ($8,000) so Alternative 3 has been judged superior to Alternative 2. Alternative 1 is the next alternative most similar to Alternative 3, so the next step was to compare these two.

The performance measures indicate that Alternative 1 is superior to 3 for the criteria:

(a) operator maintenance, cleaning, and replacement cost ($/yr.), and

(b) capital cost($).

On the other hand, Alternative 3 is superior to 1 for the criteria:

(a) user and special user thermal comfort (HDR, winter) and

(b) user and special user terminal area exposed.

The decision-makers have determined that the added comfort and lesser weather exposure of Alternative 3 make it superior to Alternative 1, despite the added cost of about $2,440 per year. The last comparison was between Alternatives 3 and 4.

Alternative 3 has the advantages of:

(a) fewer non-intervisible spaces for users and special users,

(b) better visibility of lot for users and special users,

(c) lower average travel time for users and special users,

(d) fewer barriers to special users,

(e) lower maintenance, cleaning, and replacement cost,

(f) lower operating cost, and

(g) lower capital cost.

On the other hand, Alternative 4 has the advantages of:

(a) fewer design hazards for users and special users, and

(b) better thermal comfort for users and special users in both summer and winter.

The decision-makers determined that Alternative 3 is superior to Alternative 4. Thus after the three comparisons it has been determined that the "best" design is Alternative 3.

Design Improvements

Alternative 3 was next tested for potential detail design improvements. Five aspects of the station were identified as warranting improvement.

(a) presence of design hazards,

(b) weather protection,

(c) special user travel time,

(d) special user barriers, and

(e) amenities.

The strategies tested for improving the chosen prototype design are given in Table 4.5. A comparison of the benefits and impacts of these strategies suggested that the following improvement strategies be implemented.

Table 4.5
Strategies for Improving Express Bus Station

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
I. Minimize design hazards to users and special users	A. Channelize pedestrian traffic across the two-lane, two-way vehicle lanes by roadway markings and signs	1. Reduce area of vehicle exposure to pedestrians 2. Make drivers more aware of pedestrians at crossing	1. Increase walk time 2. Increase capital cost 3. Increase maintenance cost
	B. Use texturized concrete on platform edges	Warn user of edge	1. Improve traction at edge during foul weather 2. Increase capital cost
II. Increase weather protection to users and special users	Provide canopy over platform	1. Increase protection from precipitation on platform 2. Decrease time exposed to weather	1. Increase safety from slipping 2. Change thermal comfort 3. Increase capital cost 4. Increase maintenance cost
III. Decrease travel time for special users	Provide parking for handicapped in kiss-and-ride area	Decrease special user walk time	1. Increase user kiss-and-ride walk time 2. Decrease kiss-and-ride parking available

Table 4.5 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
			3. Increase kiss-and-ride exposure to weather 4. Decrease special user exposure to weather
IV. Decrease barriers present to special users	Provide ramps to platform	Increase access-ibility to special users	Increase capital cost
V. Increase amenities	Provide public telephones	Increase telephone amenity	Dependent upon who pays installation cost

Improvement Strategies Selected

Design strategies were selected for implementation after comparing potential benefits with potential adverse effects. The following strategies were selected for implementation.

1. Channelize pedestrian traffic across the two-lane, two-way vehicle lanes by roadway markings and signs.

2. Use texturized concrete on platform edges.

3. Provide canopy over platform.

4. Provide parking for handicapped in kiss-and-ride area.

5. Provide public telephones.

The strategy to provide ramps to the platform was not selected.

DUAL MODE STATION

Dual mode transportation can be defined as that in which vehicles can operate in two manners: (1) manually controlled and self-propelled on ordinary roadways and (2) automatically controlled (and in some cases externally propelled) on special guideways. The dual mode system type to be used here was developed during the "Urban Mass Transportation Administration (UMTA) Dual Mode Transit System Development Program".

The dual mode station serves a travel corridor of Delta City, which has an SMSA population of 1,400,000. The CBD work force numbers 130,000. The major travel mode is the auto and the major transit mode used in the past has been the local bus.

The station is located on the fringe of the city limits, approximately four miles from the CBD, at a signalized intersection of a 6 lane arterial and a 4 land road.

The rectangular station site has an area of 13 acres (approximately 600' x 944'). The station site is bordered by a six-lane arterial commercial land use one one side, and industrial land use on the other two sides (see Figure 4.3). The site is relatively flat. The major objectives established for this dual mode line are:

1. To provide for a major portion of travel in the Dewey Turnpike Corridor.

2. To provide for safe traffic conditions around the station.

3. To minimize the cost of the station.

4. To enable people with handicaps to use the system.

5. To provide a pleasant environment in the station.

6. To include provisions for concessions and/or advertising in the station, if they are financially beneficial and to not detract greatly from aesthetics.

7. To minimize criminal activity in the station.

8. To minimize energy consumption in the corridor.

Criteria and performance measures for the dual mode stations are shown in Table 4.6.

The following policy has evolved for the dual mode stations in the system under consideration.

1. The stations will be in operation 24 hours per day, seven days per week.

2. Restrooms will be available for public use and at least one restroom will be available to station personnel.

3. First aid facilities will be provided.

4. Construction materials will be selected with consideration to safety (fire resistance, smoke generation, attachment and bond strength, friction for walking), durability (wear strength, weathering), ease of maintenance (cleaning, repair, replacement), and aesthetic qualities.

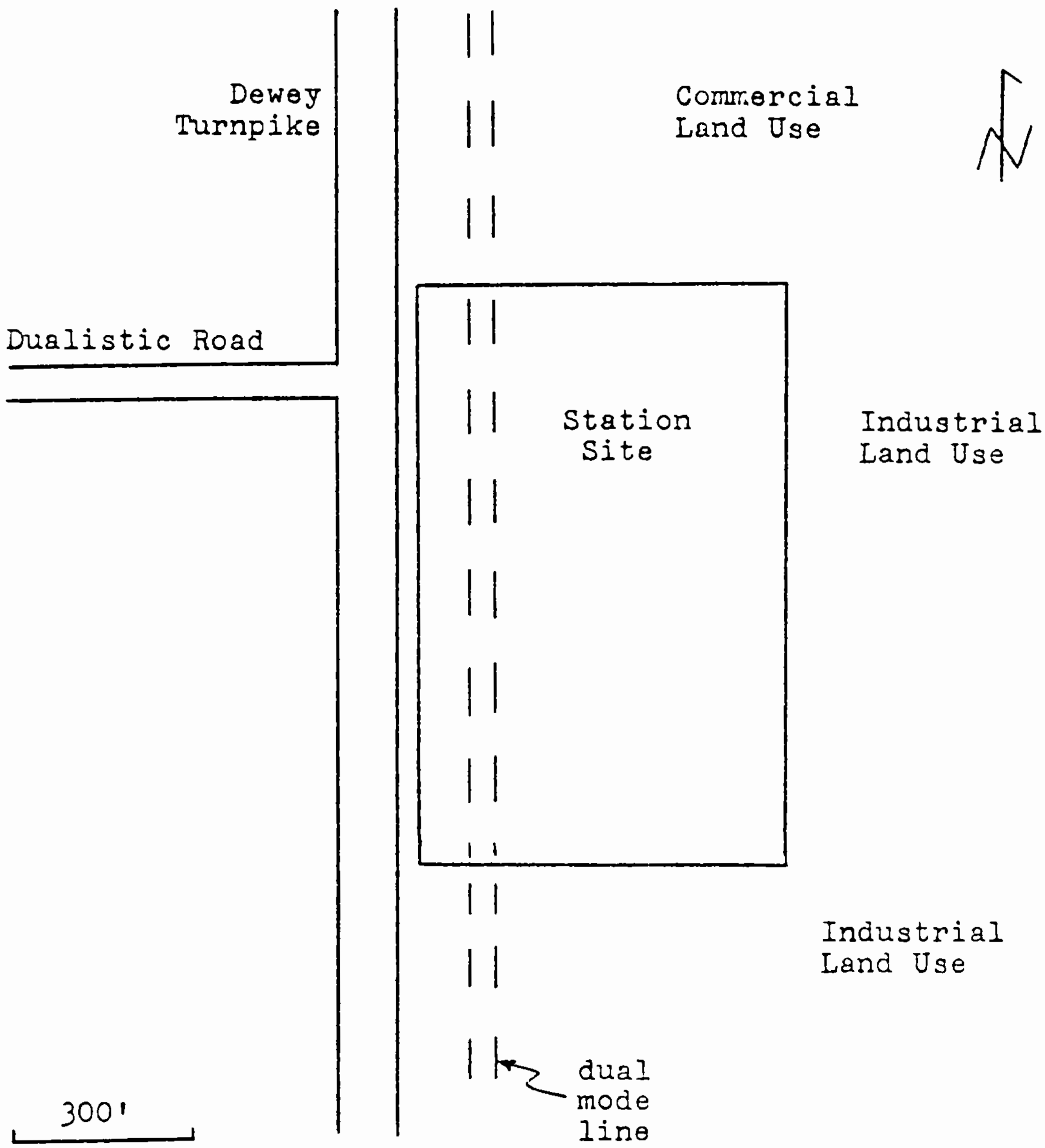


Figure 4.3 Dual Mode Station Site

Table 4.6
Dual Mode Station Objectives, Criteria and Performance Measures

Objectives	Criteria	Performance Measures
1. Minimize delays	Total delay time in queues	Aggregate waiting time
2. Minimize conflicts	Measures of crossing flows	Level of service
3. Maximize safety in and around station	Presence of design hazards in station Presence of hazards in surrounding traffic network	Hazards present
4. Maximize reliability	Back-up facilities in case of breakdown	Present or not present
5. Provide comfortable ambient environment	Thermal comfort	Relative comfort Index
6. Ensure an aesthetically pleasant environment	Provisions for art displays, graphics, and visual features	Location and type
7. Provide supplementary services	Advertising Concessions	Type, size, location Type, size, location
8. Provide adequate security	Number of separate spaces	Number
9. Eliminate level changes	Level changes	Number and type
10. Reduce barriers	Difficulty encountered	Width and type of device
11. Provide informational guides	Availability of directional information	Type and location
12. Efficiently control entry	Technology used	Ability to keep non-payers out
13. Efficiently process flows	Travel time required	Individual's time required
14. Provide proper security for fares paid	Attraction to robbery or vandalism	Type of collection
15. Use energy efficiently	Total and incremental energy requirements	Kilowatt hours
16. Minimize total cost	Cost	Dollars/yr.
17. Provide opportunity for expansion	Expansion potential	Expansion space available without major redesign

5. Public telephones will be provided in a number suitable for the expected number of station patrons.

6. Access mode accomodations will be made for all anticipated modes of access.

7. Adequate lighting will be provided in all areas of the station site.

8. Strong efforts will be made to make the use of the station by the elderly and handicapped no less convenient than for others.

9. Because of the nature of the dual-mode system (especially its operation on streets as well as on guideways) no advertising will be displayed on vehicles or in station.

10. Because of potential cleaning and maintenance problems, no food or drink will be sold in station.

The approach used in the design and evaluation of this station has been termed the "sufficient design" approach (1). This is an iterative process in which a basic design is created and evaluated relative to established criteria. It is then incrementally modified until all objectives have been satisfactorily met.

The basic design which is used as the starting point is one that was developed in "Station/Mode Interchange Design and Parametric Study: Dual Mode Transit System" (12) by the General Motors Transportation System Division. The layout of this design is shown in Figures 4.4, 4.5, 4.6 and 4.7.

The basic design is used on the lot as shown in Figure 4.8. The parking aisles shown allow for 1044 parking spaces, including 84 outdoor spaces for kiss-and-ride patrons. This basic design is evaluated to determine its performance relative to the stated criteria.

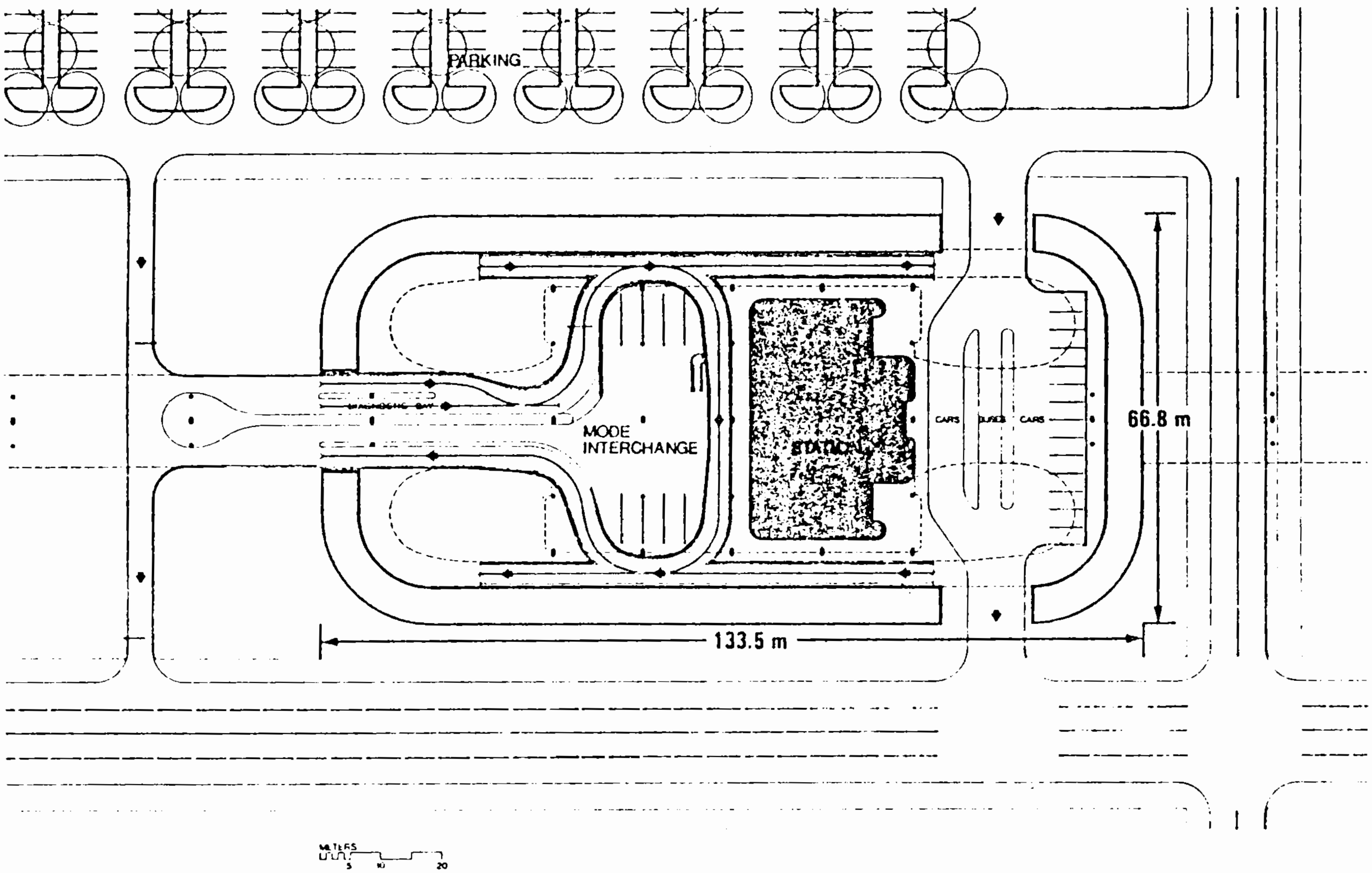


Figure 4.4 3-Bay Corridor Site Plan (Source: Reference 21)

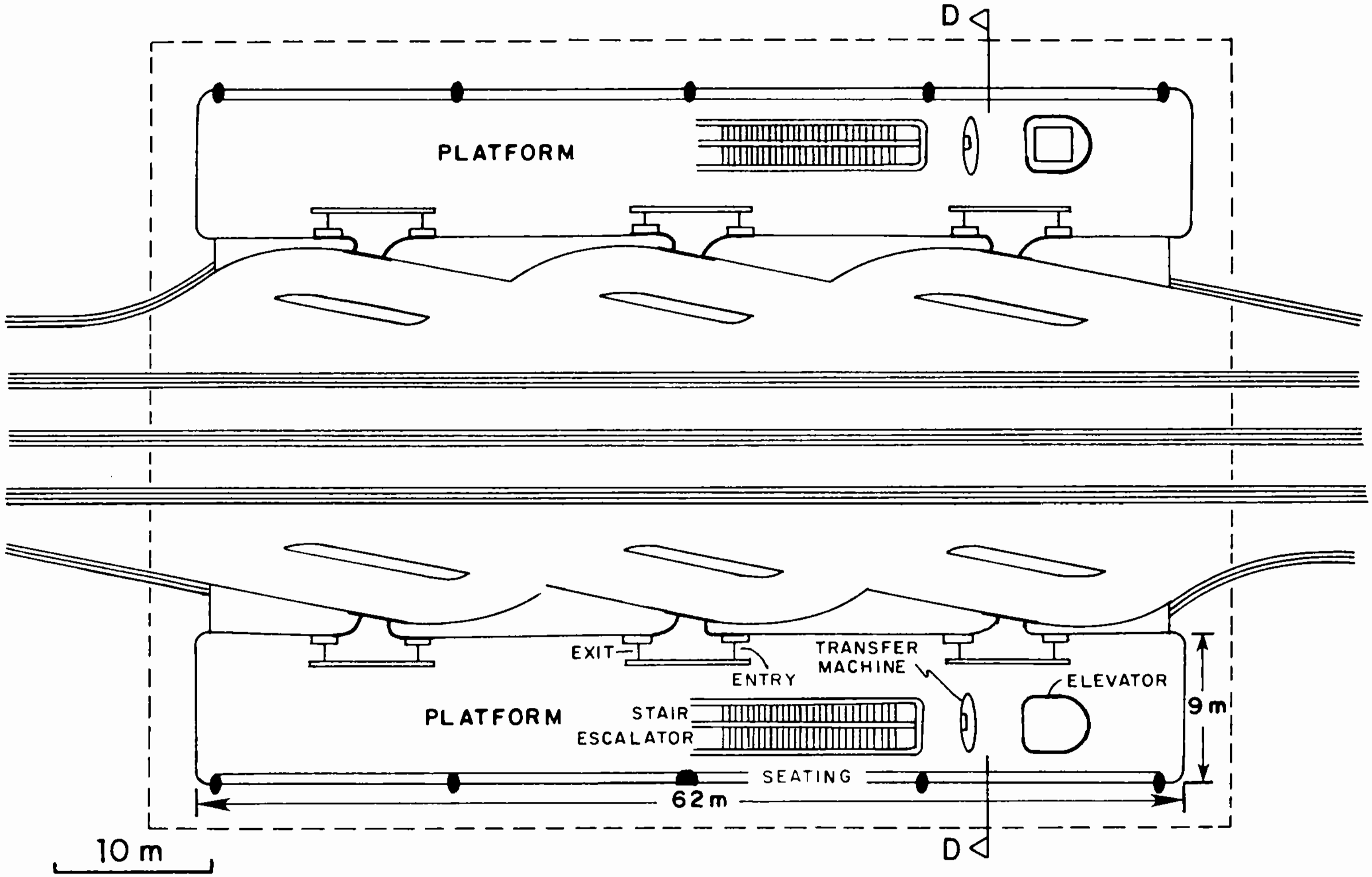


Figure 4.5 Upper Level: 3-Bay Corridor Station (Source: Reference 21)

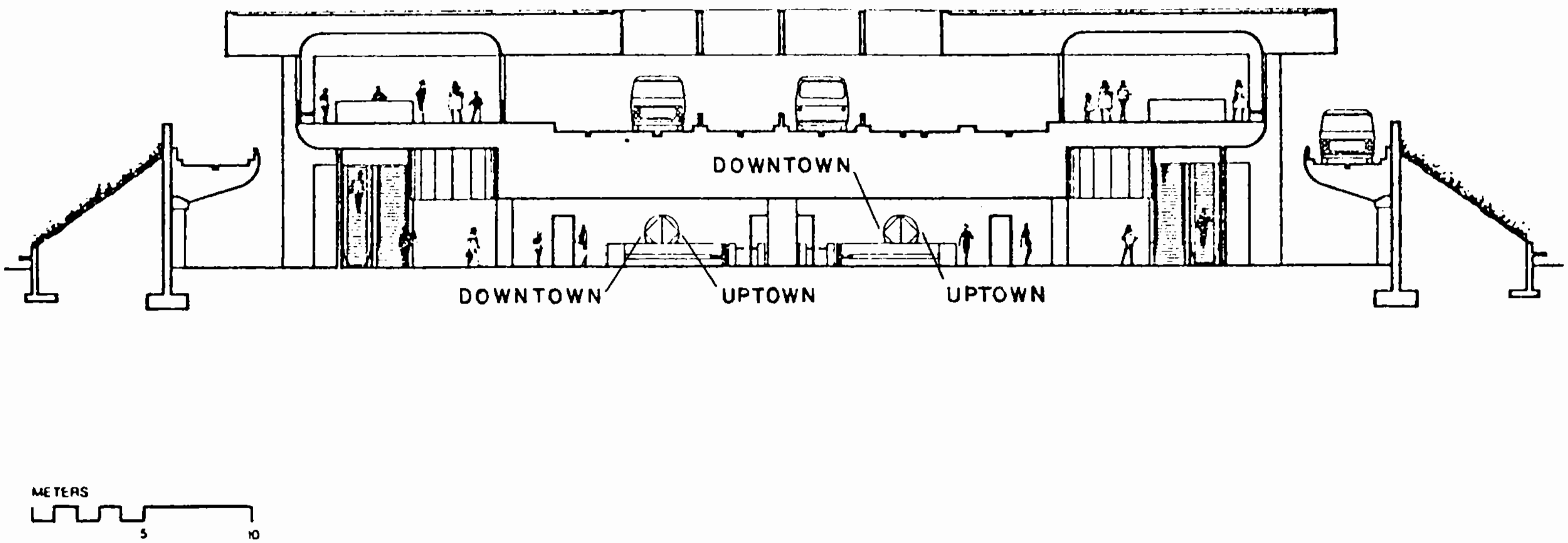


Figure 4.6 Cross Section View of 3-Bay Corridor Station
(Source: Reference 21)

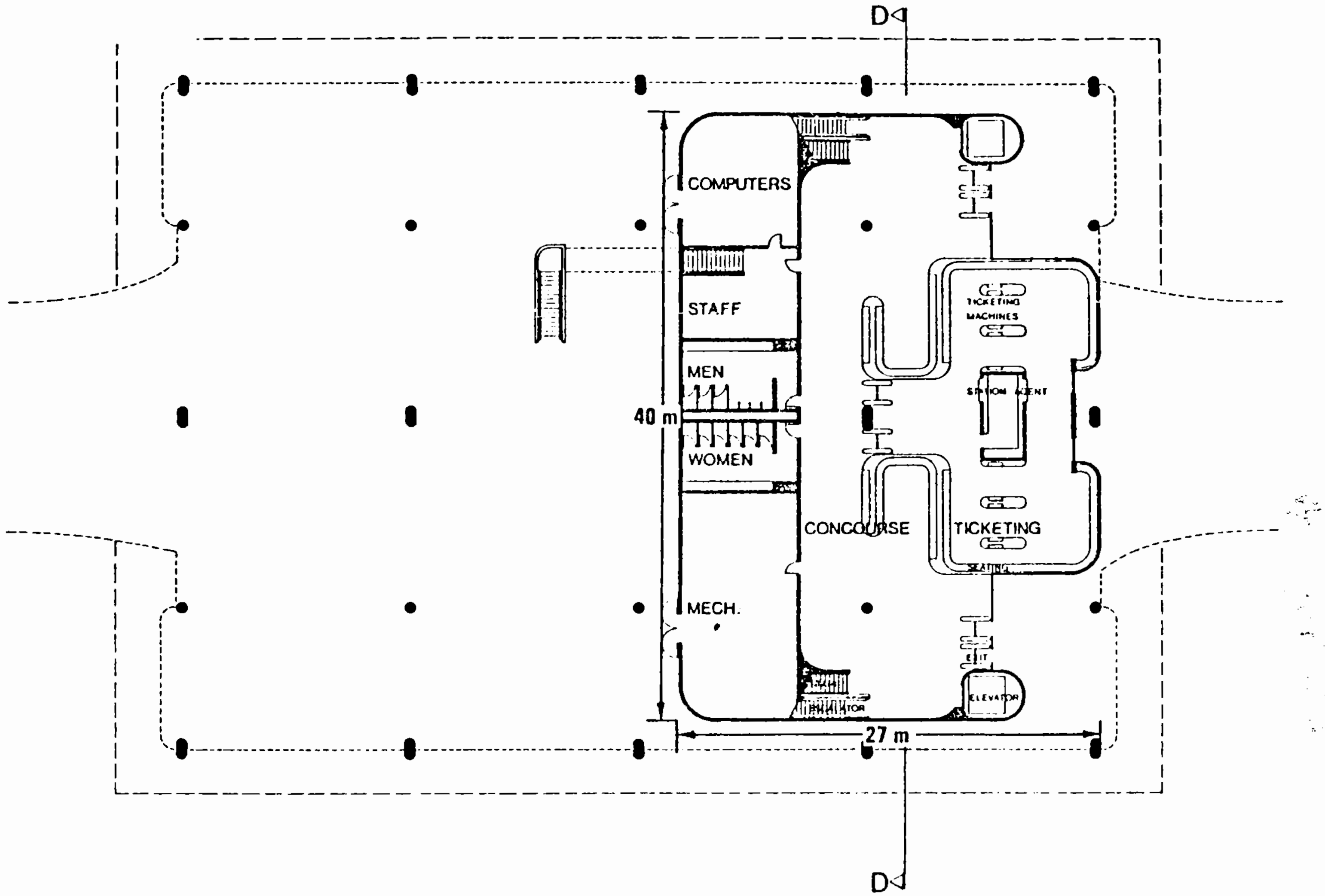


Figure 4.7 Lower Level: 3-Bay Corridor Station (Source: Reference 21)

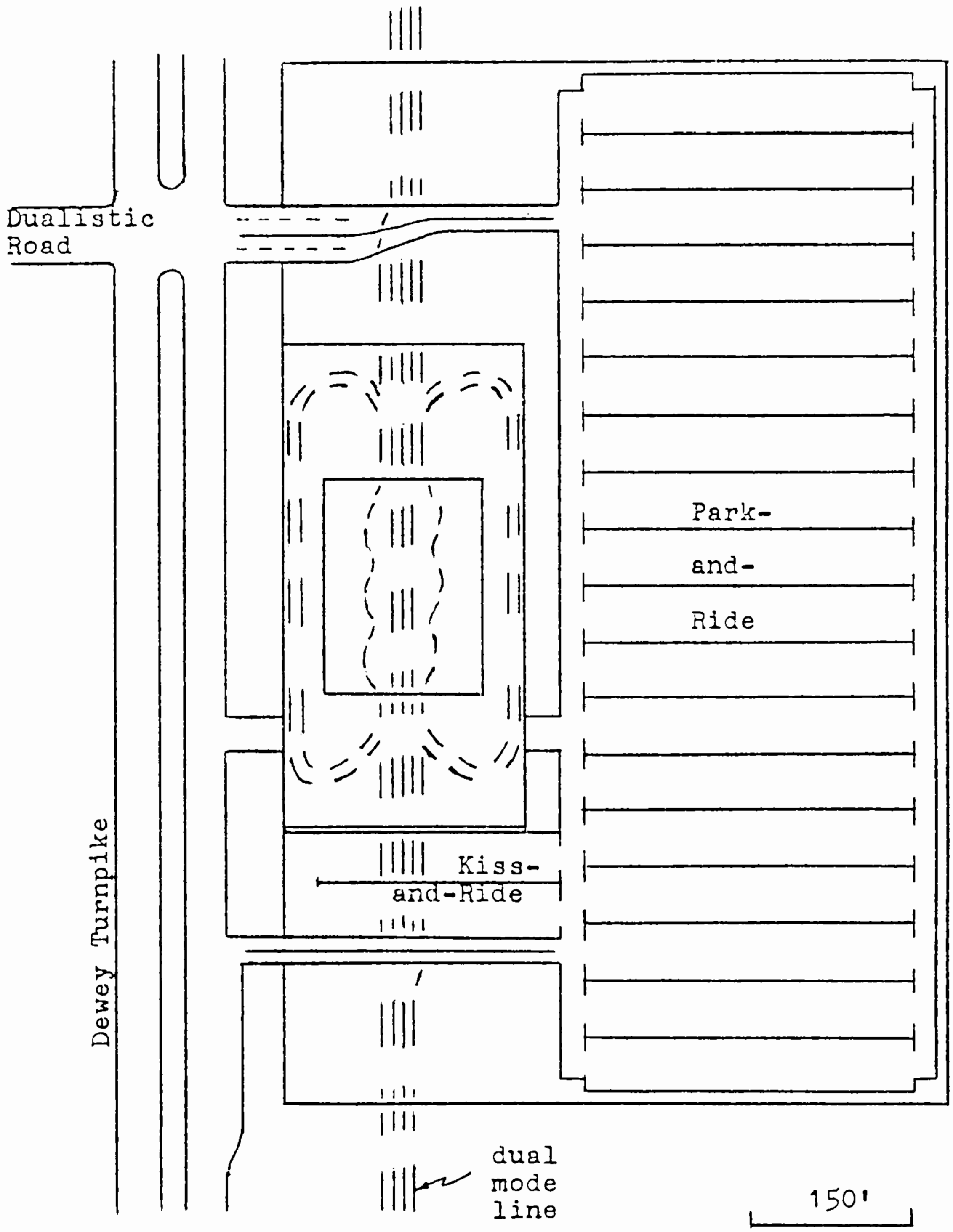


Figure 4.8 Dual Mode Station Site Plan

EVALUATION I

The performance of the basic design relative to the stated criteria was measured. To show which characteristics of the station are acceptable and which should be modified.

This evaluation pointed to several station characteristics for further investigation (see Tables 4.7, 4.8 and 4.9). Possible objectives of this investigation include:

1. To decrease the average waiting time, especially at trip request machines.
2. To improve the performance of back-up facilities.
3. To improve thermal comfort standards.
4. To provide for display of art and crafts of local talent.
5. To improve supplementary services (e.g., provision of telephones, etc.).
6. To increase station security.
7. To provide an effective informational guide system.
8. To reduce total cost (e.g., by reducing floor area, etc.).

DESIGN IMPROVEMENTS

The "sufficient design" that is employed in this example is an iterative process in which a basic design is proposed and then evaluated relative to established criteria. The basic design is then modified until all objectives have been satisfactorily met. In the previous sections the proposed dual mode station design was evaluated and shortcomings in performance were pointed out.

In the text below some strategies to improve upon station performance are identified. The direct and indirect effects of each strategy

Table 4.7
Dual Mode Station User Performance

Criteria (units)	Performance Measure
<u>Passenger Processing</u>	
Average waiting time (min.)	1.70
Volumes at flow conflicts (Level of Service)	A, A
Hazards present (subj.)	3
Back-up facilities (subj.)	2
<u>Environmental</u>	
Thermal Comfort (RWI, subj.)	2
(HDR, subj.)	2
Aesthetics (location, subj.)	0
(type, subj.)	0
Supplementary services (subj.)	2
Separate spaces (#)	6

Subjective Rating Scale:

4 = excellent
3 = good
2 = fair
1 = poor
0 = very poor

Table 4.8
Dual Mode Station Special User Performance

Criteria (units)	Performance Measure
Passenger Processing	
Average total waiting time (min.)	2.20
Volumes at flow conflicts (Level of Service)	A, A
Hazards present (subj.)	3
Back-up facilities (subj.)	1
Level changes (#)	1
Barriers (subj.)	3
Informational guides (subj.)	1
Environmental	
Thermal Comfort (RWI, subj.)	2
(HDR, subj.)	2
Aesthetics (location, subj.)	0
(type, subj.)	0
Supplementary services (subj.)	2
Separate spaces (#)	8

Subjective Rating Scale:

4 = excellent
3 = good
2 = fair
1 = poor
0 = very poor

Table 4.9
Dual Mode Station Operator Performance

Criteria (units)	Performance Measure
<u>Passenger Processing</u>	
Entry control (subj.)	3
Individual travel time (min.)	3.17
<u>Environmental</u>	
Security of fares paid (subj.)	3
<u>Fiscal</u>	
Energy efficiency (KWH/yr.)	932,667
Total cost ($/yr.)	$401,300
Expansion potential (meters^2, subj.)	3

Subjective Rating Scale:

4 = excellent
3 = good
2 = fair
1 = poor
0 = very poor

were measured and decisions made regarding includiong of these strategies within the basic design.

The following strategies were proposed for improving station performance.

1. Provide additional trip request machines.
2. Provide an additional platform entry gate.
3. Provide an additional transfer machine on each platform.
4. Provide an additional elevator for each platform.
5. Provide for display of arts and crafts of local talent in U-shaped areas between ticketing machines and the middle of the concourse.
6. Provide public telephones along the concourse.
7. Use transparent walls on elevators.
8. Provide security cameras with console in station agent's booth.
9. Provide a guide system for the sensory impaired.
10. Reduce building floor area required.
11. Provide a more realistic standard for thermal comfort in warm weather.
12. Provide a more realistic standard for thermal comfort in cold weather.

These strategies, along with their anticipated direct and indirect effects, are summarized in Table 4.10.

Improvement Strategies Selected

After the direct and indirect effects of each strategy were considered, the following strategies were selected for use.

1. Provide two additional trip request machines.

Table 4.10
Strategies for Improving Dual Mode Station

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
I. Reduce average waiting time for users and	Provide additional trip request machines	Reduce average waiting time for trip request	1. Increase system reliability for users and special users 2. Improve processing of flows for operator 3. Increase total cost
II. Improve system reliability for users and special users	A. Provide an additional platform entry gate	Improve system reliability for those using exit gates	1. Reduce average waiting time at entry gates 2. Improve processing of flows for operator 3. Increase total cost
	B. Provide an additional transfer machine on each platform	Improve system reliability for transferring patrons	1. Reduce average waiting time for transfers 2. Improve processing of flows for operator 3. Increase total cost

Table 4.10 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
	C. Provide an additional elevator for each platform	Improve system reliability for special users	1. Reduce average waiting time for those using elevators 2. Improve processing of flows for operator 3. Increase total cost
III. Improve upon station aesthetics	Provide for display of arts and crafts of local talent in U-shaped areas between ticketing machines and middle of concourse	Improve interior aesthetics	1. Worsen processing of flows 2. Increase total cost
IV. Improve upon supplementary services	Provide public telephones along concourse	Improve communication amenity	1. Worsen processing of flows 2. Increase total cost
V. Improve station security	A. Use transparent walls for elevators	Reduce number of separate, non-intervisible spaces	1. Decrease disorientation of special users 2. Increase total cost 3. Increase system reliability

Table 4.10 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
	B. Provide security cameras with console in station agent's booth	Increase surveillance of passengers in terminals	1. Increase safety 2. Increase total cost
VI. Improve directional information for the	Provide a guide system for the sensory impaired	Increase accessibility of station for the sensory impaired	1. Minimize flow conflicts for the sensory impaired 2. Reduce barriers to use for sensory impaired 3. Increase total cost
VII. Reduce total cost	A. Reduce building floor area required	Reduce total cost	1. Increase movement path conflicts 2. Reduce safety inside station 3. Increase operational barriers to special users 4. Reduce level of service in flow processing 5. Reduce energy use 6. Increase possible need for expansion

Table 4.10 (continued)

Objectives	Strategies	Expected Direct Effects	Expected Indirect Effects
	B. Provide a more realistic standard for thermal comfort in warm weather	Reduce total cost	1. Reduce thermal comfort in warm weather 2. Reduce energy use
	C. Provide a more realistic standard for thermal comfort in cold weather	Reduce total cost	1. Reduce thermal comfort in cold weather 2. Reduce energy use

2. Provide an additional platform entry gate.

3. Provide for display of arts and crafts of local talent in the U-shapre areas between the ticketing machines and the middle of the concourse.

4. Provide public telephones along concourse.

5. Use transparent walls for elevators.

6. Provide security cameras with console in the station agent's booth.

7. Provide a more realistic standard for thermal comfort in warm weather.

8. Provide a more realistic standard for thermal comfort in cold weather.

CHAPTER 5

CONCLUSIONS

The case study applications of the transit station design methodology that are described in this report provide a broad range of station design problems in view of technology, demand volumes and urban location. Under such circumstances it is difficult to justify conclusions regarding specific design practices such as all stations should permit advertisements or a certain type of security plan is best suited to all transit stations.

These applications of the transit station design methodology did show how the procedural method can be used to select and improve upon a station design that derives from stated design objectives. Technically, many subjective decisions are required even with the formalized method and, thus, objectivity must be stressed in terms of procedure rather than practice.

Examples of the inherent subjectivity within the methodology begin with the development of design criteria. Alternatives are selected from a somewhat predetermined range of design concepts and the ways of simultaneously or sequentially considering specific design parameters are unlimited. In this methodology two levels of alternative evaluation are recommended, the first or preliminary evaluation of design concepts and a second stage of detailed design where parameters of a selected design concept are altered to meet the stated objectives. The analyst has the option to reflect many factors at either level; for example, advertising and concessions were established by policy and considered in Evaluation I for the Central Area Bus terminal, while these elements were considered for their appropriateness during the Evaluation II phase for the rail rapid transit station.

The subjective ratings used to measure the attainment of many design objectives required judgmental decisions. The particular design factors that presently lack strong analytical measures include:

a) directional information,

b) hazards present,

c) personal comfort,

d) supplementary services,

e) movement barriers,

f) entry control,

g) security of fares paid, and

h) joint development potential.

For each case, statements were provided to justify the resulting ratings. The selection of the best design was a subjective decision based upon performance and cost analyses. The review of policy was based on similar analyses. Finally, decisions were necessary for selecting station characteristics needing improvement, selecting proper tactics for improvement, and the evaluation of these tactics.

The variations in adopting the methodology to specific design situations were accounted for by the degree of flexibility in station policy, the criteria selected in the evaluation, the type of inventory data available or required, the level of detail required in the design, and the number of interest groups involved. The process is similar when applied to different transit modes, varieties of travel demands and land use arrangements.

Finally, the methodology can be applied to either unique design problems or standardized system-wide station configurations. Unique station design problems utilize the methodology to consider station site, demand, acces and component concerns whereas standardized station problems would apply the methodology for system-wide design issues.

VARIATIONS AMONG DESIGN ALTERNATIVES

Of the fourty-four performance measures used for the rail rapid transit station, only 15 differed between the alternative designs. These differences provided the bases for selecting the best design.

For users and special users variation was present in travel time, number of level changes, potential for concessions, and number of separate spaces. For the operator only cost and joint development potential differed. The performance measures that did not vary between designs are listed in Table 5.1.

While the concurrent format used for design and analysis may have contributed to this uniformity, the results appear to indicate that many criteria can be replaced by "minimum desirable standards" with little impact on the quality of design or the evaluation of designs.

PERFORMANCE AND COST RELATIONSHIPS

The methodology did not explicitly point out relationships between performance and cost. For each alternative design performance and cost were estimated at different times. Only in the analysis of tactics to improve upon station performance did direct relationships between changes in performance and changes in cost become evident.

Table 5.1
Performance Measures Unvaried Between Designs

Level of Service in queues
Directional information (location and type)
Hazards present
Types of level change in aids
Thermal comfort
Illumination
Personal comfort
Advertising provisions
Movement barriers
Entry control
Security of fares paid
Non-transport income
Compatability of use for joint development

POLICY DEVELOPMENT AND EVALUATION

In the subway station design problem few station characteristics were mandated by policy and the evaluation of designs did not indicate any needed policy changes. As discussed earlier, several station characteristics could have been required through policy statements without changing the nature or the results of the evaluation process. If any needed changes in policy (and therefore design) had been pointed out, the changes could have been proposed and tested in the design improvement stage.

INFORMATION FROM EVALUATION

In the detailed design stage, most of the components of station design were selected and evaluated concurrently. While this format was not specifically called for by the methodology, it is a logical way to expedite the design/evaluation process. Information from the evaluation thus aided the design process. Information from the evaluation process also provided the basis for proposing tactics to improve upon the station design.

IMPROVEMENT NEEDS

The application of the methodology to the example station design problems pointed out some areas where the methodology may be improved. If some of the criteria used for evaluation were replaced by "minimum desirable standards," the design and evaluation process could be simplified. However, the performance of the components (e.g., lighting, thermal comfort, and entry control devices) would have to be independent of station design to ensure that there would not be different interactions of the components for different station designs. For instance, one design might be more complementary to certain concession area layouts that another.

The decision as to whether to include certain station components might be made easier by providing more information about the relationships between performance and cost. Interactions would again need to be considered.

These interactions could be considered more easily if the methodology aided the designer in determining these relationships. In this way the design could be guided to a proper combination of system components.

Any changes in the methodology would have to account for the same types of large and small decisions that are presently required. It would also be desirable to retain the ability to refine policy after the evaluation has been carried out and to use the information from the evaluation to improve upon station design.

DESIGN GUIDELINES

The earlier stated findings and conclusions support the importance of the transit design methodology as a format for organizing station design variables and performance data to efficiently develop transit station designs that meet the governing objectives. The examples show a step by step method for developing information to make decisions; they do not tell how to make such decisions. The final choice is left to the political process.

The experience with the example applications support the following statements regarding the performance of the transit station design methodology.

1. If the station design is developed within the formal process, the least cost alternative will usually prevail. This is so because the methodology directs the planner to propose only those alternatives that satisfy the important planning and design objectives.

2. If a specific policy is not varied during Evaluation I, there will be no basis to invalidate it later.

3. After a certain design concept is selected for a particular station the following items will generally be considered for improvements.

    1. Level change capacity
    2. Improved security
    3. Improved aids to special users
    4. Transparent elevator walls, and
    5. Amenities.

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APPENDIX

DEFINITIONS

These are the meanings of some terms as they are used in this report.

access modes--means of transportation used to reach a transit station

air rights--property rights, which can be sold or leased, to develop (build) in the space above one's property

arrival rate--in queueing, the rate at which customers arrive to be served by the queueing device

CBD--central business district

criteria--indicator of the degree to which an objective is attained

direct effects--the impacts of attempting to satisfy an objective upon the attainment of that objective

dual mode--specifically, a mode in which vehicles can operate in two manners: (1) manually controlled and self-propelled on ordinary streets and (2) automatically controlled (and in some cases externally propelled) on special guideways

egress modes--means of transportation used to leave a transit station

environmental criteria--criteria relating to the surroundings of a passenger in a station

express bus--a bus operating in the express mode, i.e. with high speeds and few stops

goal--an idealized end state of the environment

indirect effects--the impacts of attempting to satisfy an objective upon the attainment of other objectives

interactions--a description of indirect effects

joint development--coordinated planning and development of transportation facilities and changes in land use over, under, or in the immediate vicinity of the facilities kiss-and-ride--an access mode in which the auto passenger is driven to a station by someone who is not using the station

lever of service--generally, the service provided under various operating conditions; specifically, pedestrian level of service describes the east of pedestrian movement and associated comfort

mode--a means of transportation

objective--an apparently attainable out-growth of a goal, stated so that the extent of attainment can be measured

operator--the person, group, or agency responsible for the design and operation of a station

paid area--that area of a station that a person must pay a fare to enter

park-and-ride--an access mode in which a person drives or rides to a station in an automobile, leaving the vehicle at the station until returning

passenger processing criteria--criteria relating to the movement of people in a station

performance measure--a measure of performance relative to a criterion

personal rapid transit--highly personalized transit, usually with relatively small vehicles on fixed guideways

Poisson distribution--a discrete distribution used in probability situations

prototype--an example (e.g., prototype station)

queue--a waiting line

safety--freedom from accidental injury

security--freedom from deliberate injury or loss inflicted by another

separete, non-intervisible space--an area, separate from others, which cannot be viewed from other areas

service channel--the process of system which is performing the service to the customer, it may be single or multichannel service rate--the rate at which the service channel can provide customer service

SMSA--standard metropolitan statistical area

special user--any user who has special mobility problems, especially the elderly and the handicapped

standard--a fixed criterion

strategy--a method used to achieve an objective

trade-off analysis--a method whereby alternatives are compared to find where they perform the same and where one performs better than another, in order to find a dominance of one alternative over another

transportation interface facility--a facility where travelers change modes of transportation (e.g., a transit station, an intercity train station, etc.)

user--a person who uses a transit system

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