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16. Abstract

This report describes the proceedings of a National Conference on the Planning and Development of Public Transportation Terminals held in Silver Spring, Maryland on September 21-24, 1980. The conference included both formal papers presented to plenary sessions and small group workshops focused on particular design issues of current importance.

Formal papers covered all aspects of transit station planning and design, with special attention to passengers, access and traffic, and operations and maintenance. Recent experiences in transit station design and renovation were reviewed, including intermodal terminals, from both domestic and international perspectives. Particular systems described in detail included WMATA, BART, MARTA, and New York. An overview of the Methodology for Transit Station Design was also presented.

Workshops dealt with nine topic areas: Transit Station Design Methodology; Intermodal Terminal Planning, Design and Operations; Passenger Processing and Information Systems; Station Access and Traffic; Station Maintenance and Operations; Transit Station Security; Design for the Handicapped; Joint Development, Land Use and Station Impacts; Computer Methods and Transit Station Simulation.

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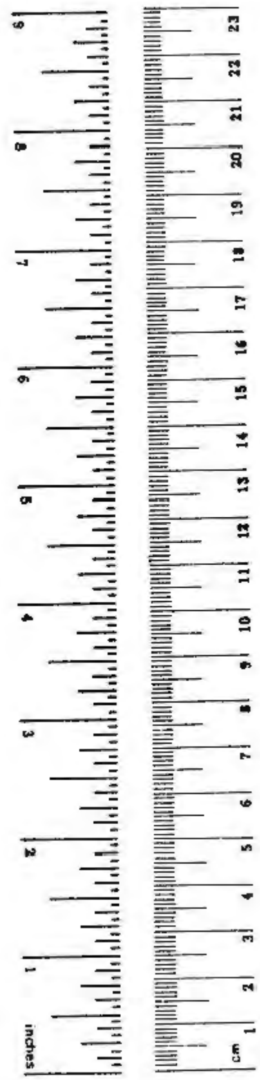
METRIC CONVERSION FACTORS

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
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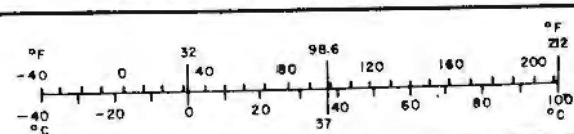
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Many people and organizations were involved in the success of the conference. The conference was organized with the cooperation of the Transportation Research Board (TRB) and the American Public Transit Association (APTA). We would like to acknowledge the role of TRB Committee A1E03 in the planning, development and conduct of the conference. The Conference Planning Committee consisted of John J. Fruin (Chairman), Colin H. Alter, David J. Andrus, Jr., John P. Braaksma, S. Lee Carlson, William J. Hayduk, Barry Kaas, Hanan A. Kivett, Walter H. Kraft, Jerome C. Lutin, W. R. McCuthen, John P. O'Connor, Robert A. Olmsted, Wilfred Sergeant, Gregory Benz, Frank J. Cihak (representing APTA), Michael J. Demetsky, W. Campbell Graeub (representing TRB), Lester A. Hoel, John A. Levy, Norman G. Paulhus, Jr., Larry G. Richards, and Peter Strobach.

Special thanks are extended to Jack Fruin and Walter Kraft, the past and present chairmen of the TRB Committee on Intermodal Transfer Facilities, for their many activities and contributions to this conference. W. Campbell Graeub provided mailing lists of possible conference participants, reviewed our conference plans, promotional material, and hotel arrangements, and made many helpful suggestions. Colin Alter recommended possible meeting sites in the Washington area and helped us make final hotel arrangements.

Lillian C. Liburdi, Deputy Administrator of the Urban Mass Transportation Administration, delivered the keynote address at the conference. We thank her for her enlightening and provocative talk, and for her interest and participation in the conference.

Cody Pfanstiel, the Director of Public Relations at WMATA, arranged and conducted a tour of the Washington Metro for conference participants. We thank him for a most valuable tour. He was assisted by Mr. Fountroy and

Colin Alter. The tour covered all aspects of Metro's operation, and participants found it extremely worthwhile.

The production of the Conference Proceedings was carried out by the Publications Group of the Research Laboratories for the Engineering Sciences (RLES) at the University of Virginia. We particularly wish to thank Jackie Harding, who patiently typed the entire manuscript and endured our many revisions, and Sandra Sullivan, Supervisor of the Publications Group.

Finally, we wish to acknowledge the many contributions of Dr. Meredith M. Richards and Mr. Douglas McCants to the smooth functioning of the conference and production of this proceedings.

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INTRODUCTORY REMARKS

Lester A. Hoel
Department of Civil Engineering
University of Virginia

This conference is the culmination of a 5-year research project funded by the U. S. Department of Transportation, Program of University Research, to develop a methodology for the design of urban transportation interface facilities.

Although the public's acceptance of transportation systems is heavily dependent upon the performance of modal interchange facilities, yet specific attention has been lacking largely because the terminal is intermodal in nature, relies on pedestrian movement and requires the integration of many systems. For the most part, methods and procedures for planning and designing transportation terminal facilities have been based primarily on "rule of thumb" techniques with little application of systems analytic approaches. The intent of our research has heen to develop a comprehensive definition of the components of a transit station, to recommend criteria for evaluating alternative transit station designs and to develop a systematic methodology for providing measures to evaluate alternative interchange facility designs.

The design and operation of passenger terminals has proceeded along three fronts. First, the practitioner has been involved with terminal problems from the viewpoint of specific and immediate design and operational situations; second, the researcher has been concerned with developing better tools and techniques for evaluating alternative designs and understanding user perceptions of the station environment; and third, state, local and federal officials are responsible for final decisions concerning implementation.

In recent years a significant amount of work has been completed in the planning, designing, constructing, operating and renovating of passenger terminals, both for bus and rail serving urban and intercity travel. Furthermore, other research, with DOT support, has been completed to develop, test and simulate rational and systematic procedures for evaluating terminal designs.

Thus, this conference is intended to bring together researchers, practitioners and public officials to share the results of these experiences and to make these results available in a format useable for others. The conference is intended to be a "state of the practice" of passenger terminals and as such to advance knowledge in this important area of transportation.

The purpose of the conference is to provide an opportunity to validate the results of our research on passenger terminals and to serve a technical and informational function by bringing together individuals involved in terminal planning. The conference will be a forum to discuss recent work, to become familiar with the state of the art and to benefit from recent developments in design practice and research. It should also furnish a means for practitioners to participate in discussions and workshops and produce recommended directions for future research and development needs in this area.

The conference format and topics are the result of work by the Conference Planning Committee, headed by Dr. Jack Fruin. Each member participated in discussions and furnished many suggestions for the program. Planning for this conference was also aided by the generous cooperation of the TRB and APTA.

The formal paper sessions will present overviews of critical station elements, recent experiences with design and renovation of transit terminals, Canadian and international perspectives, bus terminals and intermodal stations for intercity service.

The workshop sessions will furnish participants with the opportunity to discuss in detail major concerns of terminal planning. The results of the workshops will be presented in a plenary session at the close of the meeting. The workshop sessions will deal with topics of design methodology; computer methods and simulation; intermodal planning, design and operations; passenger processing and information systems; station access and traffic; maintenance and operations; land use, joint development, and station impacts; design for the disabled; and station security.

WELCOMING REMARKS

Dr. Sherwood C. Chu
Program of University Research
U. S. DOT

I am happy to-be here on behalf of the Program of University Research to welcome you to the National Conference on the Planning and Development of Public Transportation Terminals. When we first funded the University of Virginia in 1976 to have Dr. Lester A. Hoel and his team study the design of urban transportation interface facilities, this conference was just one idea among several ways to disseminate research findings to the user community. Dr. Hoel has taken that idea, nurtured it through three years of extremely productive research, and developed it into an outstanding conference for individuals involved in all phases of the station design process. I would also like to commend Dr. Hoel's colleagues, Dr. Michael Demetsky and Dr. Larry Richards for their contributions to the research and to the planning of this conference.

One of the values of conducting research is that you get to know the other scientists, engineers and practitioners in the field. Once this conference is over, I think you will agree with me that the professionals who Dr. Hoel has assembled here today are real experts in their respective fields. This can be said of the participants as well as the session chairman and speakers. I hope each of you will take advantage of this marvelous opportunity to interact with the other participants. In planning this conference, Dr. Hoel wisely allowed time for informal discussions as well as formal discussion. This could easily be one of the most successful conferences in the history of the Program of University Research.

We have been very fortunate over the years of the University Research Program's existance to have sponsored many outstanding transportation conferences. The Program has covered practically every transportation subject from rural transportation policy to international pipeline studies. Our main product is not conferences; however, the Program of University Research is designed to assure that resources of the higher education community are effectively brought to bear on transportation problems. The Program began in September 1972 and has funded some 300 projects over the past eight years. U. S. universities and colleges submit proposals annually on November 1. The Program funds about fifteen percent of the proposals which are received. This tough competition assures very high quality research results which address serious transportation problems and issues.

We have had an abundance of remarkable results in diverse areas such as economic regulation, automotive technology, tunneling techniques, system safety, and service planning for the elderly. The Program disseminates several thousand research reports each year to State and local governments, industry, and transportation practitioners. If anyone here desires to be placed on the mailing list to receive reports in one or more subject areas, please write the Office of University Research for the brochure covering all our current mailing lists. We appreciate your interest.

Again let me welcome you to the conference. With the work Dr. Hoel, Dr. Demetsky and Dr. Richards have put into these sessions, you are assured of a stimulating set of exchanges on the planning and development of public transportation terminals. The Program of University Research is proud to be a sponsor of this effort.

CONFERENCE SUMMARY

Lester A. Hoel and Larry G. Richards
Department of Civil Engineering
University of Virginia

INTRODUCTION

Planning and design of intermodal transit facilities is an area of significant concern in the development of a regional metropolitan rapid transit system. The fundamental purpose of a transit station is to transfer passengers between modes within a transportation network. Whether a station design is successful in accomplishing this purpose, smoothly and continuously in a pleasant environment, will strongly influence the degree to which the system is accepted by the riding public. A poorly designed station can reduce the advantages of the line-haul rapid transit portion of the trip if the perceived impedances within the station are sufficiently great that they outweigh the gains of the between-station portions of the trip.

Terminal planning and design is especially critical for metro rapid transit since between-station travel times cannot be easily reduced due to the relatively short distances between stations. Thus the relative effect of access and transfer at a station is significant and can influence the share of the market attracted to the new system. The simplest transfer is one in which there is no waiting time and the walk between modes is short and direct, for example, from one train to another across a platform, or from one bus stop to another. The situation is more complex for large multilevel stations, with several modes, automobile parking, and fare collection barriers.

The fundamental purpose of a transit station--to transfer passengers between modes--should be foremost in the station planning and design process. Compromises made in the station design that serve to inconvenience the transfer or create congestion in order to save cost should be avoided. A life-cycle cost approach that considers the use of the station over its useful life will serve to justify additional initial costs for station elements such as wider platforms, shallow stations and more escalators.

STATION FUNCTIONS AND DEFINITIONS

In the first formal paper, Wil Sergeant described how transit stations serve a variety of purposes, each of which can support the overall system objectives. These functions range from attracting the user to the system, processing him through the station, service functions, and joint development.

The station often provides the first image a traveler has of the system. The station exterior acts as a "store front" creating an impression to the potential user of what might be available inside. Upon entry, the station serves as a reception center; a place where the customer can inspect and form an impression of the quality of the system. The station environment, lighting, decor, general ambiance, cleanliness, and sense of security serve to create an impression of the type and quality of service that the traveler can expect. For example, consider the difference in perceptions of an intercity bus terminal and an intercity airport terminal.

As one proceeds into the station, it must now serve the function of a business office or travel agent. Here, payment is made, tickets are purchased, travel information is supplied, and records are kept. It is important that the passenger make this transaction easily, with little delay. Long waiting lines at ticket counters, poor and discourteous service and lack of information will detract from the service level. In order to process many passengers in a short time, an efficient reliable method of fare collection is required. Also space must be provided for necessary functions to take place: storage areas for stock, offices for ticket agents, record keeping and secure areas for revenue.

The passenger then proceeds to the platform area to board a vehicle. Often passengers must wait for a vehicle to arrive. With frequent service the passenger can stand on a platform. If service is irregular, a seated waiting area should be provided. The environment, amenities and services available to the waiting passenger will influence his perception of the system. Is the area sheltered from the elements, are there concessions, telephones, and restrooms? Is the station safe and secure? Clean? Comfortable? Well lighted?

The station is also a place to communicate information to passengers about the trip. Where is he; where and when will the next train arrive; how does he get from one place to another? The station is a communications network for management as well, furnishing information concerning daily operations, schedule changes, breakdowns, emergencies, special functions, etc.

The station may contain various operations and maintenance facilities and substations, tool rooms, material storage for maintenance, work rooms, staff lunch and wash rooms, and offices for supervisory personnel.

When the station is not a point of origin or destination (primarily outlying stations), it must also function as the link between access modes. Sufficient space must be furnished near the station for feeder buses or trains to discharge passengers, and parking must be provided. The station serves as a focal point for the feeder system and adequate provision for each arriving service must be included if the total system is to be successful. Access modes, and the proportion of each, will vary for each station situation, but might include walking, bicycle, moped/motorcycle, feeder bus, auto passengers or auto driver (park and ride) and light rail feeder. The design for station access should minimize walking times and furnish a safe and convenient means of transferring from the arrival mode to the transit station.

Finally, a transit station can become an attractive location for other commercial and retail enterprises as well as high density housing. In this role it can serve both as a transportation center and a commercial center. Joint development of transit and commercial facilities is a logical spinoff of a successful metropolitan rapid transit system.

STATION DESIGN FROM THE PERSPECTIVE OF THE PASSENGER

The human element in transit station design were discussed by Jack Fruin. The needs of transit users are primarily identified with three factors: convenience, comfort and safety. Convenience refers to the time and energy required to perform the transfer function. A convenient station is one which minimizes delay and exertion, reduces or avoids crowding, furnishes directional information, insures service reliability and provides customer services. Station elements related to comfort include climate control, restroom facilities, adequate waiting areas, cleanliness, and aesthetic design. Standards have been established for environmental factors such as temperature, humidity, sound and light. Criteria exist for evaluating passenger flow through terminal components such as corridors, stairways, escalators and fare gates. Safety includes such considerations as the adequacy of police protection, emergency response to accidents, availability of emergency exits, adequate lighting, non-skid walking surfaces, stair details, and warning signs near escalators. Passenger security from crimes is especially important.

A good station design is one in which all of the elements of the station function well together, producing a synergistic effect that provides multiple benefits. The single most important element in station design from the user's viewpoint is the pathway through the terminal. A simple direct pathway reduces the need for information, improves safety and security and provides a corridor around which consumer services can be provided. Directional information can be furnished by a configuration of pathways and signing. The pathway should be direct, easily recognized, and logically linked with nodes such as stairways and escalators. Pathways and nodes should not be obscured, obstructed or blocked from view by walls. Lines of sight should be clear and unobstructed. High visibility not only provides orientation and direction information, but also enhances passenger security.

Directional signing should be easy to understand, using short, familiar and consistent words. Messages should be repeated when appropriate. Explicit information about the surface location of exits, transit routes and nearby buildings should be provided, especially for underground stations.

Reliability of components within a transit station (turnstiles, ticketing machines, escalators, etc.) should be assured. The user expects a certain amount of inconvenience but it must be reasonable. For example a 60 second wait for a one-hour train ride would be acceptable, whereas the same wait for a 20-second escalator ride would not be. The maintainability of equipment, installation of heavy duty devices and standby equipment are essential if the station, and system, are to operate reliably and without breakdowns. Consideration of maintenance concerns at the planning stage will enhance system performance over the long run.

Concessions can be a convenience to the traveler and a source of revenue for the transit authority. The type of services provided will depend on the length of time the patron is in the terminal, the location of concessions along the pathway, and the socio-economic characteristics of the traveler. In a rapid transit system, a large passenger volume does not guarantee commercial success, the passenger is not a captive buyer. Transit management must consider benefits and problems associated with station concessions in formulating their policy on this subject.

Specifications for climate control, lighting, sound and temperature levels can be easily met through design and these parameters can affect passenger comfort. Extension of covered and climate controlled walkways to parking areas and traffic generators enhance passenger comfort. Underground pedestrian walkways connecting terminals with stores and offices have been successfully developed in many cities.

Cleanliness and station aesthetics may enhance the image of the transit system. Selection of finishes that are easily maintained will help to preserve the impression of the newness of the system. Regular maintenance schedules are necessary for cleaning the facility and removing trash and graffitti.

Station security is an essential requirement, if any but captive riders are to be attracted to the transit system. Security provisions include open station and platform areas, high visibility, direct surveillance by station attendants, direct telephone access to transit or local police, television surveillance of selected station areas, good lighting and direct communication for passengers via telephones or alarms. Controlled spaces can be created with well-defined patterns of movement, and the station size can be reduced with movable gates during late evening hours when patronage is low. Station design can reduce vandalism by choice of materials for durability and ease of cleaning, barriers between the platform and the wall, alarms and surveillance. Rapid removal of the signs of vandalism also tends to deter further incidents.

Stair design should be based on comfort and passenger locomotion characteristics. The trend is toward lower riser heights and wider treads. Escalators are provided in most new stations; they are safer and more attractive than stairs. Still there is the potential for accidents, pedestrians should be warned to exercise caution when using escalators.

STATION DESIGN FROM THE PERSPECTIVE OF THE OPERATOR

The operations and maintenance of passenger terminals were discussed by Robert Korach. Station operations depend on the ease in which passenger flow is accommodated at various points throughout the station. Surge volumes and heavy crowds can be handled safely and expeditiously if the station has been carefully planned. Good station operation requires sufficient pedestrian exit and entrance facilities, dependable fare collection equipment, and adequate platform dimensions. It should also be possible to disburse patrons away from station areas to avoid crowding at street curbs and sidewalks.

Fare collection systems must be adequate to handle peak volumes. Long lines and crowding in mezzanine areas, and bottlenecks which interfere with passengers debarking from vehicles must be eliminated. Train platforms should be adequate in size. Stairwells, elevator shafts, utility rooms, advertising signs, and concession stands should be located so as not to impede passenger flow. Ample space should be provided to allow passengers to spread out along the platform and to uniformly fill each train.

Stations should be designed for easy cleanup. A clean station is necessary to maintain its aesthetic value, to eliminate potential fire hazards, to avoid insurance claims, and to create goodwill. Regular cleaning can also identify maintenance problems, and help minimize the level of vandalism.

Stations should be designed to be maintained at low cost. Periodic maintenance will be required. Damage can occur due to floods, derailments, fires, etc which may require major repair. Drainage, seepage, and water problems can be avoided by careful construction and inspection practices. The design of the station for easy maintenance requires accessibility to items that will need to be cleaned or replaced. Location of lighting fixtures, signs and other similar items should consider that they must be periodically cleaned and replaced.

Maintenance and operations people should be consulted during the planning phases of a design project. These professionals will be able to review the station design in terms of how it will operate and can identify potential maintenance problems.

ACCESS AND TRAFFIC

Walter Kraft described the special problems associated with what happens outside the transit terminal. In his paper on Access and Traffic, he considered the various modes requiring access to a terminal, the relative priorities that might be assigned to each, annd the purposes or goals underlying access provisions. The basic goal of access is the transfer of passengers or cargo from one mode of travel to another. The specific details of access clearly depend on the modes involved. Priority access to public transportation terminals should be given to pedestrians, followed in order by bicycles and motorcycles, surface transit, taxis, automobiles to drop off passengers and automobiles that will park. Special considerations are necessary to insure access for the handicapped.

Other issues considered in this paper were (1) the pattern of access demand, (2) the direction of access, (3) the location of the terminal, and (4) the considerations involved in providing parking facilities.

EXAMPLES OF STATION DESIGN AND LESSIONS LEARNED

Bay Area Rapid Transit System

A reappraisal of the BART system was offered by Wilmot R. McCutchen. The BART system was opened in 1972 with 26 miles of service and 12 stations. By 1974 the entire 71 mile system included 34 stations: 15 subway, 19 at grade or elevated.

BART uses center platforms in subway stations and side platforms in suburban stations. Center platforms offer greater flexibility for loading and unloading, and for differential traffic loadings. They cost more than side platforms, although additional costs for escalators can narrow this difference. A life cycle cost analysis might show that center platforms are not as costly as side platforms. There are several station locations where center platforms might have been a better choice.

The decision to permit a variety of station designs does not appear to have posed problems or added cost. In practice many designs are similar. Certain design criteria were uniform in terms of station length, map areas, graphics, etc.

Estimation of station parking did not recognize that more parking is required in outlying stations than those close in. While total space needs were accurate, parking areas in outlying areas are over-subscribed whereas lots closer in are not.

Provision for transfer facilities between bus and rapid transit was neglected in the planning stage. Bus loading areas are now being added. Also storage for bicycles and mopeds are being provided.

Basic circulation and orientation within the BART system is good, although a newcomer may be disoriented due to the absence of clear sight lines. The method of fare collection was perhaps the most unique feature of the BART system and the one creating the most difficulties within the station. While it has many theoretical advantages in handling various fare structures, in practice it has had serious drawbacks. Aside from being complicated to operate, it is difficult to maintain and subject to breakdowns.

Successful passenger services provided by BART include advertising, public telephones and mail boxes. Concession stands in downtown stations have not been successful. Necessary improvements include removal of wooden benches, provision of platform edge warnings and locker facilities for bikes.

Security provisions in BART stations include good lighting, surveillance capability, courtesy telephones and spacious areas. The need for CCTV is evident. Provisions for partial station shutdowns are needed as are barriers to fare evasion.

Washington Metropolitan Area Transit Authority

Albert Roohr described the current status of the Washington Metro System. This system was opened in 1976 with a 5 station line. As of 1980 the system consisted of 33 1/2 miles and 38 stations. When the system is complete, it will be 101 miles long with 86 stations about equally divided between subway and/or elevated-at-grade stations. Ridership is 300,000 per day.

Washington Metro uses a unique station monitoring system. Planning staff people review the operations of a set of stations every 2 weeks. They note problems and take whatever action is necessary including follow-up of the results. This information is used in planning for future stations as well as correcting existing ones.

Estimates of required parking spaces fell far short of demand. Original plans called for 30,000 spaces. Revised estimates show a need for 100,000 spaces. An additional 25,000 spaces have been authorized.

Platform widths have been reduced as a cost saving measure. This has caused serious safety problems in the vicinity of escalators at Metro Center and Farragut West stations. Ease of circulation for passengers was sacrificed at the expense of initial cost.

In Washington several "on-line" stations are serving as temporary terminals and this has created problems in terms of train storage, maintenance, turnback facilities, train control, operating personnel accommodations, passenger handling and circulation and station access. A temporary terminal may be required to serve in this capacity longer than expected and provision should be made in the planning stages to avoid these problems.

The fare collection system, which is a stored magnetic fare similar to BART, has been a problem. It is complicated for the public to use, it changes without notice and is unreliable.

In the design stage it is necessary to insure that adequate escalator capacity is provided in the proper location. The Metro Center station is deficient in this regard. Bus services should be terminated at the rail station. This avoids competition between modes and provides an integrated system. Passenger drop-off facilities should be flow-through designs in order to assure safe, efficient movement. Well designed passenger drop-off facilities are essential. At the Washington National Airport station, the drop-off takes place in a dangerous and illegal location.

The Washington Metro system has selected uniform station design. Stations are well lighted, relatively crime free, air conditioned; they have controlled acoustics, minor litter and graffiti problems, modest advertising, public announcements, no concessions or toilets.

Metropolitan Atlanta Regional Transit Authority

The Metropolitan Atlanta System was described by Richard Stanger. The system was opened in 1979 with 13 stations on the 12-mile line. A north-south spine is under construction. Ridership is 85,000 per day. MARTA established several design policies based on previous U.S. experience and Canadian and European practices:

- The transit system was to be linked with the surface bus system.
- Stations are unmanned.
- Fare collection system is a flat fare and is barrier free.
- All stations are individually designed.

Bus loading is directly connected with station platforms. Priority is given to bus interface with separate protected roadways, minimal walking distances, good signing and graphics and full weather protection. Bus loading is incorporated into the paid areas of stations.

Stations do not have attendants at the change booth. Security is handled at a central zone which has surveillance over 6-7 stations and is located within one of the stations. It contains closed circuit TV monitors, security phones, fare gate controls, restroom door controls and passenger assistance phones. MARTA has its own security force and operates in a manner similar to the PATCO line from New Jersey to Philadelphia.

A flat fare is used. Entry is by exact fare and no fares are sold at the station. Entry may also be by bus to rail transfer or monthly fare card. There is space for token vendors. The Atlanta experience illustrates that fare polcies can have a significant effect on station design.

Uniqueness in station design was adopted, with overall control on design specifications. This decision allowed many local architects to participate in the process. The cost apparently did not exceed that of a uniform station approach. The system does not operate from 1-5 a.m. All stations are closed and for this reason, station designs must include limited entrances and exits that are easily secured. Concession space was not designed into the system.

Temporary terminal stations are overloaded and underdesigned for interim use. These terminals will be troublesome until the next phases are complete. Stations are larger than needed, expressing a tendency toward monumentality in design that should be controlled. The designs for parking lots did not anticipate as many small cars as occurred.

MARTA adopted most of its policy from the experience of PATCO, not BART or WMATA. That system with spartan compact stations illustrates that the bottom line is system reliability, access and convenience. Stations exist basically to transfer passengers between modes and should do so in a safe, rapid and smooth manner. In the downtown area, connections to major generators should be direct and use pedestrian ways. In the suburbs, emphasis must be placed on intermodal connections, adequate parking and direct paths between access modes and the station.

STATION RENOVATION

Several papers discussed the special problems of renovating older transit stations. R. A. Olmsted focused primarily on station renovation projects in New York City, but also reviewed key projects in other older systems. Renovation is usually limited by both budgetary and physical constraints. Several levels of magnitude of station improvement may be distinguished: renovation involves minor station improvement and affects only part of the station. Such improvements are often cosmetic, but may also involve such measures as improving lighting, upgrading graphics and signs, removing clutter, and providing new finishes for walls and/or floors. Aesthetic improvements, such as art work and murals, are also examples of station renovation. Modernization requires more extensive (moderate) improvement of the station; it usually affects a significant portion of the station. Examples are installing elevators or escalators and providing new or modified entrances. Reconstruction requires major modification of a station. It involves rebuilding most or all of a facility.

The earliest renovation projects in New York City were platform expansions. To meet increased demand for transit, it was necessary to lengthen the platforms, so that the trains could be longer. The first transit stations were too small; second generation stations were larger and more complex. Now, areas of these larger stations are being closed off.

Currently station renovation in New York City is focused on four goals, set by the Department of City Planning:

1. Improved pedestrian movement circulation.
2. Improved information systems.
3. Improved, hospitable and attractive station environments.
4. Improved safety and security.

Many renovation projects in New York have sought to bring the stations up to modern standards with respect to passenger volumes and environmental variables. Others have dealt with improving passenger security, providing connections to other travel modes, shopping facilities, etc., and enhancing the aesthetic and cultural value of the stations.

Sheldon Wander described the expansion and modernization of the Port Authority Bus Terminal in New York, New York. The expansion is designed to greatly increase the peak-hour capacity of the station, providing 52 additional bus loading positions with space for 26 additional positions to meet future needs. The modernization will bring all facilities up to current design standards. Improvements are being realized in terms of passenger comfort and safety, accessibility for the handicapped, information aids and passenger circulation patterns. Many shops and concessions are included in the terminal, and several major art works will be placed in the public areas.

INTERMODAL TERMINALS

Another major station renovation project was described by Hanan Kivett. The Boston South Station is being redesigned as an intermodal terminal as part of the Northeast Corridor Improvement Project. The entire program will include renovation of 15 stations along the railroad right-of-way between Washington, D. C. and Boston, Massachusetts. An essential feature of the program is to provide enhanced intermodal connections - to link the intercity rail with local rail and subway systems, bus systems, taxis and private automobiles.

The Boston South Station has been redesigned as a fully integrated intermodal terminal. It will be accessible to all modes of ground transportation, combining intercity and commuter rail, intercity and commuter bus, subway, local bus, and automobile parking. It is quite near downtown Boston, and is close to major vehicular arteries.

The project includes rehabilitation of the rail facilities, integration with other modes, parking facilities, and extensive private development at the site. The design requires realignment of the track and major reconstruction of the concourse. New sets of escalators and stairs will be installed. Retail space will be provided on the second floor, and commercial office space on three additional floors.

This project represents a level of coordination of interests and agencies seldom seen in transit planning. All of the diverse elements have been brought together: various institutions and political entities, funds from Federal sources, and a plan which meets the transportation needs of the area while preserving the historical value of the site.

Recent developments in Canada have also fostered the development of intermodal terminals. The Canadian perspective on intercity terminals was described by Peter Strobach. VIA Rail Canada, Inc. has been established to manage all rail service in Canada. One of its goals is to integrate the rail system with other surface modes, and thus passenger terminals must be redesigned to promote their use by various travel modes. The integration of services may occur at any of three levels: joint use of facilities (bus and rail each use same waiting area), integration of services (bus and rail schedules are coordinated so convenient transfer between modes is possible), and joint operation (complete integration of terminal operations). The level of intermodal coordination will be reflected in the planning of transit terminals.

The decision of VIA to locate intermodal terminals in the central areas of large cities has had two sets of consequences. First, there are constraints on the placement and design of facilities. "New terminal designs have to be integrated with older architectural styles" (Strobach). Furthermore, the facilities and components necessary to allow effective intermodal integration must be "housed in an existing physical space". These constraints challenge the skills of designers and planners who must try to accomplish often conflicting goals. Second, the placement and design of terminals becomes a political issue, and it is necessary to involve many participants and interest groups in the planning process.

EUROPEAN PERSPECTIVES

John Braaksma reviewed the European approach to the planning, development, and operation of public transportation terminals. The philosophies and experiences of transit systems in several major European cities were discussed, and examples were provided of both rail and bus systems, from the Netherlands, Great Britain, Germany, and France. Braaksma noted that European cities are different from those of Canada and the United States: they are compact, densely populated, closer together, and are downtown-oriented for both living and shopping.

The key feature of transportation planning in Europe is the integration of modes. Such integration occurs at all levels; schedules of several modes are coordinated, single tickets often serve multiple modes, and many cities have a single management structure, through Transportation Associations, which oversees all modes. Thus, the various transportation modes operate as part of a system, rather than merely as individual entities.

Several innovative approaches to bus operations were discussed. In the Netherlands, a "buffer system" allows efficient utilization of minimum terminal space. Buses unload and load passengers at the terminal platform, but the empty buses are taken to a separate waiting (buffer) area, until just before their departure time.

Computer control of bus traffic and passenger information improves the utility of the buffer system. The DOVER system is one example: it relies on transponders aboard each bus which signal the computer upon arrival at the station. The computer then assigns the bus to a platform or buffer area; it also provides information on departure times and locations to passengers in the terminal.

Joint development is a major trend for intermodal transfer facilities. Two extraordinary examples of this trend were discussed in detail: the Central Station in the Hague, the Netherlands and the Perrache Station in Lyon, France.

TRANSIT STATION DESIGN METHODOLOGY

A transit station design methodology is a systematic procedure for insuring that a station configuration fulfills its policy guidelines and objectives from the viewpoint of the transit user and the operator.

The design process begins with an inventory of data including local site studies, travel demand, access mode requirements and construction costs.

Policy must be established concerning design, operation and maintenance of the facility. Among the items to be considered are concessions, advertising, personal care facilities, public telephones, construction materials, fare collection methods, intermodal integration and provisions for the elderly and handicapped. Other aspects of station performance should be considered in this stage including the physical environment, security, and passenger orientation.

Trial station designs will be prepared by a design team consisting of architects, engineers, planners and operators. Among the considerations at this stage are adherence to policy guidelines, potential for joint development, station platform configuration, number of levels, location of paid and unpaid areas, and access modes.

An evaluation of the transit station schematics is completed to compare the system costs and to identify possible design problems and to determine the extent to which policy guidelines can be met. Following the selection of a preliminary design concept, a series of detailed design studies can be prepared.

The design of the station will include selecting the location and number of various station components necessary to achieve smooth and efficient passenger processing through the station. The station designs are evaluated in terms of travel times, queues, crossing flows, and connectivity. Transit station simulation models, such as the UMTA transit station computer simulation package, would be appropriate at this stage. Environmental criteria, such as noise levels, lighting, air quality and thermal comfort, would also be considered.

The candidate station designs are then evaluated in terms of cost and effectiveness. The viewpoints of both the user and the operator should be considered. In some cases there may be conflicts to be resolved. With the selection of a station design layout and flow pattern, the detailed construction drawings and specifications can be completed.

In summary, the transit station design methodology is a planning tool for development station configurations that take account of the specific requirements for system integration. It involves specific statements of policy concerning the role of the station, data acquisition for site selection, travel demand analysis and access mode choice, initial sketch planning, detailed design of station areas and components (e.g. parking areas, platforms, escalators, fare collection, etc.), the generation of alternative plans and their evaluation in terms of user and operator objectives and cost.

WORKSHOP RESULTS

Nine workshops were conducted, each focused on a particular topic of current importance for station design. Participants discussed the state of knowledge and practice regarding each topic, identified key issues and problems, noted major gaps in knowledge and directions for future research, reviewed innovative or especially successful approaches and concepts, and tried to identify implications for operations and policy. The workshops built upon the information from the plenary sessions, and extended, elaborated, or criticized aspects of the Design Methodology.

Workshop 1 was charged with providing a Critique of the Design Methodology. Participants felt that the methodology was valuable, but suggested improvements in four areas. (1) The set of interest groups (users, special users, operators) should also include nonusers. Reactions of nonusers are especially important in terms of station impacts and land use. Parking, access, and aesthetics are of particular interest to nonusers. (2) The methodology should include some mechanism for insuring community involvement in station planning and design. (3) Participants felt that the methodology was too complex and its results too intricate for higher level decision makers. This level of detail is appropriate for planners and designers, but a means of simplifying, condensing and interpreting the information is needed to communicate the results to decision makers. (4) The workshop identified four levels of the design process, focusing on (i) system design, (ii) area design, (iii) the terminal concept, and (iv) the final detailed design. The methodology deals primarily with the last two levels. Participants felt that more attention should be given to separating the criteria for these two levels, and to including additional criteria, especially energy impacts and life cycle costs.

In the workshop on Intermodal Terminal Planning, Design and Operations, three case studies of intermodal terminals were reviewed in detail. Participants felt that this type of review was beneficial, and that the systematic compilation and dissemination of case studies is essential. They particularly encouraged documentation of the decisions and activities leading to the final station design, as well as retrospective analyses of the successes and failures in achieving goals and objectives. It would be especially helpful to analyze the role of different parties or interest groups in influencing the final design. The workshop emphasized the need for research in three areas: (i) planning and design criteria, (ii) implementation framework, and (iii) operations and maintenance. Case studies of intermodal stations coming on-line were strongly encouraged.

The third workshop, on Passenger Processing and Information Systems, also emphasized the need for systematic and complete analyses of current practice and previous experience. In particular, it was noted that there has not been a scientifically valid, organized and systematic analysis of examples of good and bad passenger information systems. Such a study is necessary. Psychological and ergonomic evaluation of information aids is essential; what are the best ways to communicate with users? How cost effective is each for the system operator? Hopefully the systematic study of information aids would lead to a set of National Uniform Standards regarding their use.

Similarly, the systematic evaluation of passenger processing elements is needed, including analyses of examples of good and bad practice and the development of guidelines to influence future design practice.

The workshop on Access and Traffic also emphasized the need for criteria, guidelines, and a minimal set of design standards. Participants noted that access to the station should be considered early in the design process. Further, planning for access must consider the goals to be met by the station, and the impact of the station activity on the activity in the surrounding area. A set of priorities for access to the station by different parties and vehicles were established; pedestrians and the elderly and handicapped should have high priority access. Constraints on parking (limited space and parking fees) were discussed as a means of discouraging auto use.

Workshop Five, Operations and Maintenance, explicitly dealt with the costs of the station. Participants felt that the annual life cycle costs incurred in operating and maintaining a station should have priority emphasis in the design process. Research is needed on how to best estimate the costs of operations and maintenance for a station. Clearly, station planning and design should include operations and maintenance people from the earliest stages; the maintainability of alternative designs must be considered. The participants urged that the evaluation of any station design include a comprehensive functional analysis of the station, emphasizing the maintenance functions and overall operations. The station must be considered as part of the total system and its maintenance must be well planned and the ease of maintenance insured, as much as possible.

The sixth workshop focused on Joint Development, Land Use, and Station Impacts. The need for research, including detailed case studies, on the effects of joint development was noted. Comparative studies of inner city versus suburban locations would be especially valuable since different problems might arise in these two contexts. Such analyses should also assess the legal and financial complexities involved in joint development.

Similar studies are necessary regarding land use and stations impacts. It is necessary to define the objectives a station is designed to realize, and then to assess how well the objectives are met by the design. Case histories would be valuable provided there were means of evaluating the effectiveness of various designs in achieving their stated objectives. It should be possible to determine the reasons underlying the success or failure of particular designs.

The workshop on Design for the Disabled, Elderly, and Handicapped dealt mostly with specific problems transit operators have had in trying to conform to Section 504 of the Rehabilitation Act of 1973 and various federal mandates. Placing elevators in older transit stations has proven costly and difficult. Currently, studies are underway to develop and evaluate alternative designs for elevators, particularly options that will minimize space requirements. Given that elevators will be put into stations, the additional problem is how to make them safe and secure? Various technological solutions are being considered.

When a passenger in a wheelchair is able to get to the station platform, an additional problem arises in boarding the vehicle. There is usually a gap (vertical and/or horizontal misalignment) between the station platform and the vehicle. Several gap filling measures have been considered; such devices may eventually be developed as part of the wheelchair itself.

Transit authorities are often faced with several sets of design standards or codes (local, state, federal), and these standards sometimes conflict. Participants in this workshop recommended that an Ad Hoc Committee of transit industry representatives be formed to help develop standards for accomodating handicapped users in the transit environment.

Workshop Eight studied the problem of Transit Station Security. Both institutional and design problems contributing to transit crime were considered, and solutions were suggested for each major problem. An extensive discussion of closed circuit television (CCTV) surveillance revealed the need for basic psychological and human factors research on monitoring and viewing practices. How well do people detect crimes on CCTV screens? How long can an observer effectively monitor a screen? How many screens can a single observer monitor? Are some people better at this task than others? What variables relate to effective surveillance? Finally, the special problems of insuring security for the elderly and handicapped were discussed.

The ninth workshop reviewed the state of the art in the application of computer models to the planning and design of transit stations. Four computer models were discussed: (i) the Subway Environmental Systems (SES) model, (ii) the Airport Landside Simulation Model, (iii) the Detailed Station Model (DSM), and the UMTA Station Simulation (USS) program module. The function and use of each was described. The need for computer models of passenger processing was emphasized, and the complexities of modeling passenger flow through the station were reviewed. Barriers to the use of computer models include negative management attitudes, time and cost, hardware constraints, problems with output form and ease of use, and the limited availability of the programs. To overcome these barriers, the workshop developed the following recommendations: (1) coordinate DOT research and development efforts, (2) develop means for providing graphic output, (3) perform case studies of model use and validation, and (4) improve training and documentation for existing models. The participants predict increased use of computer simulation models in the design of transit stations.

Several common themes were evident in the papers and workshops: (1) Designers and planners want better and more complete documentation of the activities and decisions involved in the design of actual transit stations. In particular, what considerations entered into each decision, and what parties, or interest groups, helped influence each decision. (2) This documentation might include detailed case histories of the conception, planning, design, and construction of actual stations. There should be some mechanism or channel for the compilation, documentation, and dissemination of this information. (3) Completed stations should be evaluated in terms of the success of the design in meeting its objectives and the impacts of the design on users, nonusers, and the transit system in general. The reasons for success or failure should be determined. (4) In several areas, empirical research is clearly needed, especially in relation to the psychological and human factors aspects of passenger processing. The subjective hases for the acceptance of a station by users and nonusers should be also assessed. (5) Maintenance and operations, and the costs involved therein, should be considered in the design process, preferably at the earliest stages.

ACKNOWLEDGEMENTS

The selected slides of Hiroshige's "Stations of the Tokaido" (Japanese, 1747-1858, woodcut) are reproduced with the kind permission of the Montreal Museum of Fine Arts. The set was a gift of Mrs. Mary Fraikin in memory of her father, Maurice von Ysendyck, 1973. Toronto scenes were supplied by the Toronto Transit Commission, and the Toronto Area Transit Operating Authority. Scenes of overseas railways are by Bill Coo, with VIA Rail Canada.

"WHAT IS A STATION?"

Wilfred Sergeant
Senior Consultant
Canalog

Hiroshige! Tokaido!

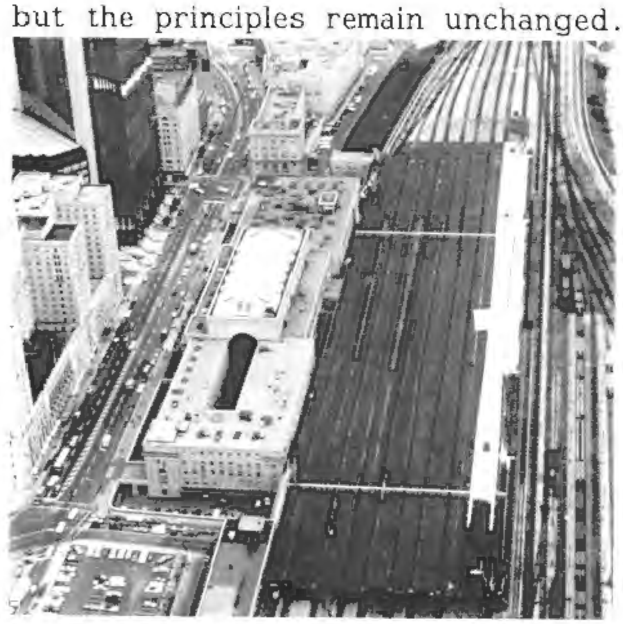
I suppose we all know about Hiroshige and the Tokaido. He was a minor official in the train, sent by the fire brigade of Tokyo, charged with delivering a gift from the Shōgun to the Emperor at Kyoto in 1832.

You may well ask, what this has to do with stations? Well, Hiroshige was an artist, and from this trip he prepared a famous series of woodcuts

known as "The 53 Stations of the Tokaido". His Tokaido was simply a broad foot path, with ferries at the mouths of rivers, but it was the main artery of commerce. The word itself translates to "The road by the eastern sea". For Hiroshige, a station

was a place where his train stopped at that time, of course, to rest, to eat, to transact business and to spend the night.

That is a far cry from the stations of the modern Tokaido line, but the principles remain unchanged.



A station has to be more than just a place where the transport system stops to allow on-loading or off-loading of passengers, freight, or both. No matter whether we are talking about long-haul, inter-city passenger service, right down to a

wayside halt for a light-rail transit line, the stations will function to their maximum potential only if they properly accommodate all of the related functions.

That is the subject of this conference, although more specifically designated as passenger terminals. This introductory paper attempts to cover the field lightly and briefly, to underline the relationships between the more specialized papers to follow.

So what is a station?

We can easily identify eight different functions. If others emerge during this conference, let us add them to the list and keep on going. This does not mean that every station has to fulfill every function, but certainly every function has to be served at some of the stations.

In the first place, a station serves the purpose of a store-front,

a shop-window, where a passerby gets a quick glance, and perceives an image, hopefully transmitting and receiving a true impression of the quality of the transportation services available behind its facade. If we want to get philosophical about it, we have to admit that we have had many facades reflecting pretty accurately the services behind them, and quite often the whole impression was not good. The basic message here is that it is not much good offering higher quality services unless we can win the attention of potential customers with a store-front good enough to cry out to them "Come and buy, come and buy the goods we have to sell".

So we succeeded in catching the eye of our potential travellers and they walked into the store. Now the

station functions as a reception center, a place to make the customers feel comfortable, maybe only to look, perhaps to make enquiries, and hopefully to buy the product. This is where image assumes its greatest

importance. Here are our candidates - we don't know whether they will or

they won't, so it is quite important to give them the right impression. If the reception area reflects the last century, lined with vertical PTG boards, and peeling paint, compared with a modern image of plastic and

chrome, we might have lost them even before they say a word.

Who are they going to talk to? What do they want to ask? Can we help them? Will they buy?

Ahah! They're going to buy!

Now our station is a business office, an agency, a place where money changes hands. This is where the revenue comes in to pay our wages, so it had better be good! There has to be a stock room, to receive supplies of passenger tickets or raw materials for ticket printing machines, and a stock control system, for issuing and re-ordering these materials. As an agency, it has work

areas where agents can carry out their duties, meet the customers, sell the tickets, take in the revenue, compile the revenue accounts, hold the money in security until it is shipped off to the bank, and collect tickets from passengers at the beginning or at the end of their journeys.

One important factor in a business office is the convenience for the customers to complete their transaction with comfort, pleasure, and

satisfaction. If any of these fall short, it can be a real turn-off that can drive the customers to a different mode of transportation the next time they have to travel. We will be getting deeper into this with Jack Fruin's paper on "Passengers and the Human Element" right after this.

The other important factor as a business office is security for the revenue taken in and the unused tickets waiting to be sold.

Now we move our passengers on to the platform. This is the place where they first make contact with their vehicles, a facility for boarding,

or alighting from, the transportation system. Can they find the right place? How long will they have to

wait? Can they find shelter from the wind and the rain? This function of

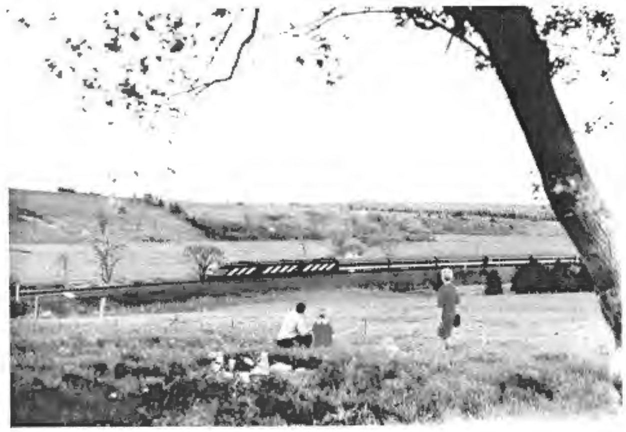
a station is to serve as a waiting area, where passengers spend time while they wait for their transportation vehicles, and maybe have access

to auxiliary facilities, such as newsstands, boutiques, and rest rooms.

There is another aspect of a station that runs through all the functions referred to so far, and that is communication. From the moment our prospective travellers first saw the facade, and after we have them as steady customers, we have a two-way communication going on. We

are trying to convey to them the nature and quality of the services we have to sell, and they are telling us indirectly just how good or bad we are in a competitive market.

So our station is a communication center, both towards the travelling public, and towards the management of the service. For the information of the customers, we have to tell them what the service is, reassure them that it is in operation as scheduled, or inform them of any irregularities with explanations and forecasts for getting back to normal. Whether this be by machines, or by the presence of the agents, the news has to get to the station, and then on to the customers. Management, on the other hand, needs to know the state of the business. Traffic statistics, revenue



statistics, status reports, and any other data needed in other departments of the organization for the proper functioning of the system, must be collected, collated, and transmitted from the station. In the event of irregularities, rapid communication from the stations may be

needed to get status updates, and plan emergency moves to normalize the service as quickly as possible.

This is really a part of operations at the station, and should be examined further in the papers on "Operations and Maintenance", to follow.

Another part of station operations stems from the fact that a station is often the most convenient location to house some of the "back-room" functions of the system, such as substations, tool-rooms, material storage for janitorial services and facility maintenance, offices, staff rooms, and wash rooms for operating staffs and for travelling management personnel. Some of the key junctions can become almost subdivision points or branch offices, housing first line supervision or higher, where they have need to be close to the operation.

The next function of a station is found on the outside of the operation, because it is, or should be, a focal point for a local feeder system; a place where passengers enter or exit from the transportation system. The station is a transportation center, through which passengers move to and from their final destinations by appropriate and adequate routes and modes of local distribution.

Access is the key.

In the market of free decision, every part of the journey counts, from leaving the point of origin to arriving at the final destination. Even the highest quality of transport is of no value if the access is not good enough at one end or the other. So, every station must be designed to function well as an intermodal transfer facility. The access may be

pedestrian, bicycle, transit bus, special feeder bus, taxi, kiss-and-ride, park-and-ride, interchange with metro or a rail commuter line.

VIA has one station with direct connections to a ferry boat service.

Are there any other modes of access?

For every one of these that might apply at any one station, the convenience to the passenger is paramount. Walking times must be minimal, safe, and comfortable, waiting

times for ticketing or for scheduled departures must be short enough, there must be an efficient system of signs to identify the flow-lines, from point of arrival, to moving through the center, to finding the correct departure modes and routes.

At the design stage, the relative priority given to the space requirements for the various modes gets a

bit tricky. A station at the back of a large parking lot discourages both pedestrian access and use of regular

transit lines that don't come right up to the station, while in a low density suburb, adequate parking and kiss-and-ride is essential if travellers are to be persuaded out of their cars and on to the system. The watchwords still have to be quick, safe, and comfortable.

In my experience, accessibility appears just about the most important feature of any station and transportation system. We shall have a chance

to go into the finer points of access in a later paper on "Transit Station Access and Traffic" by Walter H. Kraft.

Finally, if a station serves its purpose well, and becomes a pole of attraction for regular and heavy flows of population, it has a significant

influence upon the conduct of business in the community. This is where the transportation center can become the foundation for a commercial center. Since it is a node in the transportation network, it is a logical place for the offices of private practitioners, such as lawyers, doctors, and engineers, and also for company

offices and the service industries such as cleaners, delicatessens, drug-stores, and fast-food outlets. The result is an increased utilization of all the shared facilities, parking and kiss-and-ride areas, transit lines, circulating areas, and support facilities. In fact, every station should be looked at as a potential site

for a commercial center in the long range development of the urban fabric, even if this does exceed somewhat the normal functions of a station.

So, it can be all of these: a store-front, a reception center, business office, waiting area, communications center, "back room" facility,

transportation center, and commercial center. Whichever way you look at it, a station is a lot more than just the place to go to catch a train!

By the way, the gift that the Shōgun sent to the Emperor was a horse.

ACKNOWLEDGEMENT

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THE HUMAN ELEMENT IN PASSENGER TERMINAL DESIGN

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The basic functional role of the passenger terminal or transit station is to accommodate the transfer of persons between transportation modes efficiently, conveniently, comfortably, and safely. The simplest type of transportation terminal, and perhaps the ideal in attaining most design objectives, is an across-the-platform transfer between two railroad trains. The passenger need only walk a few feet to accomplish the transfer, the pedestrian pathway is level and direct, and assuming proper train schedule coordination, passenger needs for information, environmental comfort and security are minimal. However, the multiroute, multimodal, multiuse, and often multilevel transportation terminal introduces more complex planning and design problems.

At the outset it may be useful to establish the meaning of the word 'design'. Because its dictionary definition is not concise, for the purposes of this paper, design is defined as: "The process of conceiving artifacts and systems to serve the needs of man." Good design can generally be identified by the directness and simplicity by which it serves human needs. Conversely, poor design is marked by improper identification and satisfaction of human needs and is characterized by varying degrees of user dysfunctions.

Because complex transportation terminals represent the combined effort of many different interests, and by necessity the compromise of some planning and design objectives, it is important to emphasize that the primary functional objective of the terminal, the efficient transfer of passengers between connecting transportation modes, should not be compromised for lesser objectives. This includes construction costs which have been used as justification for terminal systems which may not satisfactorily fulfill user needs. The tendency of planners to make only first cost comparisons in considering terminal design alternatives is a significant problem because human needs are very often subjective and not easily quantified in dollar terms. One such example can be seen in the advocacy of deep transit systems for the purpose of reducing tunneling costs, without considering that because of the deep stations every user, for the life of the system, may be required to spend several added minutes in the station complex. For each 1,000 daily station users in a 100-year life transit system, this equates to 400,000 life cycle man hours of time for each added trip minute per day, potentially having a present worth of millions of dollars [Footnote 1].

Identifying the Needs

An identification of user needs under the three general headings of convenience, comfort and safety is outlined in Table I. Undoubtedly other factors can be added under these general headings. Many user needs factors are inter-related. Crowd avoidance is a convenience and comfort factor but can become a safety problem when extreme crowding occurs on a transit platform. Similarly, direct pathways and sightlines enhance convenience, but are also important considerations for user safety and security.

TABLE I

THE HUMAN ELEMENT IN PASSENGER TERMINAL DESIGN

CONVENIENCE	COMFORT	SAFETY
Minimize Delay	Climate Control	Police Protection
Minimize Exertion	Rest Room Facilities	Emergency Response
Avoid Crowding	Avoid Crowding	Avoid Crowding
Directional Information	Waiting Areas	Emergency Egress
Service Reliability	Cleanliness, Sanitation	Safe Walking
Consumer Services	Esthetic Design	Surfaces
		Lighting

Convenience is a very broad term that can encompass many elements in passenger terminal design and operation. Fundamentally, convenience relates to the minimization of the personal time and effort required to perform the terminal transfer function. In larger terminals it may also involve the provision of ancillary facilities and services for the passenger such as waiting areas and concession spaces. Studies have shown that passengers tend to magnify the time spent in terminals, and this time is usually weighted more

[Footnote 1 - A method of establishing some objective weighting of user values is presented in NCHRP 20-10 - Benefits of Separating Pedestrians and Vehicles -Stanford Research Institute, June 78 135 p.

heavily in trip models. Possibly this is due to the fact that in the terminal the passenger is personally responsible and actively involved in his or her progress, whereas in transport the passenger's role is passive and progress the responsibility of others. Perhaps an extreme example of the weighting of time in the station relative to trip time was observed by the New York Regional Plan Association in its studies of pedestrians [Reference 1]. RPA found that some passengers chose to climb five flights of stairs in one deep station rather than wait as little as 60 seconds in an escalator queue. This represents a considerable tradeoff of personal energy by these persons to save time.

Human Comfort requirements in terminals are easier to identify because definitive and readily measured values have been established for temperature, humidity, sound, light, threshold levels for atmospheric pollutants and other similar environmental factors [Reference 2]. Potential human discomfort due to crowding, delay, inadequate rest room facilities, and lack of seating is not as definable. Levels of service have been established for various pedestrian densities on stairs, in corridors and in queuing areas which can be helpful in assessing some of the impacts of crowding [Reference 3]. Because of the large numbers of pedestrians flowing through some terminals it is important to consider crowd control procedures in the event of service stoppages or for various types of possible emergencies. A recent series of fatalities in a number of uncontrolled crowding situations underlines the necessity for this type of analysis.

The Safety and Security of passengers in terminals is an important concern affecting both initial design and subsequent operational requirements. The most obvious example of security design impacts has occurred at airports, where institution of anti-hijacking controls required building plan reconfigurations, changes in baggage handling procedures and increased staffing. A force of more than 100 police is employed at the Port Authority's Midtown Bus Terminal because of the size of the facility and the crime problems in the local area. Crime defensive design can effectively reduce security problems and policing requirements [Reference 4]. Design features affecting passenger safety in terminals include the finishes on walking surfaces (particularly when wet), stair detailing, lighting, and precautionary signing at mechanical systems such as escalators.

Designing for the Needs

Good design is typically synergistic. Synergy is described as the combining of two or more elements to perform a function that none could do independently. Examples of synergy include the creation of a metallic alloy with super strength qualities by combining metals with far lower individual strengths, or the mixing of several medicines to form a curative compound which if taken as separate dosages of the same medicines would be ineffective. Well designed passenger terminals often appear to have a synergistic quality, serving multiple needs and producing unanticipated benefits. The reverse of synergy can also occur, akin to "Murphy's Law", where one poor design element produces many seemingly unrelated negative effects.

Perhaps the single most important element in terminal design, and the one providing the greatest opportunities for synergistic impacts, is the configuration of the passengers' pathway through the terminal system. A direct well-defined pedestrian pathway reduces passenger needs for information, improves passenger safety and security, provides an organizational spine for consumer services and enhances their rental value, and has many other benefits.

Directional Information

Directional information in passenger terminals is conveyed by the configuration of terminal pathways, by signing, and in some instances supplementary communication facilities, such as information telephones connecting with centralized information services. Pathways should directly link recognizable nodes and have distinctive boundaries or edges. Nodes are points where the passenger is required to perform some function, change direction vertically or horizontally, or board a transport mode. There are many examples in terminals and stations where pedestrians pathways have been obscured by poor architectural treatment. As one example, stairways and escalators are typical pathway nodes that in themselves are excellent visual statements of a level change linkage. Very often these nodes will be blocked from the passengers view by walls, or turned away from the logical direction of traffic flow, creating confusing decision points. Corrective directional signing will almost always be found at such locations, but the most powerful directional message is received from the space itself, and not signs. Obstructed pathways also mean interrupted lines of sight, creating potential areas for criminal activity because of reduced surveillance capabilities, and reducing rental exposure. An elevator grouping which could have been located elsewhere was placed in the center of a wide, and otherwise well-defined, corridor in one transportation center. The result has been a split corridor with obstructed views of storefronts and channelization of pedestrian flow to one side. After several years, stores remain unrented on the "lee-ward" side of the obstruction.

Directional signing should confirm the visual message established by the pathway configuration. The elements of good signing are more clearly understood if directional signing is recognized by the designer as a medium for visual communication with passengers who are unfamiliar with the transport route system and terminal and transit station configurations. Many of the elements contributing to good communication through signing and other information media are directly related to the factors known to enhance human short-term memory. Short-term memory is improved by rehearsal or the gradual systematic introduction to the terms and conventions of the signing system; by use of short, familiar, and consistent terms; by avoidance of translation or the need to convert the sign message into other units, terms or meanings, by keeping the number of individual terms or bits of information to be assimilated to a minimum, by use of a repetition to improve confidence in the directional statement and information provided, and by continuity and consistency of sign format and means of presentation.

Transit station planners should consider patron convenience and orientation problems both in naming stations and providing below level and street level directional signing. Since a subway platform can be 800 or more feet long, and in deep stations its stair and escalator connections to the street level may be physically separated by even greater distances, it is necessary to consider the location and orientation of street underground entrances in the context of both the platform and surface levels. A passenger using an escalator or stair at the platform end opposite from his or her destination may find that they are blocks away from it, potentially requiring an unnecessary walk in inclement weather. Explicit information about the surface location of exits and the surrounding buildings and transit routes should be provided at the platform level. Passenger orientation should be taken into consideration when naming stations, since the use of a cross-street name bisecting the station does not accurately convey district location. This problem has been noted in the New York City subway, with widely spaced stations having the same designation (viz.) 14th Street, 34th Street, etc.

Service Reliability

Passengers are justified in having reasonable expectations for service consistency and reliability in transportation systems and terminals. Service reliability in terminals usually relates to the numbers and on line availability of turnstiles, ticketing machines, escalators and other mechanical devices. Users of any system have expectations of a level of service and reliability with a range of tolerance based on experience, or their own subjective judgment of reasonable variances in performance. An an example , a 60 second wait for a 20 second escalator ride would be considered poor service by most, but a delay of this magnitude would pass virtually unnoticed during a one hour train ride. Delays may be significantly magnified by a passenger if there is the risk of a missed connection with another interface mode. Since users measure reliability in terms of service consistency, wide variations in service times should be avoided. Maintainability principles should be applied to all mechanical equipment to increase mean times between failures and decrease mean times to repair. Maintainability goals are improved by selecting heavy duty equipment, assuring adequate accessibility for inspection and parts replacement, provision of standby equipment or equipment parts, training personnel in equipment inspection and repair, and supplying adequate tools for repairs.

Consideration must be given in the functional plan to maintainenance scheduling and the assumption that elements of the system will be out of service for normal routine maintenance procedures. Substantial cost savings were realized in one passenger terminal by moving all nighttime off-peak operations to a smaller consolidation berthing area. This strategy produced reductions in energy and security costs, and allowed mechanized rather than manual cleaning methods in the vacant terminal space. The smaller consolidated terminal operation should be capable of functioning as a separate entity, with independent access and all the necessary support features and services. Additionally, tenant leases, union agreements, or other administrative factors may require modification to allow for such operating alternatives.

Consumer Services

Snack bars, newsstands and other rental concessions are a convenience for terminal patrons and a potential revenue source for the terminal operator. Revenues from consessions and other rentals are a substantial financial consideration at airports, varying from one third to two thirds of the total revenues from all sources. The potential revenues from concessions in typical commuter facilities is limited and must be carefully planned to be economically viable. Airport patrons spend much more time in terminals than transit users and thus are more likely to use such facilities as a bookstore or "sit-down" restaurant. Commuters have very short terminal stays and are more likely to make impulse purchases at high exposure locations. A large passenger volume does not guarantee the success of retail development in a transit terminal. One recent market survey in a bus transportation center showed that only a small percentage of daily commuters patronized its retail concessions on a regular basis. The most important factors affecting the viability of rental space include the retail viability of the area surrounding the terminal and the resident and nearby worker population. Patronage by passengers depends on the amount of time the passenger spends in the terminal, personal income, trip length and the type and location of retail space within the terminal itself. Certain types of concessions depend heavily on impulse buying and require maximum exposure to passenger flow. Others are less sensitive to the passenger flow lines and volume, but still require clear statements of their availability, through direct lines of sight, signing, service directories, or other means. Mistakes in the retail planning of terminals will occur where the passenger is considered to be a captive consumer, with no choice but to use the facilities that are made available, or where retail space disrupts passenger flow lines and other terminal functions.

Comfort

The internal requirements for passenger terminal temperature, humidity, sound levels, lighting, and other similar environmental factors are well established and need not be discussed in detail. However, the terminal planner should give consideration to planning strategies that extend the range of climate-controlled access surrounding a terminal, since very often there are long walking distances from parking lots or large traffic generators causing inconvenience and discomfort in weather that is too hot, cold, wet or windy.

Uncomfortable weather of this type occurs more than 50 percent of the time in many areas of the United States.

Several cities have covered pedestrian networks connecting major transit centers and stations. The 6 kilometer long underground pedestrian network in Montreal, Canada connecting with many of that city's downtown transportation terminals, retail stores and hotels is an outstanding example of this concept. Similar smaller underground pedestrian networks are associated with subway system transit stations in New York City and Tokyo. A covered elevated pedestrian network is provided in Minneapolis, Minnesota but no significant terminal facilities are integrated into the system.

Aesthetics is not a definitive human need, but it is important in establishing favorable patron impressions of service and comfort. Architectural treatment, finishes, lighting, and cleanliness are the primary aesthetic design considerations in terminals. Maintainability is a significant factor in the selection of architectural materials and finishes to preserve terminal appearance. Cleanability, vandal resistance, and changes in appearance of materials over time should be considered. General terminal housekeeping and sanitation is an aesthetic factor including cleaning schedules and methods, number and locations of trash receptacles, trash disposal methods and equipment, and loading berths for disposal trucks. The architectural design of tenant areas and the activities of tenants is an aesthetic factor. Tenant lease provisions should assure that architectural finishes, display window treatments, and signage are compatible with terminal design objectives. Tenant standards for cleanliness should be clearly defined in such leases, enforceable by recapture of the premises if necessary to assure compliance.

Safety

Safety and security are primary human needs which must be served by the terminal design. Passenger perceptions of the levels of crime and vandalism are known to affect transit ridership. The basic approach to security design of transportation facilities is the creation of defensible space either in the form of controlled enclaves in which patron entry and exit is carefully observed by security personnel or by other types of formal and informal territorial monitoring. Internal building and external site configurations which are well-lighted, avoid blind spaces, provide clear and uncluttered lines of sight, have well-defined patterns of passenger movement, as well as clear differentiation and controls between public and employee spaces, tend to discourage crime. The presence of security personnel reduces crime and improves the general perception of security effectiveness, but can substantially increase terminal operating costs. One security post manned on a 7 day, 24 hour basis can require 5 personnel, with the inclusion of relief time, vacations and holidays.

Security costs have been reduced by taking advantage of the surveillance value of other non-security facility personnel. Security of transit stations has been improved by locating change booths so that platform areas can be observed either directly or by the use of supplementary closed circuit television. Adequate means of communication is an essential aspect of security to assure rapid response to criminal activity or to an emergency. The security design of terminals also involves consideration of other types of potential emergencies, and the need for emergency vehicle access, pedestrian evacuation routes and evacuation procedures. Facility personnel should be trained to respond to the various types of emergencies. In high volume passenger terminals, the panic potential under threat of fire, explosion, or other emergency conditions can be a factor in determining corridor configurations and widths. The potential for panic in public spaces is reduced where there are clearly defined non-ambiguous evacuation routes, pedestrian evacuation capacity is sufficient to provide rapid consistent movement without delays, and where definitive emergency procedures are established and employed by trained staff. Standby generating equipment, automatically activated in an advent of a power failure, should be used to provide emergency power for elevators and lighting to delineate evacuation routes and exits.

Walkway surfaces, stairs, and escalators in the terminal require careful consideration in design. The wetted friction characteristics of floor finishes must be considered since large volumes of passengers will track in water and mud. Some terminals install temporary rubber matting at entrances to reduce tracked-in dirt. Non-slip strips have been installed to reduce slipping, and also grooving, similar to that used on highways, has been cut into floors for that purpose. Stair accidents are a significant concern because of the possibility of serious injuries and even fatalities due to a bad fall. A study by the National Bureau of Standards estimated that 3,800 stair related fatalities occur each year, but mostly in the home.

There appear to be several misunderstandings of the human element in stair design. Most building codes use a 22 in. (559 mm) width increment for building evacuation calculations and many engineers have adopted this dimension as a traffic lane width suitable for stair design. This belief has been fostered by the fact that the 95th percentile of male shoulder widths is approximately this dimension, unclothed. The use of this lone dimension has resulted in many narrow inadequate stair designs. Body sway, heavy clothing and hand carried articles add to the required width for comfortable human movement on stairs. A 30 in (762 mm) wide lane increment is recommended for transit stair widths, with a 5 ft. (1.5 m) stair being more suitable for the normal 2-lane stair design.

Another stair design detail apparently misunderstood is the dimensioning of risers and treads. Structural engineers sometimes detail very steep stairs with high risers and narrow treads to simplify structural framing. Designers are currently using much lower riser heights and wider treads than in the past, with a recent State University of New York Campus Construction Specification set at a 5 in. (127 mm) riser and 14 in. (356 mm) tread. The combination of the low riser height and wider tread provides a more comfortable and safer stair with greater lifting tolerance for foot movement and a wider platform for foot placement. The serviceability of more gently sloped stairs has been amply proven by a 6 in. (152 mm) riser and 14 in. tread stair that has been in constant heavy use for many years on one of the platforms of the New York Pennsylvania Railroad station.

Other safety considerations in stair design include highlighting levels, recommended at 25 foot candles by the Institute of Rapid Transit and provision of proper height hand railings extended 18 in. (457 mm) beyond stair landings. The traffic characteristics of stairs require adequate width for total traffic in both directions and adequate clear spaces at ends for circulation and queing.

Escalators are proven to be much safer than stairs, possible because most people stand on the treads rather than walking up or down the moving escalator. However, there have been serious accidents involving entrapment, and in some instances amputation, of human extremities, at the combplates or along the sides of the escalator. Many of the more serious accidents are related to footwear such as sneakers or sandals. Transportation terminals and other public buildings have been using cautionary signing to reduce these accidents (See Figure 1).

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CAUTION
Hold Handrail
Attend Children
Avoid Sides
CAUTION

FIGURE I

STATION OPERATIONS AND MAINTENANCE

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This subject, Station Operations and Maintenance, should include a discussion of the practical aspects of station operation of a real-life rapid transit system. The Philadelphia/Lindenwold Hi-Speed Line, although it is relatively short (14.5 miles), has the three most commonly found types of rapid transit construction: subway, aerial (or elevated), and ground level. On each of these types, we find stations that are built to the requirements of that type of construction subject to the physical layout of the station location site.

Starting at the Philadelphia or western end of the line are three nearly identical subway stations, all located under a typically narrow downtown Philadelphia street. These are two-level stations with an upper pedestrian concourse of ample passenger capacity and a lower train platform of the island-type between the tracks. Stairs and escalators connect the train platform and pedestrian concourse, with the fare collection facilities located at various points in the pedestrian concourse. Only stairs connect the pedestrian concourse to the street above, but there are usually two to four stairways per street intersection. There are no pedestrian entrances into adjacent commercial buildings. From both operating and maintenance points of view, these stations are well laid out and handle large crowds expeditiously.

The next subway station in Philadelphia is a larger transfer connection point with two Philadelphia subway routes. It is a two-level station with train, fare collection, and pedestrian facilities located on the upper level, and only train facilities on the lower level. Many stairs and escalators connect the various parts of this station, including access to the street intersection above. There are also pedestrian entrances into adjoining commercial developments. This station is an outstanding example of one that was created like Topsy. Beginning in 1908, there was one subway route and a simple station, than in 1932 a second subway route was added at right angles to and under the first, and finally, in 1968 a third route was added by building track in what was previously a pedestrian-only concourse above the second route. The result as expected is a chopped-up facility, difficult to operate and even harder to maintain.

The fourth and last station in Philadelphia is a hybrid-type station that has been opened and mostly closed to the public over a 45-year history. It is presently closed because the area surrounding the station cannot generate any passenger demand. This is typical of its entire history. It is a one-level subway station with divided train platforms, two small fare collection areas (one of which may never have been used) and narrow passageways to very narrow stairs leading to the street level. During the July 4, 1976 Bicentennial celebration, the only time capacity crowds ever used this station, it was impossible to unload more than one out of every two trains on a six-minute frequency due to the cramped facilities. It actually took twelve minutes to clear 600 or more passengers per train. Again we found this station very difficult to operate, although maintenance and cleaning were no problem since the station was so little used.

Moving to the New Jersey side of the line, there are two older subway stations in downtown Camden, the first of which is similar to the first three stations in Philadelphia. This station is only partly opened but serves its users well. The second station is an unusual one-level station with large headhouses at the street level. It is, however, well-planned and easy to operate and maintain, although like the first Camden station it has certain parts closed off to the public because of insufficient rider demand.

The seven newer stations in New Jersey are aerial, below grade, or at grade. Three are located on aerial fill with fare collection being in buildings under or alongside the fill. Two are located on aerial structure with fare collection being in a building under the structure. One is located below grade with the fare collection building spanning the tracks. The seventh and newest station is located at grade with the fare collection area being tunneled under and alongside the track area. In all cases except the seventh station, the fare collection facilities are compact and designed for the expected riding. Unfortunately, the terminal station is of this same size and has proven woefully inadequate since the daily passenger load at that station is about four times the original estimate. We have tried many times to improve the operation of this station, but the only practical solution seems to be an extension of the line beyond this station to dilute the crowding problem. The newest station incorporates many of the thoughts and experiences gained from using the original six stations, and is spacious, with easy maintanance. It is a three-track through station, designed for maximum flexibility in train operation as well as good station operation.

The description of the Hi-Speed Line stations shows that proper planning, based on accurate research, can result in easy-to-operate stations. It also clearly shows that poor research and cobbled-up expansion programs can result in stations that are difficult to operate. At least three items become important in good station operation.

First, pedestrian entrance and exit facilities at the station sites must be adequate to handle the largest expected usage. Since a feature of rapid transit is its ability to handle unusually large crowds for unusual events, it is necessary to provide more than just adequate doors, stairways, escalators, and passageways to move large crowds. Merely installing a large stairway to a street exit that ends abruptly at a curb line will not prove adequate to move a large crowd out of a station. The crowd has to move somewhere away from the stairwell site and a busy street or station roadway is not conducive to further movement of a surging crowd.

Second, fare collection facilities must be adequate to handle the largest crowds. Ticket sales lines, either behind manual or machine dispensers, cannot back up into one another or into other fare collection paraphernalia. Since two-way movement is required through most fare collection areas, conflict between these two groups must be minimized. Back-ups of passengers exiting through fare collection areas must not retard train movements to the point where passengers cannot even exit trains because of full platforms, stairs, and passageways.

Third, train platforms must also be adequate to handle unusual peak crowds. Boarding passengers must be able to "spread out" along a platform in order to equally fill up the cars of a multiple car train. Stairwells, elevator shafts, utility rooms, advertising signs, trash containers, concession stands, and other impediments to train platform flow should be minimized.

Other factors to be considered in station operations are signs and station announcements. PA systems should be designed to be distinctly heard.

Passengers on train platforms are already in a dungeon-like atmosphere, and the addition of an unclear or booming PA announcement does little to improve the passenger's perception of an already undesirable condition. Signs should have a purpose or not be installed. A few years ago we ran a survey in our stations to see if we could remove excess signs, and as a result we removed about half the signs at the main downtown station, and revised the other half. Signs and standard PA announcements should be reviewed periodically to see if they are even applicable to today's operation.

Before discussing the remaining topic - station maintenance - the subject of station cleaning should be mentioned. Station cleaning should serve two purposes. One of course is the aesthetic value of a clean station. The second is the elimination of safety and fire hazards, such as piles of debris, pools of spilled soft drinks, and mounds of sticky items on benches, all of which cause insurance claims, both major and minor, and ill will. Careful cleaning of stations will also reveal developing maintenance problems that can be corrected before they become major problems. In the operation of a station, daily cleaning becomes a necessity if passenger confidence in the quality of the rapid transit system is to be maintained. Emergency cleaning is also necessary around the clock to remove obvious emergency hazards. Stations should be designed so that cleaning can be done at minimum cost. Dirt-collecting areas and corners should be eliminated where possible. Cubbyholes, architectural barriers and super-artistic monuments have little value in a station if they simply become oversized trash receptacles. On the other hand, good placement of trash disposal containers will enhance the cleanliness of a station and make the passenger want to participate in keeping the station clean and presentable.

Station maintenance becomes an important factor to a rapid transit system, particularly as that system ages. When a system first starts, warranties generally cover the initial repair problems, including mechanical and structural defects. Once corrected under the respective warranties, these items should hold up for some time. The first time maintenance or repairs are needed to a new station is usually the result of a natural or man-made catastrophe. Lightning, flooding, fires, and even train derailments can cause damage to a station that could well require major repairs. As time goes on, painting, fixing of sidewalks, and roofing become major maintenance problems.

Preventive maintenance and continued inspection of the station by maintenance people should insure that major structural problems do not show up by surprise. Even the warranties or bonds should be carefully filed away because a roof defect after ten years may well be covered by a warranty or bond.

Maintenance should also be kept in mind when designing station items, such as imposing lighting fixtures which may be great for aesthetics, but will cause horrendous problems when a light tube needs replacing. Likewise, installation of exposed outside signs that always face the bad weather should be reconsidered in light of replacement and maintenance costs of that sign. Leaking and seeping water problems in subway stations also become interesting maintenance problems when they occur on a regular basis. Actually they become even more interesting operating problems when the resulting water is one foot over the track level. A cheap caulking job during construction may save capital cost, but will add operating costs for the life of the station.

Other maintenance problems in station operation include such miscellaneous items as fire extinguishers, emergency lighting, poorly designed concession stands, poor surfacing on well-used platform levels, various types of advertising signs, and a host of other items too numerous to mention. Good station design should minimize these problems. Escalator and elevator servicing and maintenance should be left to the professionals in those fields; transit systems cannot seem to afford the skilled technical personnel required for these sophisticated people movers. However, station air conditioning can usually be handled by the same technicians who take care of the air conditioning in other transit system buildings.

One further subject to be dealt with concerns station siting or physical location. As stated before, one Hi-Speed Line station was built forty-five years ago in a Philadelphia area with no potential for passengers. Almost a half century of operation and non-operation has not changed this condition, since the station is located under a park, and in recent years an additional park has been created adjacent to the station. I am sure no present-day planner can ever remember a city park being turned over to the type of commercial development or residential area that can support rapid transit patronage. In downtown Camden, the two stations were built one block apart. Since the total riding at the two stations is less than many other stations on the line; one would have done the job. Also one new New Jersey station has had little patronage and even less growth throughout its ten-year history. Studies of the original rider estimates show vast herds of passengers originating north of this station. Unfortunately, these riders were north of a river and there never was a plan to bridge this portion of the river. Thus, extra operating and maintenance problems have been created because of poor site selection.

In conclusion, it should be apparent that good prior planning is necessary for good station operation and maintenance, and simplicity in construction helps to achieve that goal. Considerations of future expansion of both the system itself and the area surrounding the station are necessary to reach the goal. Finally, the people who have to operate and eventually maintain the station should be included in the planning process. I agree that most of us were not in a position to comment on a station built forty-five years ago, but we are here today and we are demanding to be heard. If professional operators are not listened to, the planners may well be drafted to operate and maintain the stations they have smugly designed so poorly.

ACCESS AND TRAFFIC

by

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Vice President

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My topic of access and traffic seems to be a catchall for what happens generally in the area outside terminal buildings, and I will try to limit my remarks with that in mind. However, before discussing access and traffic, I think we should again consider the primary function of a terminal. There are many definitions that have been and could still be given. The one that I usually think of is that a terminal's primary function should be the efficient transfer of persons and goods from one mode of transportation to another, where the word efficient includes such considerations as easiest, safest, fastest, and most economical.

ACCESS

A number of questions come to mind when discussing access, such as access for whom, access for what, and what does access mean? For the answer to the question of access for whom, we can consider the user who requires access to the terminal, such as the passenger, the employee and the visitor. Access for what includes consideration of what modes would require access. These could include:

- automobile
- bicycle
- boat
- bus
- moped
- motorcycle
- pedestrian
- train
- trolley or light rail
- trolley bus
- van

The automobile can be further divided into:

- o carpool
- o kiss-and-ride
- o park-and-ride
- o single occupant vehicle
- o taxi

Other modal considerations include access by service, emergency, and goods delivery vehicles.

What is access? Funk and Wagnall's Standard College Dictionary gives the following definitions of access:

1. The act or opportunity of coming to or near; admittance.
2. A way of approach or entrance; passage; path.

These provide a good definition of access and are sufficient for our purpose. It should be noted that while the specifics of access differ by mode, the result should be the same, namely that of efficient transfer.

ACCESSIBILITY AND MOBILITY

Recently, there has been much discussion concerning the words accessibility and mobility, since mobility does not necessarily provide accessibility. As you are aware, we have been updating existing facilities to provide accessibility. Section 504 of the Rehabilitation Act of 1973 states that "no otherwise qualified handicapped individual shall, solely by reason of his handicap, be excluded from participation in, be denied the benefits of, or be subjected to discrimination, under any program or activity receiving federal financial assistance."

A conference on "Transit Station Use by the Handicapped: Vertical Movement Technology" was held by a Subcommittee of Transportation Research Board's Committee A1E03 Intermodal Transfer Facilities on May 20-23, 1979, in Reston, Virginia. The conference proceedings were published in April, 1980 by the Urban Mass Transportation Administration. The conference was attended by design professionals, transit operators, government, industry, academia and representatives of the handicapped community. A number of issues were addressed, including accessibility. Recommendations were made in the four areas of:

- Architectural and Structural Design
- Operating Aspects
- Prosthetic Equipment and Technical Aids
- Vertical Equipment and New Concepts

For questions on the conference and on the specifics of the recommendations, I refer you to Dr. John J. Fruin, who was the Conference Chairman.

In most cases, having accessibility provides mobility; however, in some, it does not. For example, in the Tri-State Region of New York, New Jersey and Connécticut, many senior citizens who have no handicaps do not have mobility, since they do not use the total transportation system outside of their state. Their discount fare tickets are only good for the state in which they reside, and they generally do not take trips at the higher fare rate. In this case, they have complete accessibility but do not have mobility because of the cost problem. I am sure that this problem can be solved in time.

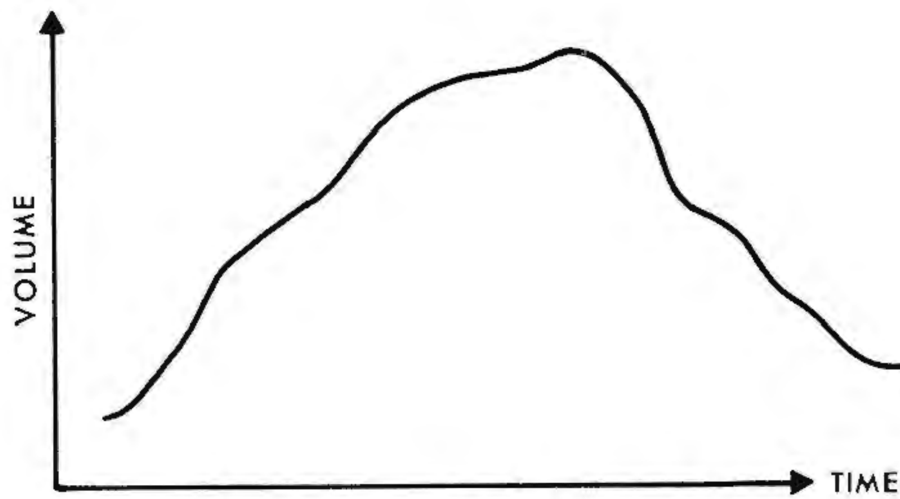
DIRECTION OF ACCESS

Another consideration of access is whether the access is to or from the terminal, since the access requirements will vary by mode as shown in Figure 1. Inbound arrivals at certain facilities occur on a random basis and provide for a smooth and continuous increase and decrease (Type A). In other facilities, the flow of vehicles and passengers is more acute, and may occur on a pulsating basis (Type B), particularly in air and rail transit stations.

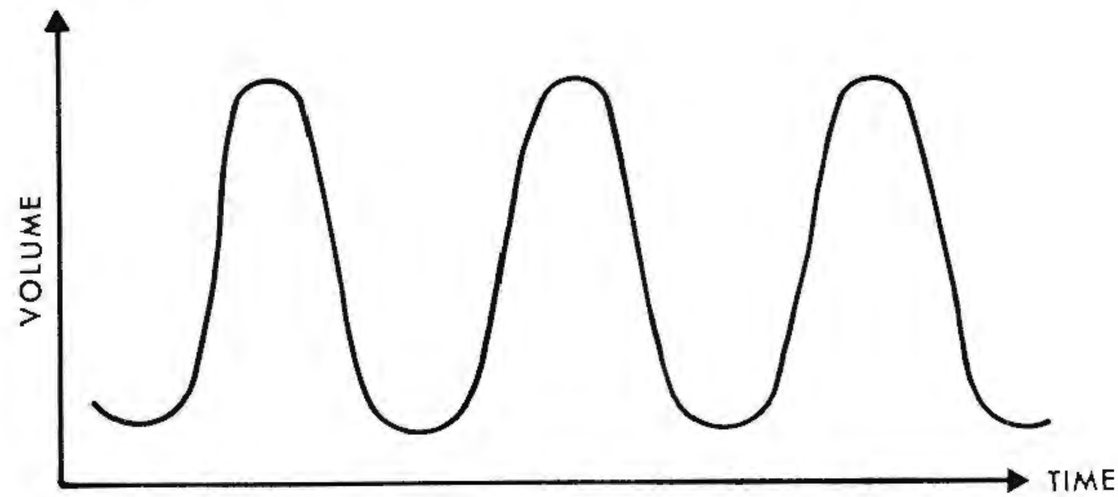
ACCESS SYSTEMS

Another way to consider access is to investigate the access system and look at the different types that are available (Figure 2). Type A is an access pattern that frequently occurs at bus terminals where buses and automobiles use the same line haul system, pass through the same access system, and then enter the terminal. This type of system works well for low volumes. In some cases, it does provide for a separation of movements into and out of the terminal, which is always a desirable goal. An interesting consideration here is that the access may be limited by constraints in either the line haul or terminal portions of the system. Holding areas for passengers and modes are affected by the scheduling of the line haul system where infrequent scheduling may cause more vehicles and persons to be stored for longer periods of time. Also, insufficient berthing facilities in the terminal

FIGURE I



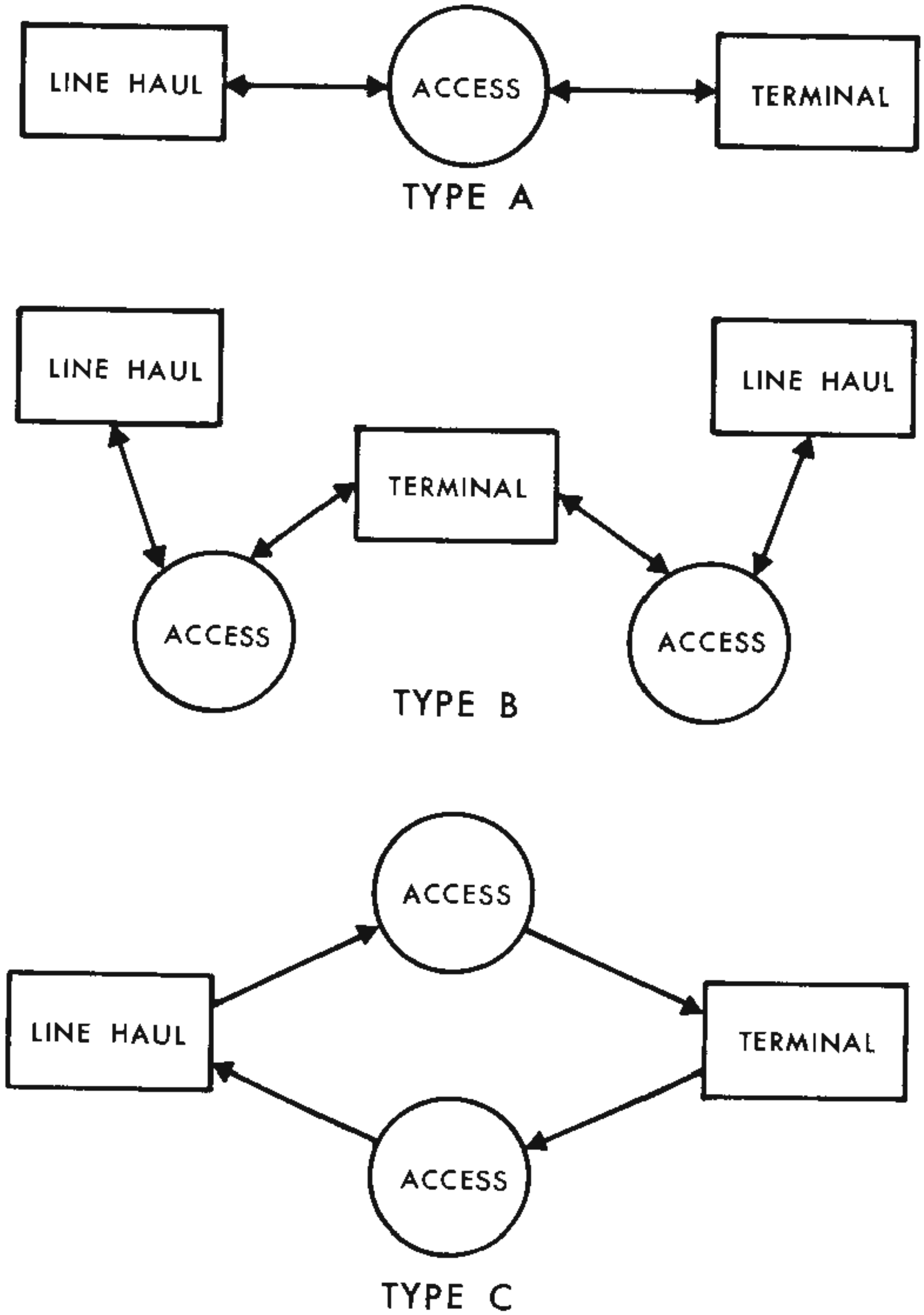
TYPE A



TYPE B

ARRIVAL PATTERNS

FIGURE 2



ACCESS SYSTEMS

could affect the access system. Likewise, an intersection on the access road may have insufficient capacity or poor geometrics and thereby back-up traffic into parking areas or areas adjacent to the terminal proper.

The Type B access system is usually found in a rail transit system where there is a line haul system for the rail transit, which would have access and platforms in the terminal. On the outside of the terminal there would be facilities for automobiles, passengers, park-and-ride, kiss-and-ride, and other access modes. This type of system does provide for more separation of routes of access than the Type A system.

The Type C system of access is one that is preferred and is necessary for high volumes. It provides for directional flow through the access system from the line haul system to the terminal. Actually, this illustration only shows half of the system, since the other half could be a mirror image. This type of access system is usually found in ferry and air terminals.

LOCATION

The location of the terminal also affects the access modes. In a downtown terminal, the predominate access modes will be walking or transit. In outlying areas, the predominate form of access mode would probably be park-and-ride, kiss-and-ride, and bicycling.

In general, access from any mode should be by the shortest possible route; that is, pedestrians should have to walk as short a distance as possible, drivers should not have to walk too far from their vehicles (whether automobile, bus, bicycle, moped, or other vehicle), and the access should also be as direct as possible.

PRIORITY OF ACCESS

While it is desirable to provide access on a first come, first served basis, in many cases, access demands occur simultaneously, and it becomes necessary to establish a priority of access. Items to consider in developing this priority include the importance of the mode with respect to the terminal's function, the vulnerability of the mode to conflict, and others. As a means of stimulating discussion, I propose the following priority to access list, with the highest priority being at the top of the list:

PRIORITY OF ACCESS

1. Pedestrians
2. Bicycles and Motorcycles
3. Surface Transit
4. Taxis
5. Automobiles to drop-off passengers
6. Automobiles that will park

The most positive method of providing priority of access is by spatial separation, either horizontally or vertically. Alternatively, priority can be provided by a time separation (e.g., traffic signals).

PARKING

There are a number of alternative means of dealing with certain segments of the access system, such as how should kiss-and-ride facilities be provided. Should they parallel to the curb of the terminal, or should special holding areas be provided for them? I think that many of these questions will be discussed and answered during the workshop sessions. I would, however, like to deal with another portion of the access system, which is automobile parking, not for kiss-and-ride, but for park-and-ride facilities, employee facilities, and other automobiles. The objective of any parking system should be to provide a space for the motorist that is as close to his or her terminal destination as possible, in a manner that will minimize conflicts with other modes while walking or driving. To aid in this, parking aisles should be perpendicular to the terminal space, so that people walking will be fully visible to automobiles, since they will be traveling in the same area and in many times in the same direction. One item of controversy that has occurred in recent years is the size of the parking stalls, specifically the size of the parking module. Automobile sizes have been changing and have become smaller. They should continue to become smaller as the changeover peaks between 1985 and 1990. Considering that vehicles are smaller and that most terminal parking facilities have a low turnover rate, which might be close to one, new design concepts should be considered that will provide as small a space for parking as possible. This will also tend to reduce walking distances and may increase parking area capacity. At the present time, it will be necessary for designs to consider both large and small automobiles, which can be done by either providing designated small car spaces or changing design standards.

Determination of the number of small car spaces in a facility is usually based on research on local small car usage and estimation of future change (i.e., a best guess). However, consideration must be given to whether the building module in the garage is flexible enough to provide for small car spaces, or if more space will be lost due to changing the large spaces to small car spaces.

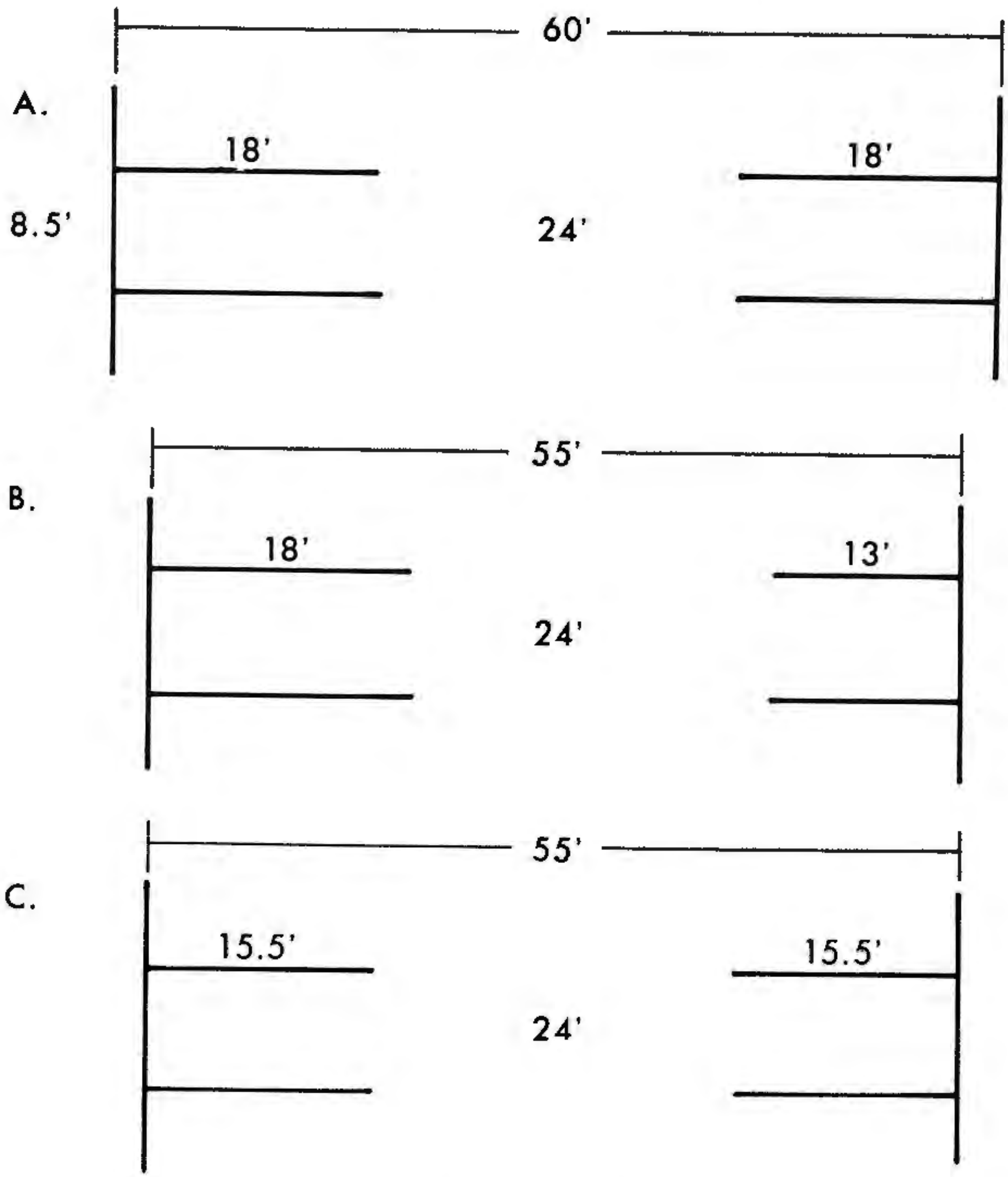
Design standards may be changed by taking the typical parking module and providing smaller stalls to reduce the module width. Figure 3A depicts a typical module width of 60', with two 18' stalls and a 24' aisle. This module has traditionally been used because many automobiles require the large size stall. For example, a 1977 Ford LTD measures 6.5' wide by 18.8' long. As additional points of reference, a 1979 Fiat Strada measures 5' wide by 13' long and a 1980 Chevy Malibu Classic measures 6' wide by 15.8' long. If it is assumed that there is an even mix of small and large automobiles, a parking module could be designed as shown in Figure 3B, where a 55' module provides for an 18' stall for the large automobiles, a 24' aisle and a 13' stall for the smaller automobiles. If this design were only for smaller automobiles, the 24' aisle could be reduced, since smaller automobiles have a smaller turning radius than the large automobiles.

Another way of arranging the parking module, which would accomplish the same goal as shown in Figure 3B, would be to use the module shown in Figure 3C. This module is again 55' wide, but provides for 15.5' stalls and 24' aisle. In this case, a larger automobile would hang over the end of the stall, a smaller automobile would have excess space, and a medium size automobile would extend for the full length of the stall. It may be interesting to see if smaller size stalls will induce the driver to pull the vehicle more to the front of the stall.

CONCLUSION

In conclusion, I hope that I have sparked your interest by raising some of the issues of access without dealing in detail with any of them. I think that detailed discussions will follow in the workshops, where many of the

FIGURE 3



PARKING MODULES

questions, such as when to provide access for the handicapped, what types to provide, how to provide kiss-and-ride facilities, and many other issues, will be addressed.

THOUGHTS ON THE PLANNING AND DEVELOPMENT OF MARTA STATIONS

Richard Stanger

Manager of Urban Design

Metropolitan Atlanta Rapid Transit Authority

Preface

This paper reviews aspects of the planning and development of Atlanta's rapid transit stations. In many regards, of course, the process reflects similar experience in San Francisco (BART) and Washington (WMATA). In no small measure this is because many designers who worked at BART and WMATA also came to work at MARTA. Nevertheless, Atlanta's stations work differently, and it is well to review at the outset why this is true. Three reasons are these:

1. From the first the Atlanta system was to be an integrated bus/rail system, not just a rail facility and not a rail facility added to a bus network. This principle is an increasingly important consideration in station design.

2. It was designed and built in the late 1970's after PATCO, after BART, and, basically, after WMATA. Important lessons were learned from these systems in such areas as fare collection, security, accessibility, and system control, which were incorporated into the MARTA project.

3. By this time as well transit designers and many developers were clearly seeing the urban development possibilities inherent in rail transit. "Value capture", "joint development", and "urban initiatives" are new terms reflecting this interest. Not surprisingly, MARTA has a comparatively better record than BART or WMATA in this regard.

In any attempt to compare the BART, WMATA and MARTA situations, these three points must be kept in mind.

The Atlanta rail system is just over one year old. It operates 12 miles and 13 stations, oriented east and west from downtown. The north/south central spine is still under construction. Rail ridership now stands above 85,000 riders per day - an eight-fold increase in a year. The ten outlying stations--have barrier-free areas, but virtually all future outlying stations will incorporate this feature. Other Phase A stations provide close-in bus bay facilities with ample weather protection.

Figures 1 and 2 depict the barrier-free design at the North Avenue Station (to open September 1981) using a cut-away model. Ordinarily, bus loading areas in such a busy commercial district would be relegated to the perimeter sidewalks. At North Avenue, advantage was taken of extra space behind the main pedestrian entrances plaza along West Peachtree Street to the left. Buses unload around a hexagonal island and transferring patrons proceed directly to the platforms.

MARTA's overall policy of systemwide integration of bus and rail, especially the decision to provide barrier-free transferrng, has forced the designer to assure bus priority. Given the large amount of space buses require, it is easy to compromise. To do an adequate job, separate, protected roadways are needed, minimal walking distance is imperative, and a better level of patron amenities is called for. Among the latter features are good signing and graphics, usable seating, full weather protection, and a generally higher quality of finishing materials than would tend to be the case if the loading area were not physically a part of the rail station.

Unmanned Stations

The second major differentiating policy decision was to have unmanned stations. Both BART and WMATA are designed to have a station attendant at the fare gates. The term unmanned, at least at MARTA, is a misnomer. Between the patrolling police, system supervisors, maintenance crews and bus operators, there will usually be a staff person in a station. In reality, the term signifies two things: 1) that there will not be a booth for a stationary station agent, and 2) that some equipment will be able to operate in his absence.

Obviously, passenger assistance and security monitoring are still necessary functions. To handle this, MARTA opted for a system of five zone security centers, one for each of the four outlying rail lines and another for the downtown stations. An average of seven stations will be served by each zone center located within one of the stations. This precinct approach was chosen over the alternative of monitoring all stations at central control to

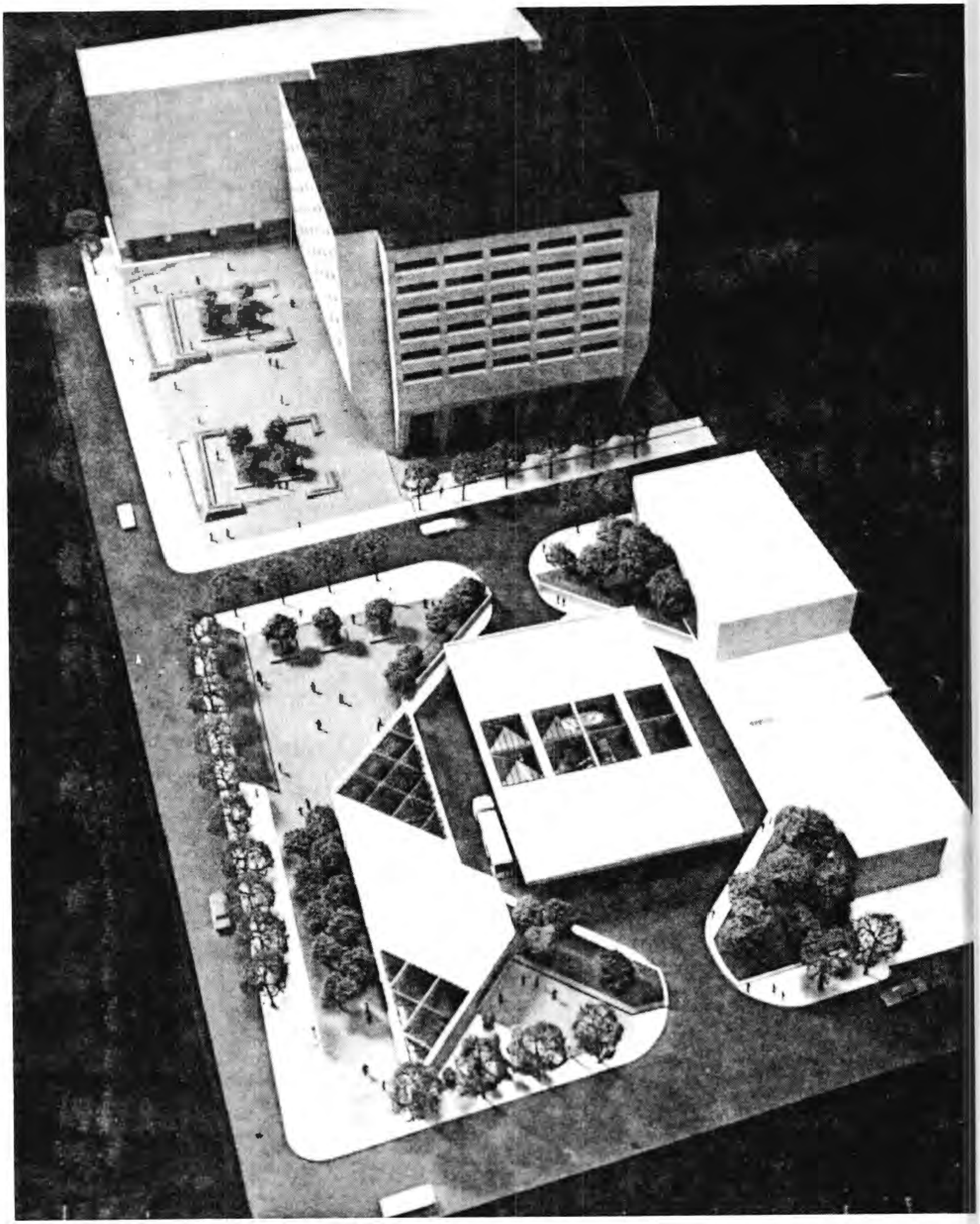


Figure 1 North Avenue Station model showing barrier-free transfer design and joint development.

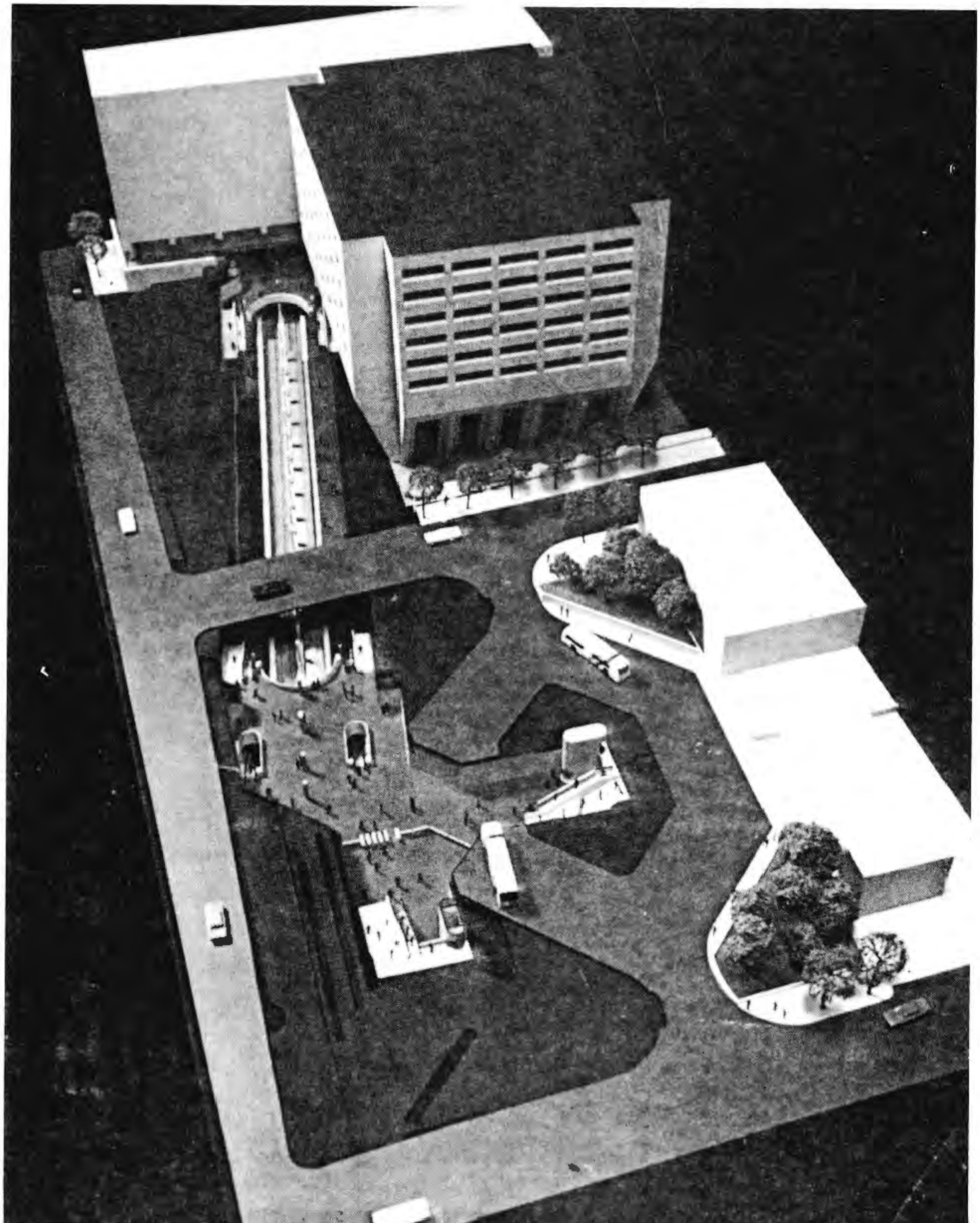


Figure 2 Cut-away view detailing connections.

guarantee a certain minimal effective surveillance level in case of future manpower reductions. Two zone security centers are presently operating. All closed-circuit television cameras, security phones, passenger assistance phones, fare gate controls, restroom door controls and intrusion alarms are monitored at these locations. MARTA's security force for its thirteen stations includes 27 police officers and 12 monitors. The security philosophy and approach were modelled after those employed by PATCO.

Fare Collection

The MARTA fare collection system is also fundamentally different from those at BART and WMATA. These latter systems are based on a graduated fare structure which automatically precludes barrier-free design. (The only fare collection system workable within a distance-based fare structure in a bus/rail system is the European self-service system. No technology exists - nor will for some time - which can retain a record of distance travelled for a rail and bus trip.) The BART and WMATA systems also utilize a number of vending operations which require large storage and queuing spaces.

The MARTA flat fare structure allows the fare gates to be free-wheeling upon exit. At present no fares are vended at the stations; entry is by exact fare, bus-to-rail transfer, or monthly TransCard. Space has been provided, however, for simple token vendors, otherwise more space could have been saved.

Since the principle purpose of a concourse is to collect fares (the other, secondary purpose being vertical circulation, especially access across the tracks) simplifying the fare collection function could have a dramatic effect on the design of the concourse. Especially significant here is the decision to use a European-type self-service system. MARTA seriously considered this option--any new rail system should have good reasons not to use it. At MARTA it was rejected because the flat fare structure and bus/rail integration policy allowed the use of very simple fare gates. Had the decision gone the other way, out station concourses could have been greatly reduced in size, and in some cases eliminated. The resulting cost savings should be credited to the self-service alternative in any fare collection study. Self-service, by eliminating the fare gates, also greatly increases accessibility. This objective is compromised at MARTA, the only unmanned, accessible rail system in the world.

MARTA's fare collection system was also tailored to reflect the overall bus/rail network. Roughly 60% of arriving patrons will transfer from buses, so the transfer problems dominated the fare collection study. Although WMATA expected about the same volume of bus-rail transferring, provisions to handle this conveniently were not adequately incorporated.

Station Uniqueness

The MARTA Board of Directors also as a matter of policy decided that all stations should look different. This, of course, sets MARTA apart from WMATA. It was subsequently decided to award the design of each station to a different design firm, primarily to help the local design firms ailing from the 1974-75 recession. Standardization was retained over such details as lighting fixtures, doors and hardware, plumbing fixtures, etc. through the Manual of Architectural Design. Interestingly, this didn't seem to significantly affect the cost of the stations. Preliminary calculations indicated that the costs-per-square foot for the first five at-grade stations all hovered within a few dollars of $85; the comparable figure for aerial stations was $105, again with little deviation among the four aerial stations.

Two additional policy decisions should also be mentioned. There are not as significant as the first four, but they do affect the design of the stations. The first was the decision not to run the rail system all night but to close down all stations between 1:00 a.m. to 5:00 a.m. This forced the designers to design limited and securable entrances which could be easily operated. At that time (1975), MARTA was the only U.S. system to purposefully close down at night. BART and WMATA both initially closed down for system testing purposes, but were to operate all night.

The second decision - on concessions - illustrates an interesting point. The MARTA Board of Directors never acted one way or the other on concessions. The General Manager, however, favored concessions except those of food and drink. The operations and financial planning personnel set up criteria for the inclusion of concession space. Yet the designers apparently did not want concession spaces. Necessary space allocation and conduit runs were never included. As a result, even though there is a policy in favor of concessions, none of the MARTA stations have concessions.

Lessons Learned

This section discusses a number of lessons learned either during the design process or based on operating experience. There are innumerably more, of course, but these are the most important and most germaine.

1. Keep strict control of the conceptual design process.
2. Develop a strategy for handling staged construction.
3. Reduce the size of the stations.
4. Increase the physical tie-ins with surrounding development.
5. Increase efficiency of parking lots.

Conceptual Design Process

Initially MARTA's conceptual design process was redundant and costly. The basic work was done by MARTA's General Consultant with MARTA staff having primarily a review function. However, the architectural/engineering design firm that was subcontracted to do the detail design was often allowed to make modifications to the conceptual plan. Design costs ballooned, and the results were often not improvements on the original plans.

MARTA took several steps to correct the situation. First, it took on the task of preparing the conceptual plans for every station. This allowed much better control of this, the most important, phase of the work. The present conceptual design effort is overseen by a Steering Committee of three, representing Operations, Engineering and Planning. The other step taken to control the design process was to require the A/E firm to strictly adhere to the developed conceptual plan. This not only maximized A/E talents but also guaranteed the functional integrity of the plan.

Temporary Terminal Stations

The most pleasant surprise MARTA has upon rail start-up was the success of the service. This success was most dramatically felt at the two temporary terminal stations, Avondale and Hightower. Both had overflowing parking lots almost immediately after opening and are almost at their ultimate demand. Unfortunately, Avondale and Hightower Stations were not designed to be terminal stations. MARTA thought it could build the system much more quickly than is actually feasible, and so for another ten years Avondale and Hightower will be overcrowded.

The lesson learned is to project for possible interim terminal stations an estimate of possible interim demand by mode. The parking lots are sized for the long-term demand, with any interim excess provided for, if possible. Usually, however, interim parking demand cannot be met and some overcrowding has to be accepted. Not so for bus bays. The number of bus bays required for interim demand at the temporary terminal are provided, often at substantial cost. Once again, this reflects MARTA's concern for bus priority.

Station Size

There is general agreement that MARTA stations are too big. For several reasons, all new rapid transit stations are too big: 80% federal money (everything is bigger with federal money), the tendency to make something new better (bigger) than its predecessors, and the BART/WMATA influence on many new system designers. PATCO stations should have been models to work from. (It is interesting to note that PATCO is not part of this program, perhaps in part because its stations are too small.) It is also noteworthy that the conceptual design of the initial MARTA stations was strongly controlled by architects, who naturally tend to favor monumentality and isolation from adjacent land uses.

The process is now controlled primarily by engineers, which presents other problems but does help to reduce monumentality. Future stations tend to be less conspicuous, often being within open-cut sections. Costs are scrutinized more closely so that such "luxuries" as skylights, high ceilings, artwork, and landscaping are fewer. There is still a good ways to go, particularly within ancillary spaces. These various rooms are typically quite oversized - except in the view of the engineers.

Urban Development

MARTA is also incorporating into its station designs more pedestrian amenities and development tie-ins not viewed as appropriate in the past. Examples include more usable plazas, provision for a future roof/plazas, pedestrian bridges, space for future air rights touchdown points, and a transit mall. Previously, MARTA's station designers felt strongly that unless a developer was ready to build, cash in hand, the transit system should not include tie-in features speculatively. The excellent examples of joint development MARTA does have came about because the timing and cash coincided with its schedule. The designers have now begun to allow such features into their designs, in anticipation of future construction.

Parking Lot Designs

Another discovery made after rail start-up was the surprising number of small cars using the lots. At Avondale Station, 50% of the cars were under 15 feet long (the size of a Capri). The designs for the Phase A lots had assumed a much smaller mix of small cars and so such spaces were fitted in haphazardly. New lot designs have as many as 65% of the spaces tailored for smaller cars with aisles only 50 feet apart. Sections of the lots in 250-foot modules are designed for easy conversion from four 63-foot aisles to five 50-foot aisles. This change will increase parking lot capacities by up to a third.

Major Station Design Accomplishments

There are certain very good design features to be studied from MARTA's Phase A station design experience. New systems reviewing MARTA's work should focus on these aspects of the process.

Integration of Bus and Rail

In the heyday of rail construction in this country - before 1940 - the physical integration of modes within the station structure was not unusual. It has become so since then. MARTA may go a long way toward reversing the trend. While there are certainly additional improvements to be made, the re-incorporation of bus loading areas into the paid area of its stations is MARTA's biggest contribution to good station design. It is the essence of the concept of the integration of bus and rail. By increasing convenience, it increases the attractiveness of the system and, therefore, system patronage. It also allows the possibility of timed-transfer operation, the ultimate step in system effectiveness. It also properly brings to the bus a co-equal status with the train.

Urban Development

In spite of reluctance on the part of designers to accommodate, MARTA, even in its relative infancy, can show excellent examples of joint development projects and good urban design. The Georgia State, North Avenue, and Omni Stations would compare favorably with any joint development projects anywhere. The Civic Center, Peachtree Center and Five Points Stations have excellent tie-ins to existing (and future) developments. Other stations have been specifically designed to encourage and incorporate future air rights and value capture possibilities. For a new system which has yet to open its downtown stations, what Atlanta has done is exceptional.

Station Operations

The philosophy of unmanned stations, with its complimentary security arrangement, has provide to be very workable and flexible. Both were extensively copied from the PATCO system and compliments that system's innovation and foresight. After a year of operating 19 hours each day, MARTA can still claim it has not had a serious patron assault. Except under a complicated fare structure or collection system, a special fixed attendant's booth does not seem warranted.

Landscaping

There have been many favorable comments on MARTA's landscaping effort, which has been seen as a major visual benefit of the system. It is mentioned here to emphasize its importance; there is a tendnecy (for instance, at MARTA) to reduce landscaping to cut costs. (This is really false economy because landscaping is the least expensive way to cover ground.) What has been learned at MARTA, however, is to treat landscaping more in line with how highway departments treat it. The use of extensive hydroseeding of wildflowers, the use of many small plant specimens instead of fewer large ones more susceptible to dying, and the use of handy, native species instead of possibly nicer, more exotic plant material are all becoming part of MARTA landscaping criteria.

In Conclusion

Faced with the dilapidated, dangerous image of rail stations in our older cities, transit planners in the 'sixties began to feel that large, beautiful stations were a major factor in attracting commuters away from their automobiles.

The experience of PATCO's Lindenwold Line, with its compact, spartan stations - and high ridership - could have shown otherwise. By 1972, however, the excitement of the BART project, with its stunning station designs, overshadowed the simple lession of PATCO. What counts is almost entirely how the system works, its reliability and access convenience.

Another misconception has been that stations are "systems of interacting components or modules." (Reference 1). They are this but only superficially. To see them only in this way misses the essential point: stations exist solely to serve the fundamental job of transferring passengers between modes within a transportation network.

Stations must provide for the rapid, safe, and easy interchange of passengers. In an urban context this means that a downtown station should make it as easy as possible to walk from the train to the destinations, using direct connections, pedestrian streets, etc. In outlying stations the emphasis may need to be on quick, convenient transferring from bus to rail, both modes being treated as the partners they are. To know how to design a station, one must first understand the characteristics of the overall transit network, the operational requirements of the modes served, and the nature of the fare collection and security systems. Anything else is secondary.

The Procedural Guide to station design - the focus of this conference - did not really convey this hierarchy. It was stressed in this paper on purpose. The design of rail stations, like any design, is in large measure an art. Yet it is based on certain principles. These transcend the design technicalities necessary to complete the work. The difficulty is to comprehend the principles involved. It requires study of other's mistakes and successes, so that new systems may improve. This paper has tried to help by exploring some of MARTA's experiences.

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RECENT EXPERIENCES IN TRANSIT STATION DESIGN: WASHINGTON METRO

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Senior Urban Planner
Washington Metropolitan Area Transit Authority

I believe we at the Washington Metro are in an excellent position to discuss current experience in transit station design.

We started operations in early 1976; we opened five stations in March of that year. We now have a total of 38 stations in operation and will open three more this November. Figure 1 shows the status of our operating schedule. For those interested, the 38 stations are on about 33-1/2 miles of track.

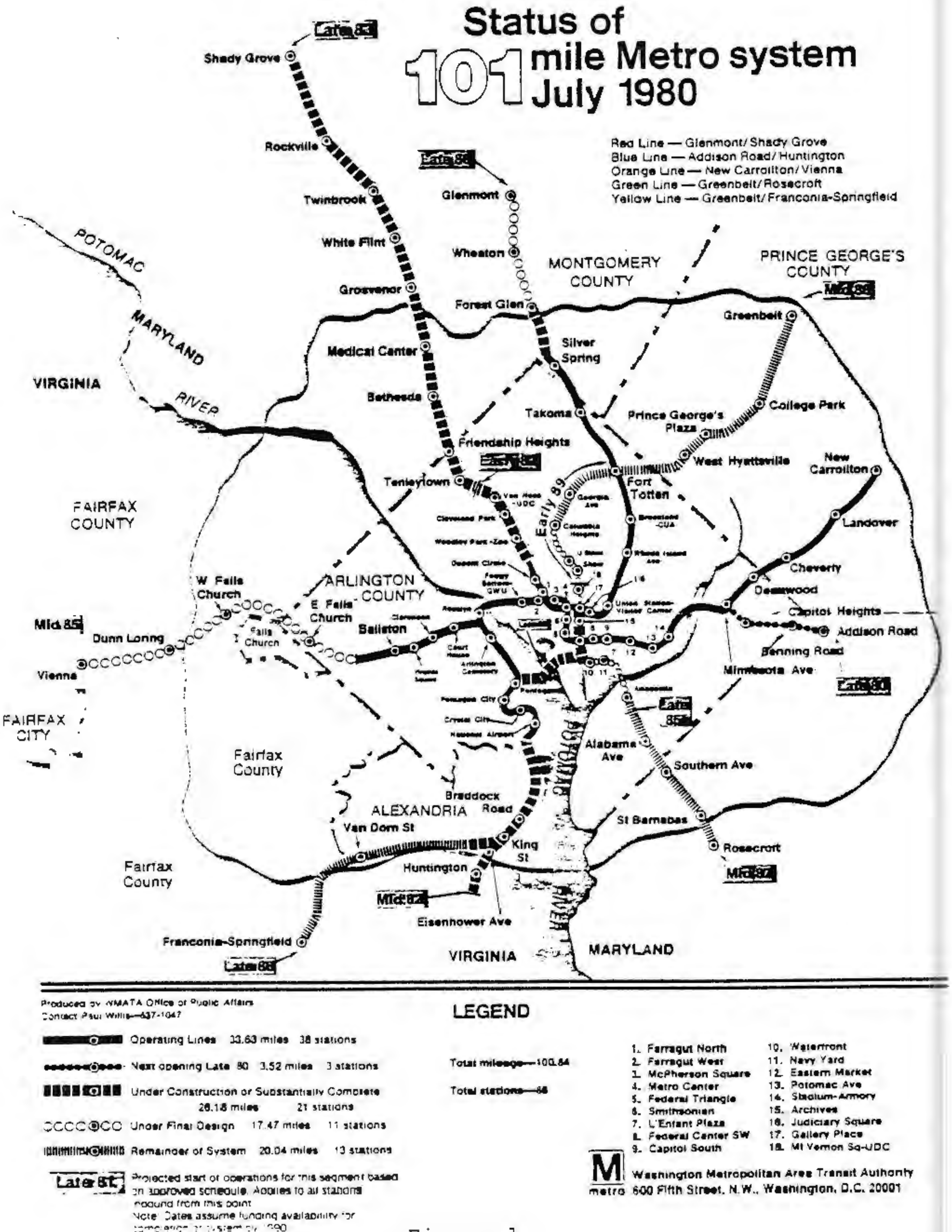
The operating stations run the gamut of type, setting and use: from subway to surface to elevated -- from downtown to urban to suburban -- and from very lightly used to overloaded.

I note that a tour of the system is scheduled for you later in the conference. I would strongly urge you to take the tour. In fact, I have assumed that your stay here will include some personal review of our system, and I have purposely omitted showing slides of the system since the actual thing is available and is much more impressive.

By way of background, I refer you to "Design of Pedestrian Facilities for the Washington Metro", a paper given at a conference in 1974. In that paper I review three basic topics:

- The statistics and standards on which station site planning and layouts were based.
- The planning and coordination process, as it was when we started in the early sixties and as it is now.
- And a general classification system for station type.

The best way to approach the discussion is to review our operating stations and how the designs are working. Prior to looking at some of the individual stations, however, I should describe our station monitor system. The monitor system is the principle means by which the Office of System and Service Planning continuously reviews the working of each station. The



Status of
101 mile Metro system
July 1980
Red Line — Glenmont/Shady Grove
Blue Line — Addison Road/Huntington
Orange Line — New Carrollton/Vienna
Green Line — Greenbelt/Rosecroft
Yellow Line — Greenbelt/Franconia-Springfield
Shady Grove
Rockville
Twinbrook
White Flint
Grosvenor
Medical Center
Bethesda
Friendship Heights
Tenleytown
Glenmont
Wheaton
Forest Glen
Silver Spring
Takoma
Fort Totten
Prince George's Plaza
West Hyattsville
College Park
Greenbelt
New Carrollton
Landover
Cheverly
Deanwood
Capitol Heights
Addison Road
Benning Road
Minnesota Ave
MONTGOMERY COUNTY
PRINCE GEORGE'S COUNTY
POTOMAC
MARYLAND
RIVER
VIRGINIA
FAIRFAX COUNTY
ARLINGTON COUNTY
W Falls Church
E Falls Church
Ballston
Dunn Loring
Vienna
FAIRFAX CITY
Fairfax County
ALEXANDRIA
Braddock Road
Van Dorn St
King St
Huntington
Eisenhower Ave
Franconia-Springfield
Alabama Ave
Southern Ave
St Barnabas
Rosecroft
Early 89
VIRGINIA
MARYLAND
Produced by WMATA Office of Public Affairs
Contact Paul Willis—637-1047
LEGEND
Operating Lines 33.63 miles 38 stations
Next opening Late 80 3.52 miles 3 stations
Under Construction or Substantially Complete 26.18 miles 21 stations
Under Final Design 17.47 miles 11 stations
Remainder of System 20.04 miles 13 stations
Projected start of operations for this segment based on approved schedule. Applies to all stations inbound from this point
Note: Dates assume funding availability for completion of system by 1990
Total mileage—100.84
Total stations—86
1. Farragut North
2. Farragut West
3. McPherson Square
4. Metro Center
5. Federal Triangle
6. Smithsonian
7. L'Enfant Plaza
8. Federal Center SW
9. Capitol South
10. Waterfront
11. Navy Yard
12. Eastern Market
13. Potomac Ave
14. Stadium-Armory
15. Archives
16. Judiciary Square
17. Gallery Place
18. Mt Vernon Sq-UDC
Washington Metropolitan Area Transit Authority
600 Fifth Street, N.W., Washington, D.C. 20001

Figure 1

monitor system was installed at my suggestion by the Assistant General Manager in charge of transit services. It was done shortly after the system opened. The monitors are exclusively the staff of the Urban and Site Planning Branch of the Office of System and Service Planning. Each monitor reviews a specific set of stations every two weeks. The monitor notes any problems and takes whatever action is necessary, including follow-up. I should note that the monitor has no authority over, nor is he concerned with, the station attendant except to assist him in any way possible to operate a better station or eliminate a problem. The monitor personnel involved are all long-term WMATA planners. Their experience goes back through all the planning and design of WMATA. They know how things were done and why - and that includes both good design and the goofs, and they can explain these things to operating personnel. Beyond that, when problems arise in the station operation it is usually these same monitor personnel who are called on to solve them. So we literally have to live with our mistakes. Worse yet, we have to live with everybody else's mistakes. But as we catch and correct them we learn, and we try not to repeat them.

Just a few general comments now on what we have done right, and why -- and what we have done wrong, and why. I will be stepping on a few toes, including my own. Keep in mind that the Monday morning quarterback has never lost a game, but he never played in one either. Keep in mind that over the years since the early sixties the influences and cast of characters, both political and technical, which guide Metro are constantly and naturally changing. The raising of Metro is like raising a teenager --you have to experience it to believe it.

To the general comments then:

- Our original parking plan called for 30,000 parking spaces for the full 100 mile system. We knew the demand was far beyond that. Our most recent net income analysis set the demand at over 100,000 spaces. So, as we open our lots they quickly become overloaded. The overloading, the new air pollution rules, energy shortage and gasoline costs have changed the picture now, and the board has recently approved about 25,000 more spaces. So now we have scheduled over 55,000 spaces - still only half of what's needed but certainly a large step in the right direction.

The width of our platforms was the subject of hot debate between the engineers and planners. The engineers won due to cost constraints. So now we have places in the system where the platforms are too narrow to work well. Metro Center and Farragut West are good examples: at both these stations there are actually safety problems on the platform in the area of the escalator landings during the peak periods. Widening the platforms had serious cost implications; but we in planning still hold that the ease and safety of passenger circulation should have outweighed the cost problem.

Turns and curves in the alignment should be consciously avoided. At least they should be reduced to the minimum possible and practical; and the possible and practical should be strained to the limit. Avoidance of track maintenance and replacement make it well worth the effort. Beyond that, passenger comfort is also a consideration. I am afraid the planners have to take the fall for this one - we could have done better.

The staging and funding of Metro's construction is a very complicated and involved process. The problem is that is also is a very flexible one. When the phasing plan was developed, we knew which in-line stations would have to be designed to serve as temporary terminals; and this was done. However, due to many factors, other stations had to serve as temporary terminals. Unplanned temporary terminal accommodations can, and usually are, major and costly.

This involves train storage, maintenance and turnback facilities, train control, operating personnel accommodations, passenger handling and circulation facilities, and station access - both vehicular and pedestrian. The problem is that it is the nature of the animal that the phasing will change. But many of the design accommodations for terminal operation have a long turnaround time for redesign and simply can't be adjusted. In the end, we produce and operate a terminal with make-do facilities and equipment borrowed from other stations. Portions of the switch system for the turnback track at National Airport have to be replaced every 2 to 2½ months; this would ordinarily be done every 2 to 3 years. Every element of the fare collection system, vendors, gates and addfares, have had to be added at Silver Spring; and these are by no means short term conditions. National Airport has been a temporary terminal since July 1977, and will be until 1982. Silver Spring will continue to be a temporary terminal until 1987.

- General maintenance has been forced to use make-do and sometimes cumbersome methods to clean and maintain the system. More attention to the problems of general maintenance during the planning and design could have helped. I have to add, however, that this criticism is universal for anything of any size and complexity that was ever built.

- Metal dust, primarily from the braking system, has been the source of much grief: the stations and everything in them collects a greasy coat of dust. Lights are a particular problem since their intensity is quickly affected. Also, everything in the mechanical and electrical control rooms collects the dust, which can cause serious problems. The mechanical and electrical rooms are supposed to be protected from dust infiltration by close-fitting doors, but the piston effect of the trains blows the stuff into everything

- Not enough concern was given, either in design or during construction, to the maintenance requirements of the power system. This is particularly true where replacement of major components is concerned. There are situations in the system where permanent concrete walls would have to come down to remove and replace transformers or other such equipment. A particularly vexing example is where an appropriate access hatch was designed and built - then completely sealed and paved over.

- The elevator system was imposed on us as a requirement a comparatively short time before we started operations. Location and design decisions were made in a hurry. The elevator system was originally meant for only the handicapped, but, as you know, it is now open to anyone. Some of the elevators are quite remote and insecure. Some do not require the patron to pass through the faregates. We will be saddled with this operating and security problem forever. There is now a plan to place special faregates at the elevator entrances. Sad to say I have no reason to believe these faregates will operate any better than what we already have. The most striking examples of poor elevator location in the system are National Airport (Figure 2), Takoma (Figure 3), and Tenleytown (Figure 4).

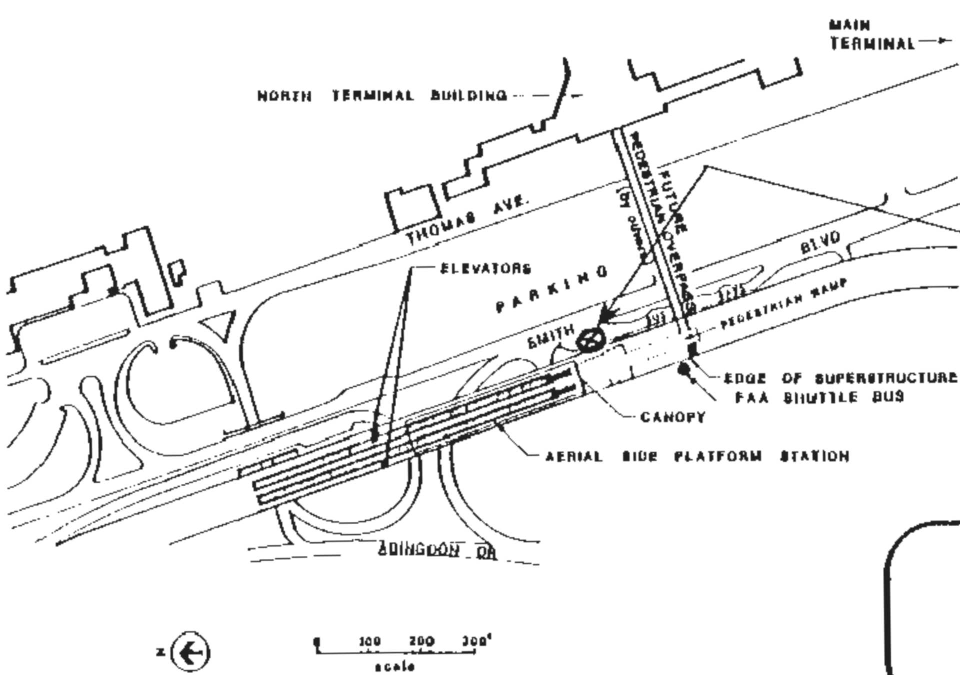
- No discussion of the Metro system is complete without mention of our fare system and our fare collection system. Everyone is aware that our fare system is far too complicated for the public. I doubt that the people who created it understand it. I know I don't. What makes it worse is that it changes quite often, but no one seems to know how to do anything about it. Perhaps it will eventually get so bad that public reaction will overcome all obstacles. The fare collection system itself seems to be improving; at least I am getting fewer complaints about it from the monitors. But is has been, and still is, a very painful shakedown period both for the public and for us. The system is being studied again, and I don't think anyone wants to venture a guess as to the outcome.

Now a few sample comments concerning the stations themselves:

- Figure 2 shows the National Airport Station Site Plan. The National Airport Station is an excellent example of an old saying of mine that you either supply a convenient place for automobile drop-off (in transit jargon we say "Kiss & Ride") or the drop-off takes place wherever it is convenient - whether you like it or not. At National Airport it was decided that there was no appropriate space for Kiss & Ride. I have placed an X where it takes place now. It is dangerous since the Kiss & Ride autos have to leave and join high speed traffic on Smith Boulevard under very risky circumstances. The Kiss & Ride facility should have been designed into the station site plan in the first place, but circulation features of the Airport and the transit station made it difficult, if not impossible.

- Figure 5 shows the Farragut West Station. The Farragut West Station is simply overloaded. Its total daily ridership is about 27,000, with about 17,000 during the PM peak. The station operates fine while headways are maintained and the fare equipment works. If either breaks down the station attendant has to take quick action or a dangerous condition develops quickly.

STATION PROPER												SITE PLAN						
MEZZANINE							Knock out Panels		Escalators	Stairways [Public]	Elevators	PARKING Auto	Bicycles		Motorcycle	Bus Bays Off-street		
	Entrance Ways Into		Fare Collection Ultimate (Initial)															
	SYSTEM	OTHER	VENDORS	GATES -Aisles-	ADDFARE	BUS TRANS-FER	ARCH	OTHER					RACKS	LOCKERS by others		SAWTOOTH	PARALLEL	STORAGE
–	1	1	10(7)	9	2	2	–	–	4	–	2	See General Notes Plate 1			–	3	–	–



The station was designed to allow the addition of a future north entrance. Cost of adding the entrance would be borne by others.

HUNTINGTON (C) ROUTE
NATIONAL AIRPORT STATION
Arlington, Virginia

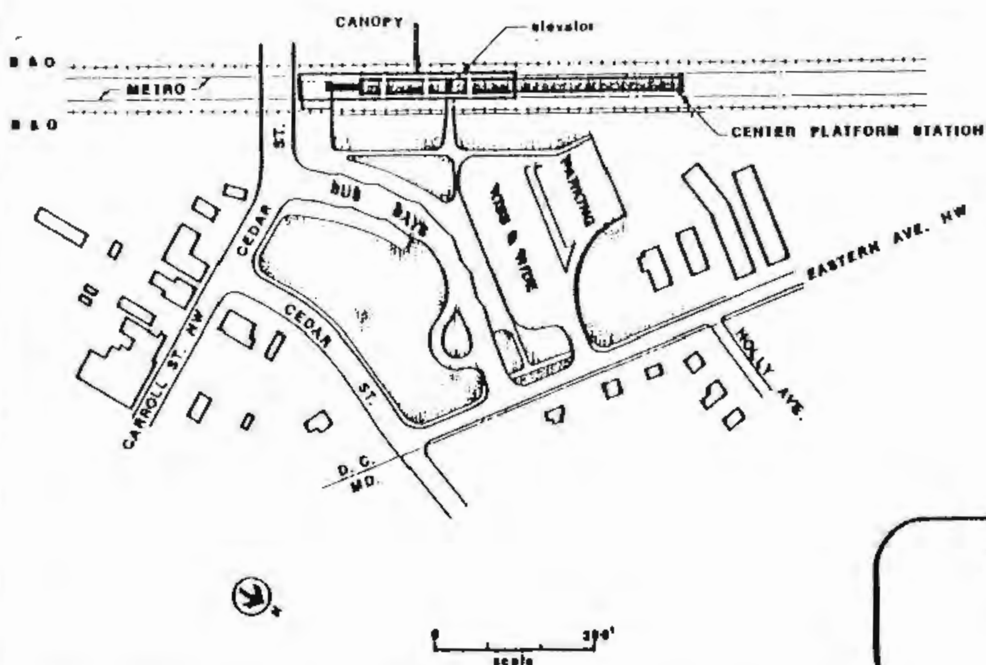
LATEST REV.

SPLN(TRSV)-FPLN(COMP)-PROG(DECO) JULY 1980

Figure 2

STATION PROPER / SITE PLAN

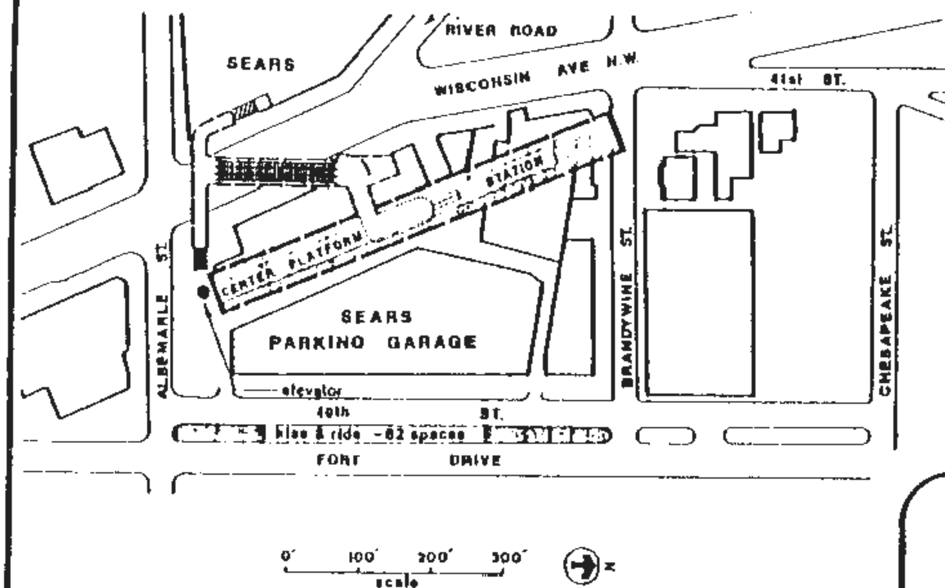
	MEZZANINE: Entrance Ways Into — SYSTEM	MEZZANINE: Entrance Ways Into — OTHER	MEZZANINE: Fare Collection Ultimate (Initial) — VENDORS	MEZZANINE: Fare Collection Ultimate (Initial) — GATES -Aisles-	MEZZANINE: Fare Collection Ultimate (Initial) — ADDFARE	MEZZANINE: Fare Collection Ultimate (Initial) — BUS TRANS-FER	Knock out Panels — ARCH	Knock out Panels — OTHER	Escalators	Stairways (Public)	Elevators	SITE PLAN: PARKING Auto	SITE PLAN: Bicycles — RACKS	SITE PLAN: Bicycles — LOCKERS by others	SITE PLAN: Motorcycle	SITE PLAN: Bus Bays Off-street — SAWTOOTH	SITE PLAN: Bus Bays Off-street — PARALLEL	SITE PLAN: Bus Bays Off-street — STORAGE
–	1	–	8 (7)	7 (5)	2	2	–	–	3	–	1	See General Notes Plate 1			20	9	–	1



GLENMONT (B) ROUTE
TAKOMA STATION
District of Columbia

LATEST REV. ______

STATION PROPER												SITE PLAN						
	MEZZANINE						Knock out Panels		Escalators	Stairways (Public)	Elevators	PARKING Auto	Bicycles		Motorcycle	Bus Bays Off-street		
	Entrance Ways Into		Fare Collection Ultimate (Initial)															
	SYSTEM	OTHER	VENDORS	GATES -Aisles-	ADDFARE	BUS TRANS-FER	ARCH	OTHER					RACKS	LOCKERS (by others)		SAWTOOTH	PARALLEL	STORAGE
–	2	–	8 (5)	8 (4)	2	2	–	–	9	–	2	See General Notes Plate 1						



Landing under Wisconsin Avenue at Albermarle Street for connecting passageway to access on both sides of Wisconsin Avenue. All bus interface are curb drop along City streets. 62 kiss & ride spaces are system built in the median strip between Fort Drive and 40th Street from Albermarle to Brandywine Streets.

SHADY GROVE (A) ROUTE
TENLEYTOWN STATION
District of Columbia

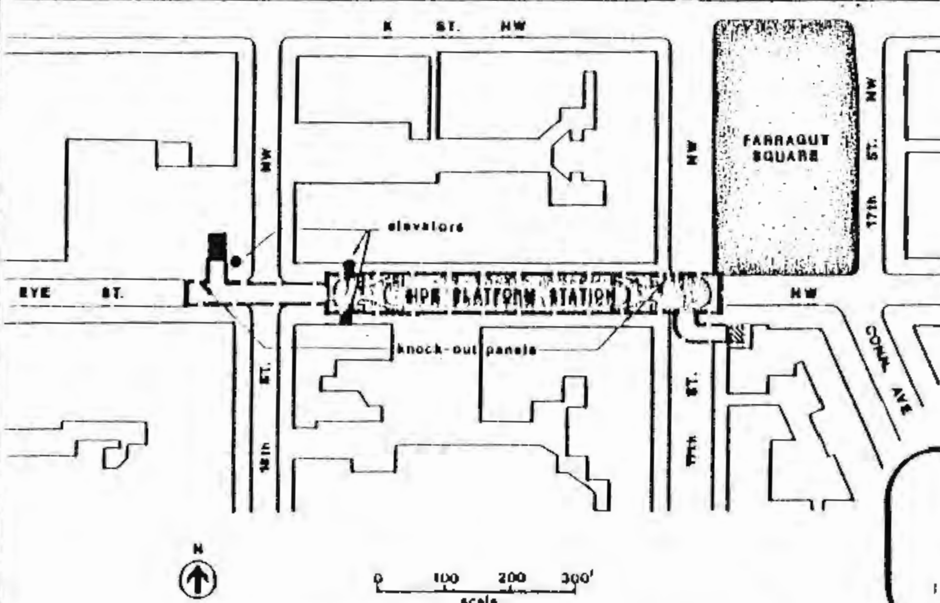
LATEST REV. ________

SPLN(TRSV)-FPLN(COMP)-PROG(DECO) JULY 1980

Figure 4

STATION PROPER / SITE PLAN

	MEZZANINE						Knock out Panels					SITE PLAN						
	Entrance Ways Into		Fare Collection Ultimate (Initial)										Bicycles			Bus Bays Off-street		
	SYSTEM	OTHER	VENDORS	GATES -Aisles-	ADDFARE	BUS TRANS-FER	ARCH	OTHER	Escalators	Stairways [Public]	Elevators	PARKING Auto	RACKS	LOCKERS by others	Motorcycle	SAWTOOTH	PARALLEL	STORAGE
E	1	–	8 (7)	8 (5)	2	3 (2)	1	–	7	–		See General Notes Plate 1						
W	1	–	9 (7)	9 (5)	2	3 (2)	–	1	7	–	3							



The west entrance passageway is extended and a knockout panel has been installed for access into the current International Square development. Knockout panels have been constructed in the arch in "paid" space in both Farragut North and Farragut West Stations to accommodate a possible future underground passageway for passenger transfer between the lines. All costs beyond knockout panels to be borne by others. See also Farragut North Station - Plate 3.

HUNTINGTON (C) ROUTE
FARRAGUT WEST STATION
District of Columbia: Sector -O-

LATEST REV. ____

Figure 5

- Figure 6 shows the Metro Center Station. This is the transfer station for the Red, Blue, and Orange lines, all of which are operating. The problem arises in the number and location of transfer escalators. We are adding the necessary escalators. Installation of these should begin any day now.

These are some of the problems in the system. We have learned from our mistakes, so I hope you can too. But we also learn from our successes. We must be doing something right:

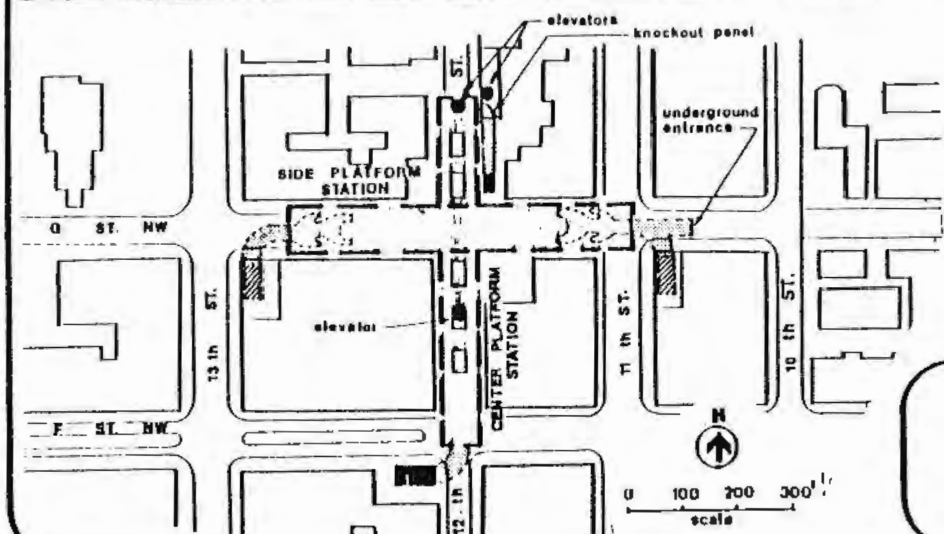
- We are carrying over 300,000 people per day now. This is slightly more than we projected, but it quite significant because our projections were generally considered to be optimistic (Outrageously so by some.)
- Most of the bus system is being turned back at the rail heads and the interface and passenger movement is working well. To give you an idea of numbers: the Pentagon Station handles over 200 buses during the peak hour. Silver Spring handles over 135 and Ballston almost 100; and these are "temporary terminals".
- Our Kiss & Ride facilities are a flow-through, rather than drive in - back out, design. The flow is smooth, safe and efficient. The various schemes for the flow through which suit different local conditions are shown in Figure 7.
- In spite of problems I spoke of earlier, the consistent response from the general public is good. We've received much praise for the design and operation of the trains and stations. We have seldom been criticized without some qualifying praise.
- We still have to make exceptional arrangements to handle exceptional crowds, such as the yearly 4th of July celebration or the recent Pope's visit. But fairly large crowds, such as Redskin games or less auspicious religious and other public gatherings, are handled routinely.
- A major, time-consuming, costly alternative analysis was done by a separate political steering committee and came to the conclusion that our routes were right in the first place.

STATION PROPER

	MEZZANINE						Knockout Panels		Escalators	Stairways [Public]	Elevators
	Entrance Ways Into		Fare Collection Ultimate (Initial)								
	SYSTEM	OTHER	VENDORS	GATES -Aisles-	ADDFARE	BUS TRANS-FER	ARCH	OTHER			
N	1	–	6 (3)	6 (4)	2	2	–	1	31	–	3
S	1	–	6 (6)	7 (5)	2	2	–	–		–	
E	1	1	9 (8)	9 (6)	2	2	–	–		–	
W	1	–	9 (8)	9 (6)	2	2	–	–		–	

SITE PLAN

PARKING Auto	Bicycles		Motorcycle	Bus Bays Off-street		
	RACKS	LOCKERS [by others]		SAWTOOTH	PARALLEL	STORAGE
See General Notes Plate 1						

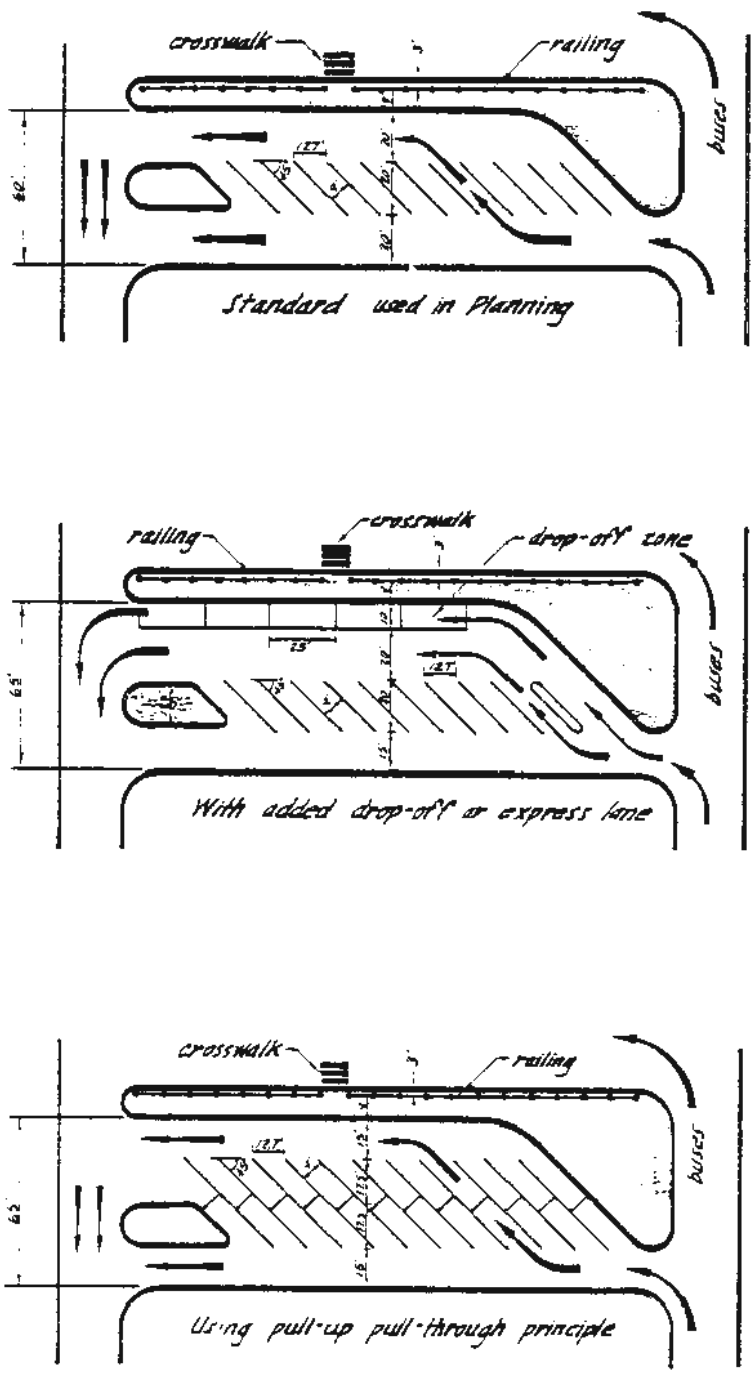


Six additional transfer movement escalators between upper and lower platforms are scheduled to be installed. These escalators are included in the count shown. The north mezzanine has been rearranged to enclose the platform-to-platform elevator in "paid" space.

Knockout panel in east wall of north escalator passageway. All costs beyond knockout panel to be borne by others.

SHADY GROVE [A] ROUTE
METRO CENTER STATION
District of Columbia: Sector -O-

LATEST REV. ______



SCHEME "A"

12 SPACES

SCHEME "B"

15 SPACES

SCHEME "C"

23 SPACES

PROTOTYPE METRO KISS'N RIDE FACILITY

WMATA - Office of Planning

SCALE: 1" = 40' I. s.

DATE: November 3, 1971 s.b.

Figure 7

- The stations:
  - are secure, the system is comparatively crime free.
  - have very little litter problem.
  - are practically graffiti free.
  - are air conditioned.
  - acoustics are controlled.
  - are well lighted, but lighting has to be constantly maintained and could stand some improvement.
  - contain pleasant, controlled advertising.
  - have public announcement systems which keep the public advised.
- The trains:
  - ride on continuous welded rail for a quiet, smooth ride.
  - the track bed has vibration and noise control slabs and pads where needed.
  - contain a public address system by which the public is kept informed.
  - are air conditioned and noise is controlled.
- A good percentage of our riders, over 25%, are being diverted from auto.
- Workers and shoppers are using the system to move around downtown at an increasing rate. Our "Lunch Bunch" traffic has created a third peak period that almost rivals the am and pm peaks.
- Development is occurring at our stations. Metro is changing commuting and shopping in the region. Metro is influencing business and financial decision making because of the ability to move people quickly and comfortably.

I believe there are three marked trends in station location, layout and design.

The first is citizen and local government participation. During our initial efforts and into the late 60's, there was very little citizen participation. There were the efforts of local planners to be of some help and to channel our station location and design into line with their overall urban planning policies, but little beyond that.

With the public hearing requirement and the environmental study process, the local community demanded attention to their opinions. With local cost sharing and our takeover of the bus system, with its big and getting bigger operation deficit, local government, both staff and legislature, became much more interested in our layout and design.

The result is more attention now to community impact of both station and line, and more accountability for costs, both operational and construction. Sad to say the other side of the coin is delay while the community and local government come to terms with final decisions on alignment and station layout. We've been studying and doing preliminary planning on the Greenbelt and Rosecroft Lines for several years now. We still have no firm alignment on the Greenbelt Line, either in the District of Columbia or in Maryland. A decision was reached to use the Rosecroft Alignment for the F route, but that decision is now being challenged in the courts.

Another trend is the strengthening of security on the transit property. To start with there was a design effort to open the stations up by having no dark corners and good surveillance, including closed circuit TV. I consider both efforts as failures at Metro, since we do have plenty of dark corners, and the TV surveillance is often not working correctly or, if it is, the attendant is out of the kiosk trying to cope with fare collection problems. But the trend is there. There is effort in station layout and design to eliminate as much as possible the opportunity for crime and vandalism by incorporating open stations, better lighting, constant and more attentive surveillance, and adequate communication with enforcement personnel.

A third trend is toward ultra-large parking lots at the outlying stations, especially at the terminal stations. To review Metro for this trend just look at the terminals: if you will follow me around the system map:

Shady Grove Station	3,000 spaces
Glenmont	1,800 spaces
Greenbelt	3,000 spaces
New Carrollton	1,900 spaces
with another	1,900 at Landover
Addison Road	1,100 spaces

Rosecroft	3,000 spaces
with another	2,000 at St. Barnabas
Huntington	3,150 spaces
Franconia-Springfield	3,150 spaces
Vienna	3,300 spaces
with another	2,900 at West Falls Church

To cope with such volumes of autos and the feeder bus systems, local jurisdictions must emphasize station access in their highway plans. Stations are becoming major focal points of transportation interface; and this brings with it land use trends, some desirable from the transit viewpoint and some not.

Both my remarks and the handouts are rather general. If anyone wants more detail on any specific matter of Metro, just write or call me, and I will be glad to oblige.

BART STATIONS: A REAPPRAISAL

Wilmot R. McCutchen
San Francisco Bay Area Rapid Transit District

Just over eight years ago, on September 11, 1972, the Bay Area Rapid Transit System (BART) inaugurated a 26-mile service through twelve stations in the East Bay, extending from Oakland to Fremont. During the next two years, service was expanded throughout the 71-mile BART system, including stops at 34 stations - 15 subway and 19 either at-grade or elevated above ground. Just this year, the San Francisco MUNI started service on its level in the four-joint use subways under San Francisco's Market Street and has extended its routes to include the four MUNI stations built by BART on Outer Market Street and at the West Portal of the existing Twin Peaks Tunnel. This is the culmination of over twenty years of planning, design, construction and operation, so it is indeed timely to take stock of the planning and design effort as judged by the operational results achieved so far.

It is interesting, from my own viewpoint, to compare notes with the paper (1) I presented to the Man/Transportation Interface Conference in the Spring of 1972. That paper contains many specific design and planning features of the BART system, and I will not develop all of these here again. Instead, I want to evaluate certain factors, which arise principally out of the station planning process, from the advantage of 20/40 hindsight - not 20/20, because many station design "solutions" are still unclear, even from a backward look. There are several workable solutions to some design problems, and I will attempt to discuss some different approaches that were taken on BART, and how we fared with each.

Basic System Design

First of all, let us look at the basic system layout (Fig. 1). The BART service area is roughly a square drawn on the S. F. Bay Area, 30 miles on a side. The BART system was visualized as an interurban system, connecting principal urban centers by means of high-speed, trunk rail service. Existing transportation corridors were utilized wherever possible. In the major downtown population centers of San Francisco, Oakland and Berkeley, the line is in subway. Also, in these major population hubs, the BART system takes on

SAN FRANCISCO BAY AREA RAPID TRANSIT DISTRICT

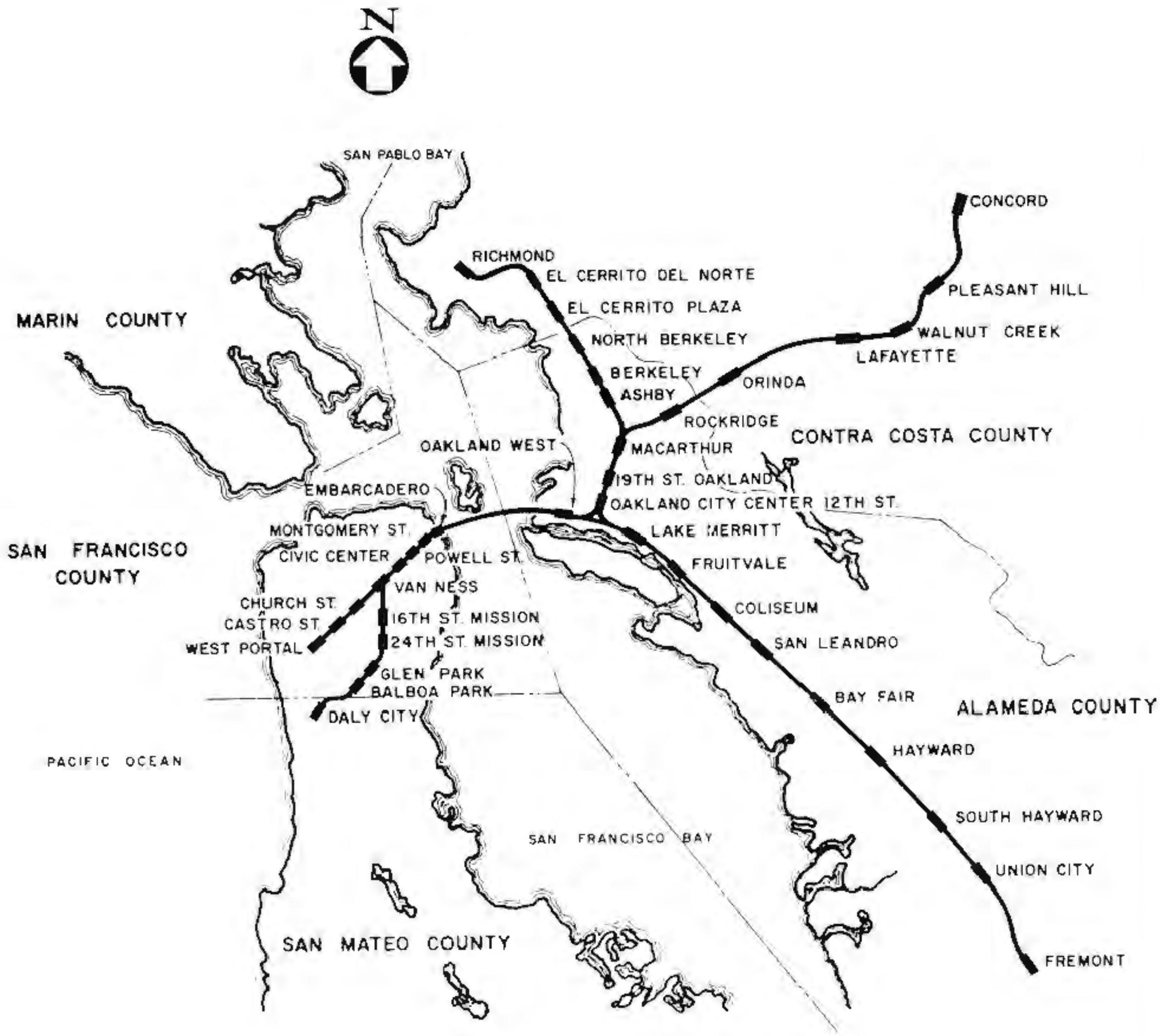


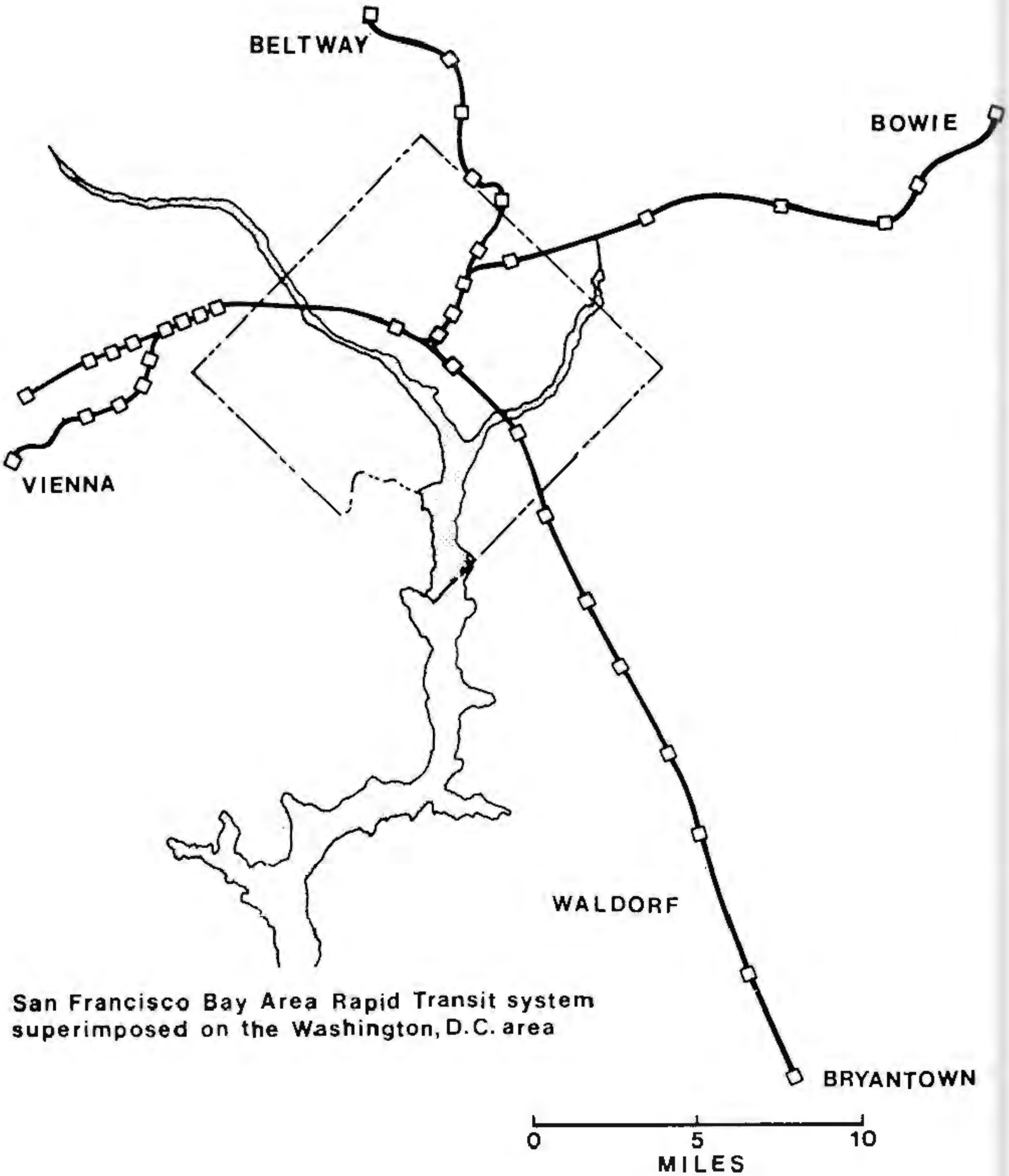
FIGURE 1

the added character of a local subway rail transit. It was conceived by the early planners, however, that the BART system would be augmented by local transit, be it rail, light-rail or bus. This basic layout influenced station spacing and character. Downtown stations are mainly in subway, averaging about six-tenths of a mile separation, while suburban or outlying stations are at-grade or above-ground and are spaced on an average of three miles apart. For comparison with the Washington Metro, Fig. 2 shows the BART network placed to scale on the District of Columbia and adjacent areas.

Based on planned travel times, station dwell times and passenger service areas, the original station numbers and locations have worked out well. During the course of detailed route location, some stations sites were adjusted (e.g. Lafayette, Coliseum) and some which were originally planned as aerial stations were put in subway (N. Berkeley, Ashby). Only one station - Embarcadero - on Lower Market Street in San Francisco, was actually added to the original allotment. The locations of above-ground stations, in established transportation corridors such as freeway medians or adjacent to rail lines, caused the least possible intrusion into neighborhoods. Only during the main downtown station construction was there considerable disruption to normal community activities.

The modes of operation and the projected patronage largely dictate the type of station platform, whether center (island) type or side platform type. Generally, the BART subway stations are center platform. The above ground stations are center platform at terminal stations and wherever turnback operations were planned in the system. Otherwise, suburban stations with a predominant travel direction in morning or afternoon were made side platform.

There still seems to be lively debate among transit planners over the merits of side versus center platform stations. Center platform stations offer great flexibility for passenger loading and unloading, such as at terminal stations, and for traffic reversals generally. On the other hand, they are structurally more expensive than side platform stations, although this cost is offset by the greater amount of escalators and elevators required for side platform stations. Passengers can be sheltered from the elements more easily with the side platform design. From hindsight, there are still arguable points as to whether some of the BART stations would have functioned better with a different design. Perhaps the Oakland West Station, located at the east end



San Francisco Bay Area Rapid Transit system superimposed on the Washington, D.C. area

FIGURE 2

of the Transbay Tube, could have served better as a center rather than side platform station. Also, if the very early and tentative plans for four tracks through downtown Oakland and Transbay had been implemented, the Oakland West Station would have been modelled after MacArthur Station, that is, with two center platforms. These early plans were not implemented, mainly for cost reasons.

There are also a variety of opinions on the subject of a standard architectural style for station design versus a more distinctive design for each station. The BART planners opted for the individualized station designs, although the same architect working with an identical structural form would sometimes arrive at similar architectural solutions. Certain design criteria, however, such as platform length, vertical circulation, maps and signage, fire sprinklers, platform clearances, and minimum surge space, were uniform.

Station Evaluations

In evaluating the station designs collectively, seven general categories of functions can be used for convenience. The following will highlight some of the design features considered to have worked well in practice, compared with those where improvements would be desirable. I have titled these categories: Access (including intermodal transfer facilities); Entry, Exit and Circulation; Fare Collection; Amenities; Lighting, Communications, Alarms and Security.

Access & Intermodal Transfers

Table 1 lists the types of access and intermodal transfer facilities which have either been successful or required improvements when operations got underway. Perhaps the area where early planning most missed the mark was in the allotment of parking spaces to individual stations. Twenty-three stations have parking facilities for automobiles. The original capacity was 17,692 stalls, but this has been increased to a current count of 21,441 stalls, with additional spaces to be added where possible. Also, stall conversion to accommodate smaller cars is underway. Some present capacity, however, such as at North Berkeley and Coliseum Stations, is still under-utilized. Generally, stations near the major downtown cores do not usually have full lots whereas stations near the end of each line are greatly oversubscribed. This type of demand forecast distribution seems to have been missed in the original planning, although the original forecasts in total far exceeded the spaces which could practicably be built in the original construction.

Another important area where improvements have been needed is in BART-to-bus transfer facilities. Since the opening of revenue service, major bus loading areas have been added at Fremont (Fig. 3), Daly City and Concord (Fig. 4), in response to the rapid and large development of local or express bus service in outlying areas. In addition, a BART-Greyhound transfer station is under design at Richmond and at Concord, and a BART-Amtrak connection has been built at Richmond. Still to be solved at these intermodal facilities is the optimum arrival-destination information display for passenger transfers.

Table 1

Intermodal Transfers and Access

Improvements Needed	Good Design Features
1. Optimize parking spaces.	1. Circulation & road width.
2. Better demand forecast for parking.	2. Landscaping & environment.
3. More definitive directional signs, control signs and station identification.	3. Size of stalls.
4. Better parking control measures.	4. Drop-off locations.
5. Better intermodal transfer facilities.	5. Bike racks.
6. Bike and moped storage (lockers).	
7. Station/community development.	
8. Handicapped access.	

Entry and Exit; Circulation

A chief function of a transit station is, of course, the entry and exit to and from the transit vehicle and the circulation from entry/exit to the boarding/alighting step (Fig. 5). Tables 2 and 3 list some of the good and less optimum features of these functions for the BART stations collectively.

Table 2

Entry and Exit

Improvements Needed	Good Design Features
1. Orientation for newcomers.	1. General orientation.
2. Station identification.	2. Maps.
3. Ticket purchasing directions and processing.	3. Surge space for ticketing function, waiting, circulation.
4. Covered entries - subways, bus.	4. Train destination signs.
5. Signage and symbols.	

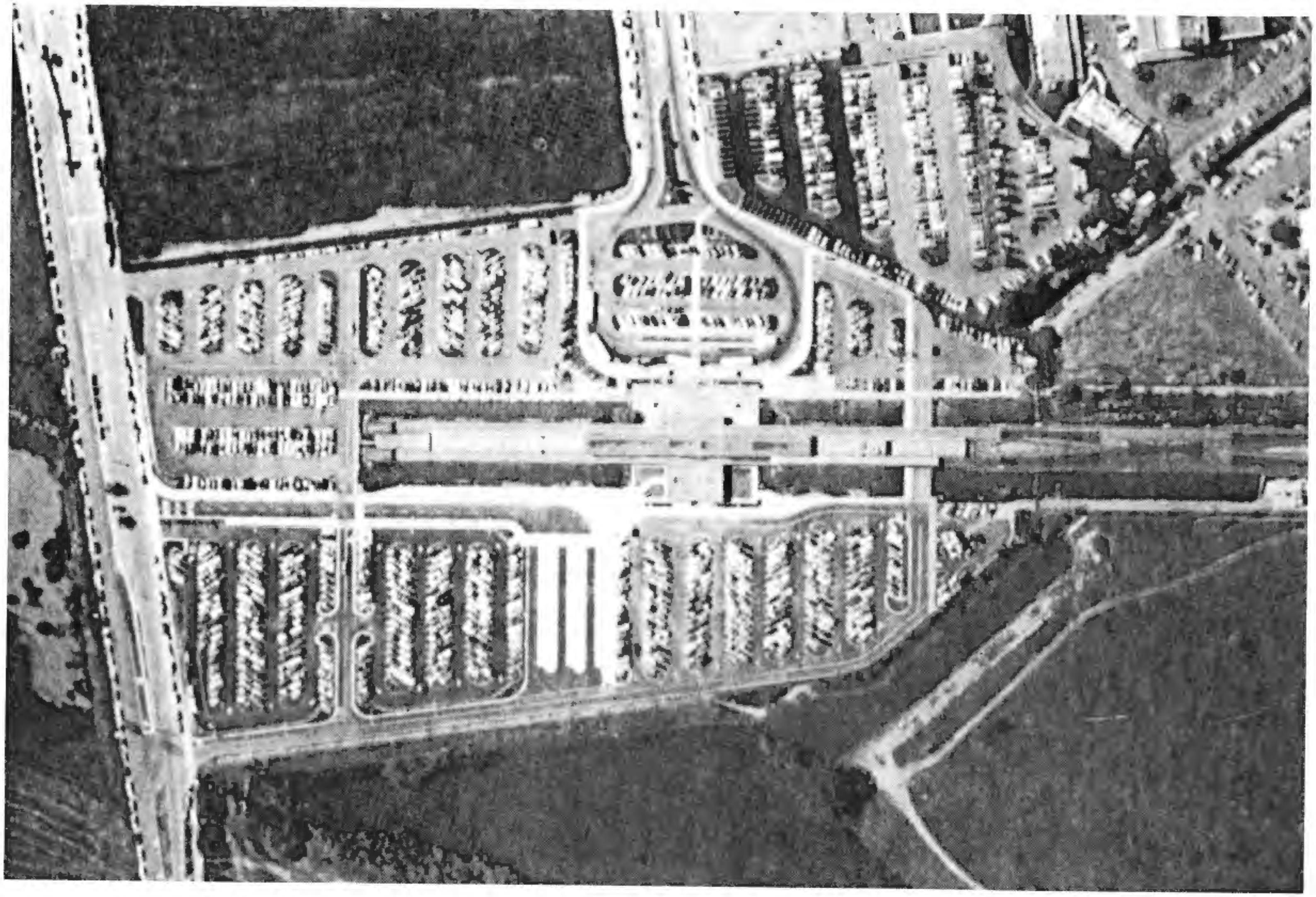


Figure 3 Fremont Station, a terminal station, has had added approximately 350 parking stalls, twelve bus stops and three bus loading lanes (lower right quadrant) since revenue operations began in 1972.

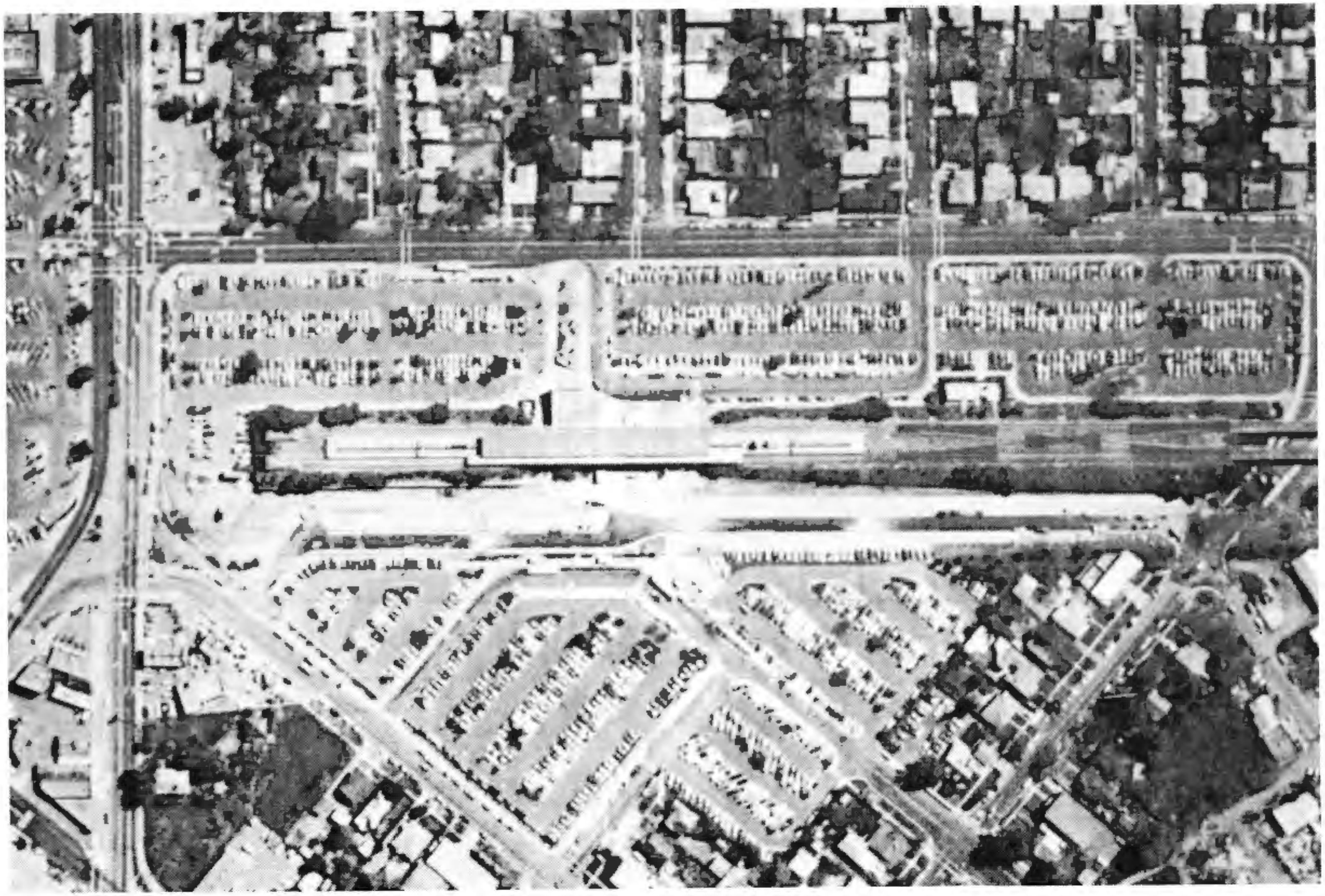


Figure 4 Concord Station, a terminal station provides approximately 1700 car stalls, a new 17 bus-stop access lane adjacent to the station. Also planned is an inter-city bus depot at the lower right of the station embankment.

Figure 5 Berkeley Station showing circulation paths from the main escalator entry to trainside.

Table 3

Circulation

Improvements Needed	Good Design Features
1. Escalators.	1. Queuing and surge space allocations.
2. Reversible treadle escalator reliability	2. Directional flows parallel to platforms.
3. Elevators should not be in free area after ticketing.	3. Spacing of elements optimal.
4. Weatherproofing escalators.	4. Generall good surveillance.
	5. Obstruction free areas on platforms.
	6. Speed of escalators - 120 fpm.

From an orientation standpoint (2), the BART stations make a passing grade. The patron who is acquainted with the system even slightly has little difficulty finding the way by sight lines in and out of the system. The uninitiated passenger, however, usually finds more than a normal degree of trouble in negotiating fare purchases, using his ticket for entry and exit, and finding his way to the correct platform. Signing is usually pointed out as the cause and cure of this problem, although this solution does not seem to be the whole answer. Some people simply do not read signs and will usually require human intervention by the station agent.

In other circulation criteria, the BART stations come out quite well. Queuing spaces are usually quite adequate, the spacing of vertical circulation elements is optimal and uniform, and platform loading and unloading areas are free of obstructions (Fig. 6).

Fare Collection

The fare collection design adopted by BART is perhaps the greatest departure from traditional ways of ticket processing. Certainly no other single feature of the system, other than vehicles and train control, has caused more problems from a maintainability, reliability standpoint. On the other hand, for the initiated commuter, the BART ticket is the great convenience and timesaver it was intended to be in the original concept.

Figure 6 BART criteria provides at least eight feet of clear space from platform edge for patron circulation.

Table 4

Fare Collection

Improvements Needed	Good Design Features
1. Too complicated and confusing.	1. Stored fare on ticket.
2. Needs ruggedizing for reliability.	2. Convenient for high value tickets.
3. High maintenance and servicing costs.	3. Automated selling function.
4. Consider easier processing possibilities. a. Joint fare system b. Zone and discount fares c. No fare gates	4. Clean industrial design of machines.
5. Change for large bills.	5. Adaptability to different fare structures and discounts.

The BART fare system is the "stored fare" system; that is, a ticket can store value on its magnetic tape up to twenty dollars at the time of purchase. Thus a patron can take any number of trips to various destinations within the system, which has a graduated fare structure, without having to be concerned with the exact cost of an individual ride. The single trip cost is automatically deducted from the stored value by the fare gates and a new ticket value encoded and also printed on the ticket.

The fare system permits great flexibility in preparing fare structures, giving discounts for various purposes, and automating the ticket selling function. The system is not without its drawbacks, however. For the first-time rider, the ticket buying and processing functions seem complicated and confusing (Fig. 7). For the type of service to which the machines are subjected, the components must be rugged and kept clean and properly adjusted in order to be serviceable and dependable. There is some question as to whether the present generation of fare equipment is, therefore, altogether suited to the mass transit environment. Consequently, from time to time, there is consideration or study for zone fares, stored ride fares, no fares or flat fares.

Amenities

Every transit station should offer its patrons certain amenities in order to make the trip more comfortable, varied or interesting. Wherever possible, the transit property has sought to obtain revenue from some of the offered amenities, or at least to get a pay-back of cost. While the types of amenities offered depend on individual transit system policies, listed in Table 5 are the

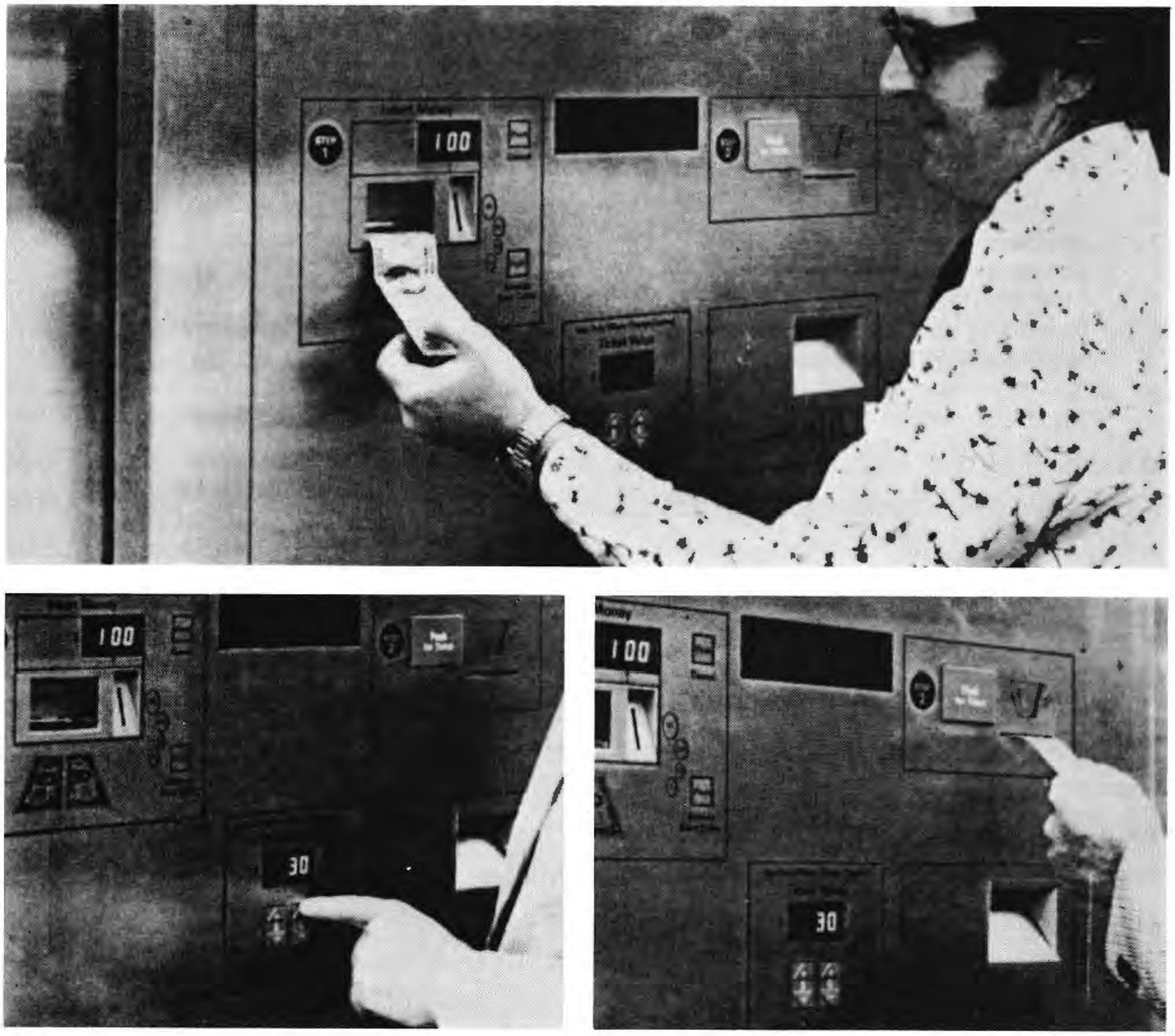


Figure 7 Ticket vending machines sell "stored value" tickets for use in the automated fare collection system. The later model machines shown also give change, if desired.

categories pertinent to the BART system for which either the original design concept has worked out well or some improvements are needed.

Table 5

Amenities

Improvements Needed	Good Design Features
1. Concessions.	1. Advertising - blended with station architecture; standard 2 and 6 sheet format.
2. Wooden benches.	2. Public telephones on platforms.
3. Windscreens.	3. Courtesy phones.
4. Platform edge warning.	4. U.S. Mail boxes.
5. Handling bike lockers and mopeds - rental spaces.	

Platform edge warnings are both a safety item and an amenity to give the blind patron assurance as to his orientation on the platform. BART has not yet solved this problem satisfactorily without introducing unacceptable tripping hazards for the majority of patrons. Courtesy phones and public telephones throughout the station are also both an amenity and a security assist for all patrons.

The concessions and advertising experience has met with mixed success. Both were integrated into the original station designs after much study and thought as to types of concessions to offer and types of advertising to display. It was decided to have manned concession booths at only the major downtown stations, at least initially, with vending machines and newsracks elsewhere. Advertising in stations was restricted to two-and-six-sheet ads and to messages on the train destination signs. The results have been, for the same patronage, that the concessions are barely viable whereas the advertising program is flourishing. Moreover, the ads increase the vitality and interest in a station's appearance.

Security

Since the lighting provided in stations, along with communication facilities and various alarms installed, all impact on security in passenger stations, I have grouped these categories together. Tables 6 and 7 list the design criteria where improvements could be made to enhance overall security and where good security is considered to exist already in the BART system.

Table 6

Lighting, Communications, Alarms

Improvements Needed	Good Design Features
1. More uniform controls.	1. Good ambient illumination.
2. More centralized controls, automated.	2. Good emphasis over sensitive areas - fare gates, platform edge.
3. PA capabilities at end of platforms.	

Table 7

Security

Improvements Needed	Good Design Features
1. Close down of extra fare areas in non-rush hours.	1. Generally good surveillance capability; eliminating blind spots.
2. More CCTV needed. Install <u>initially</u> (conduits at least).	2. Good design a deterrent to abuse/vandalism.
3. Toilets - all in paid area. Controlled by agent.	3. Courtesy phones.
4. Station shutdown.	
5. Re-vamp keying.	
6. Motorize all grills.	
7. Secure access to AFC equipment.	
8. Barriers for fare evasion.	

The original BART station design criteria stressed fundamental architectural features that would "build-in" security factors for patrons. Well-lighted, inviting, spacious and attractive stations, with blind spots and re-entrant corners minimized, were established early as design goals. The station agent's booth was placed to afford maximum visual surveillance of the concourse area (Fig. 8). Toilets, in particular, were to be located in paid areas under the station agent's surveillance and control. Good circulation and surge space, already mentioned, permits patron movement through the station with lessened chances of exposure to petty crimes like pickpocketing.

Where problems in particular station features have arisen, in many cases, the basic design criteria for one reason or another were not followed. One of the cited improvements in Table 7 recommends a better station shutdown system. The original criteria did not envision protracted station shutdowns, but did specify closure of part of the platform and some fare gates during non-peak hours. The BART station security and operations would be enhanced if they could be closed more tightly during non-operating hours, either on a whole or part station basis.

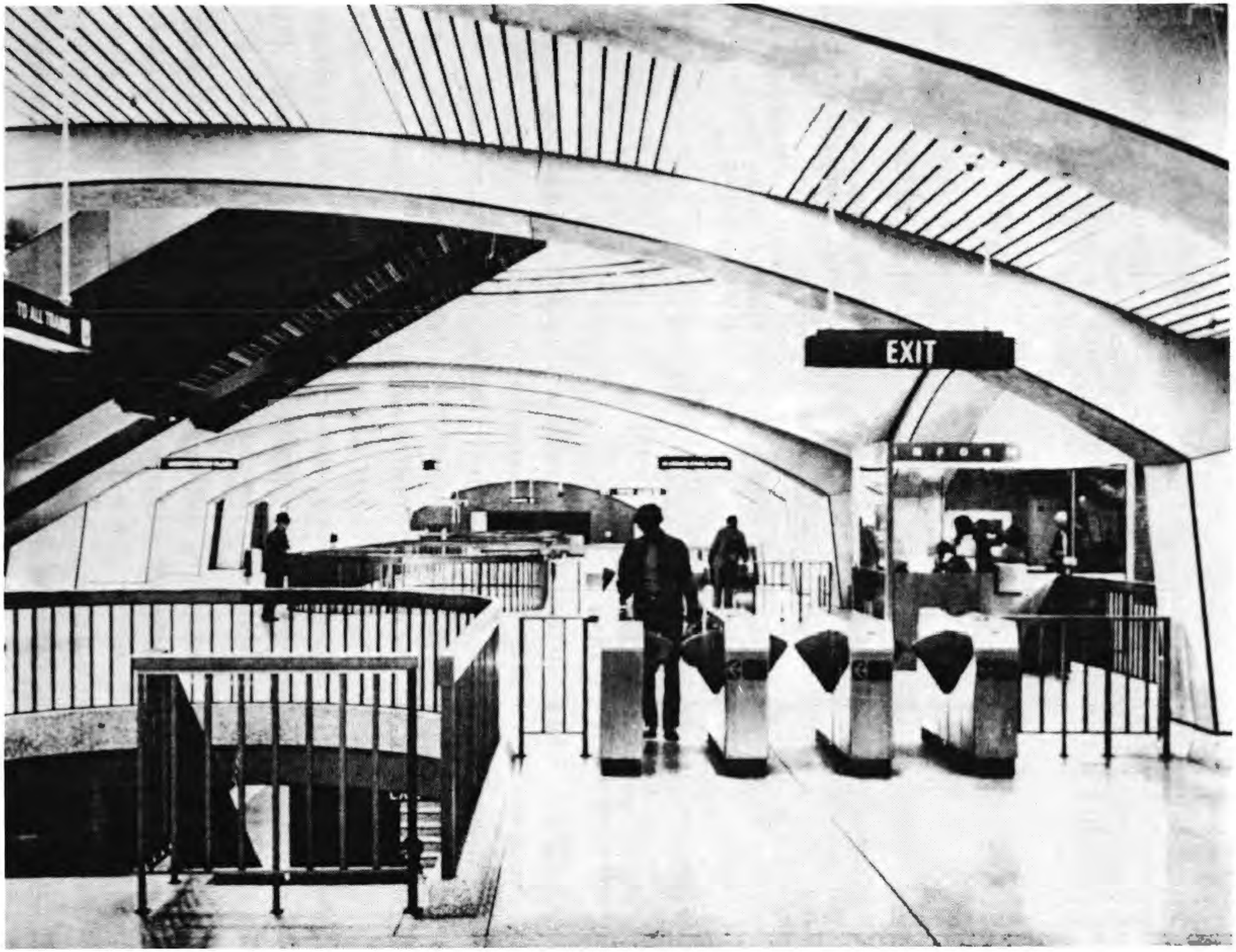


Figure 8 Unobstructed view from station agents' booth and well lighted ticket gate areas enhance station security.

Conclusions

Using the evaluation factors listed in this paper, the planning and design of the BART stations in the original system achieved successful results. Some shortfalls in parking spaces at end-of-the line stations and in intermodal transfer facilities occurred. Part of these shortages occurred because of budgetary constraints, and part because of incorrect forecasting of demands. Advertising has proved successful, while the concession program has not yet met expectations. Design for security and lighting has been successful on the whole, but some improvements such as lighting controls, station shut-down procedures, and closed circuit TV could be instituted.

BART stations also conform satisfactorily with the general guidelines of the transit industry, as reflected in the American Public Transit Association's "Design Guidelines" (4).

Acknowledgements

I wish to thank W. M. McDowell, Manager of Station Operations, BART, for his valuable comments and insights into station operations. The opinions expressed in this article, however, are those of the author and are not necessarily those of the Bay Area Rapid Transit District.

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THE DESIGN OF INTERMODAL TERMINALS: A CASE STUDY

The Northeast Corridor Improvement Project

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Northeast Corridor Project

INTRODUCTION

The Northeast Corridor Improvement Project (NECIP) within the Federal Railroad Administration is undertaking the massive upgrading and rehabilitation of 457 miles of railroad right-of-way between Washington, D. C. and Boston, Massachusetts. The primary objective of this $2.5 billion investment is to provide reliable and dependable 2 hour and 40 minute intercity rail service between Washington, D. C. and New York and 3 hour and 40 minute service between New York and Boston. An integral part of this program is the rehabilitation, expansion or reconstruction of 15 stations along the right-of-way. One of the major features of the station development program has been the enhancement and reinforcement of intermodal connections with existing rail transit/subway system, local bus systems, taxis, rent-a-cars and, of course, private automobiles.

At selected locations the incorporation of intercity bus facilities has provided an opportunity to develop fully integrated intermodal terminals incorporating virtually all available modes of ground transportation with the intercity and commuter rail system at a single downtown location. Benefits to be derived from the development of such intermodal terminals include commonality of vehicular and pedestrian circulation facilities, public services, concessions, and information systems, as well as simplicity and directness of intermodal connections among the various surface modes of transportation.

Several of the stations being improved under the NECIP have existing or potential intermodal capability, particularly with regard to the accommodation of intercity and commuter bus facilities. Boston South Station is the best example of all elements coming together: diversified institutional and political entities, funds from several Federal agencies, and physical plans responsive not only to specific transportation needs but also providing a framework for major commercial air rights development. Therefore, the ensuing documentation will focus solely on the actual development of a full intermodal terminal at

Boston South Station with regard to design objectives, the physical planning concept, and the institutional framework for actual implementation of the project.

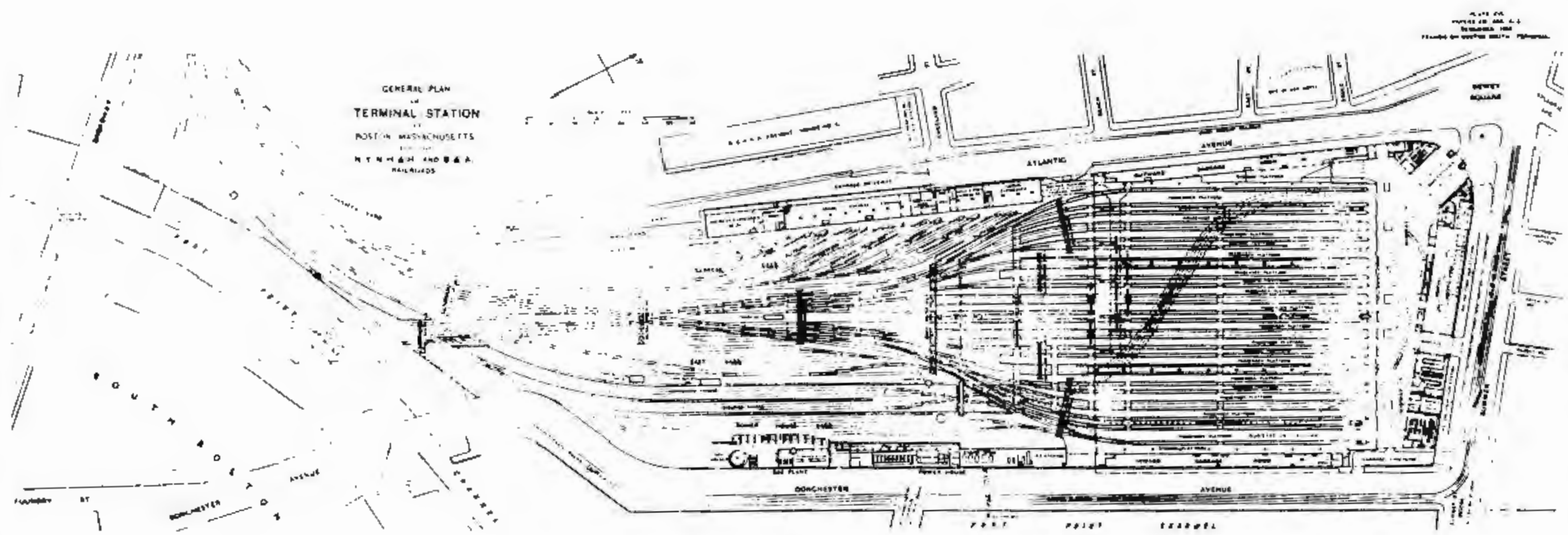
BACKGROUND AND EXISTING CONDITIONS

Boston South Station Transportation Center, when complete in the Spring of 1984, will bring full circle the 80-year history of this transportation terminal. In 1916, South Station was the busiest railroad station in America. Since the decline in railroad travel, however, the importance of the station had diminished and parts of it were demolished over the years. Only the station's placement on the National Register of Historic Places prevented its complete destruction in the early 1970's. Today, the station once again is on the verge of becoming a major transportation center.

When completed in 1900, the station and its 26 tracks occupied the entire block between Atlantic and Dorchester Avenues south of Summer Street. The trackheads were immediately adjacent to the concourse, providing a direct and convenient connection for rail passengers. The concourse, or midway as it was called then, was never considered a pleasing space, and its relationship to the headhouse, with its imposing neoclassic facade facing Dewey Square, was incongruous. That, however, did not lessen its status as a highly functional, efficient, major transportation terminal serving as many as 27 million passengers in one year.

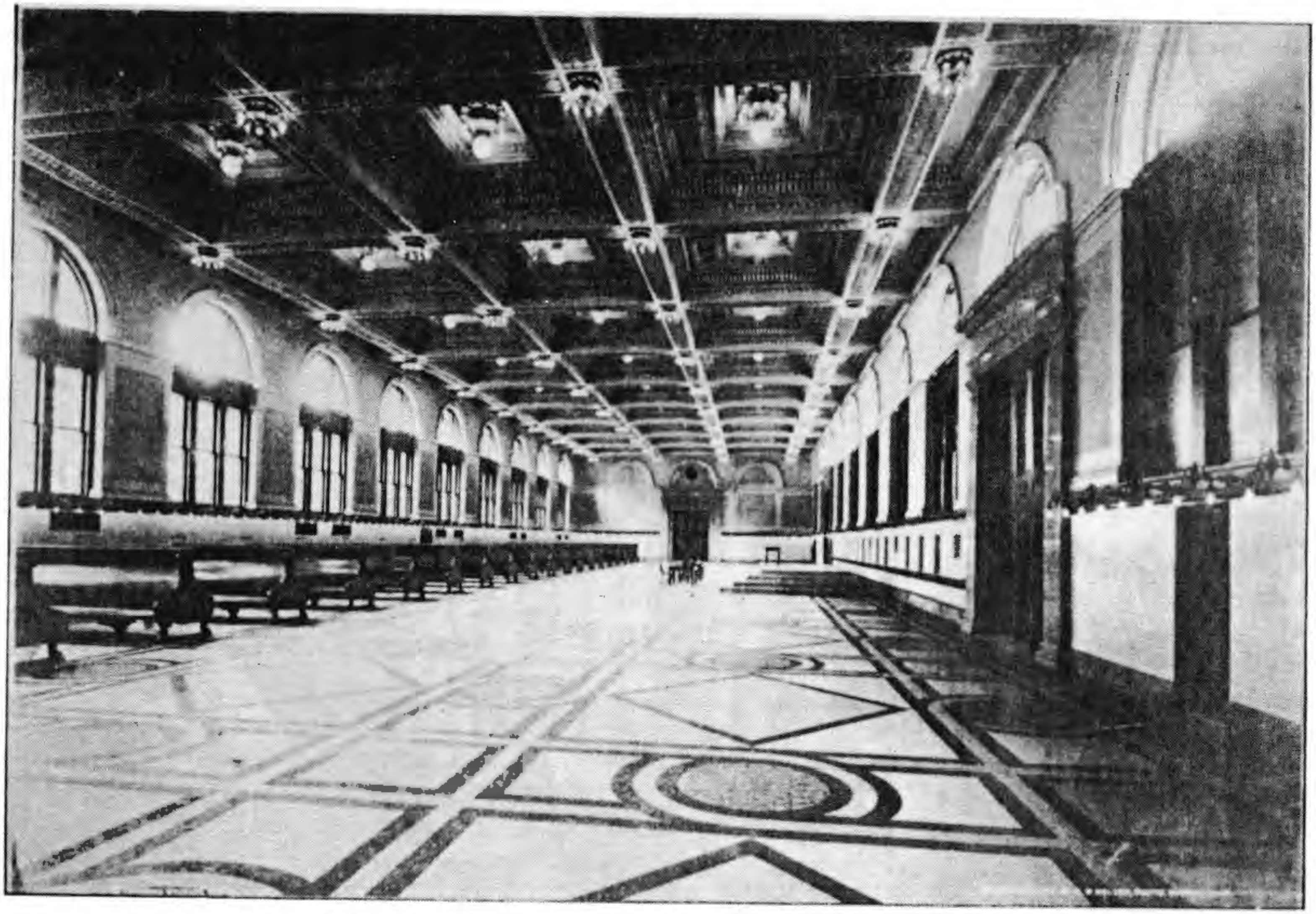
Rail passenger demand began a sharp decline in the late 1940's, and the station fell into disrepair, with major portions being demolished in the 1960's and 70's to make way for U. S. Postal Service facilities and commercial office space. Fortunately, the headhouse and its curving granite facade remain, now protected from demolition by its National Register status. Also remaining are about one-third of the old waiting room, its ornate coffered ceiling and a portion of the old concourse intact, its roof trusses and skylights now covered by an oppressively low plaster ceiling. The tracks still in use are now far off to one side of the concourse, which opens to a part of the train yard now used for storage.

The Federal Railroad Administration (FRA) as part of the NECIP, the Massachusetts Bay Transportation Authority (MBTA), and the Boston Redevelopment Authority (BRA) began planning the Boston South Station Transportation Center in mid-1977. Conceptual and preliminary designs were



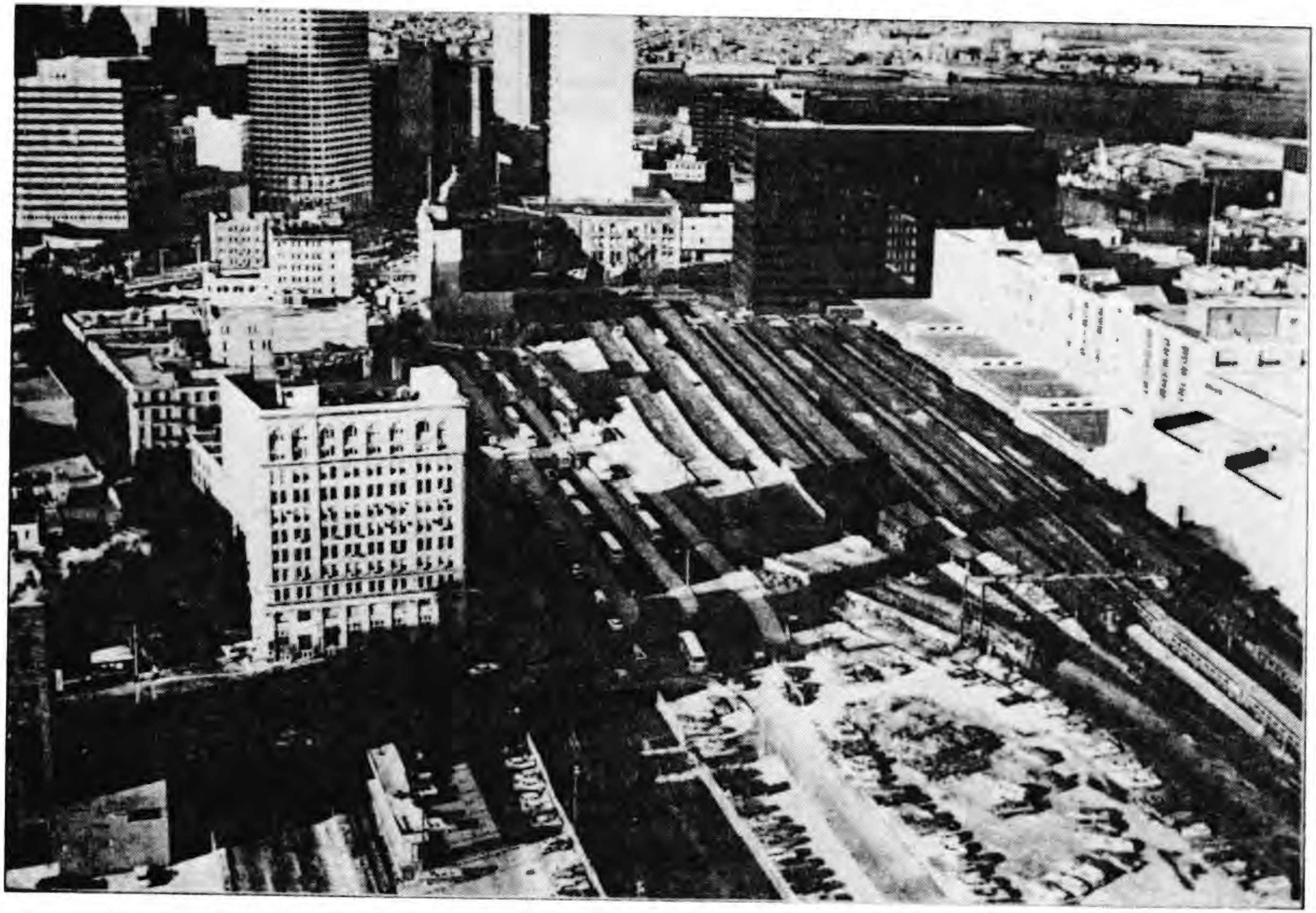
Plan of the original concourse and platform level; reproduced from a drawing presented to the American Society of Civil Engineers in 1900.

Boston South Station was seen from Dewey Square in the early 1900's. The symmetrical neo-classic facade does not reflect the assymetrical plan and diverse functions of the station.

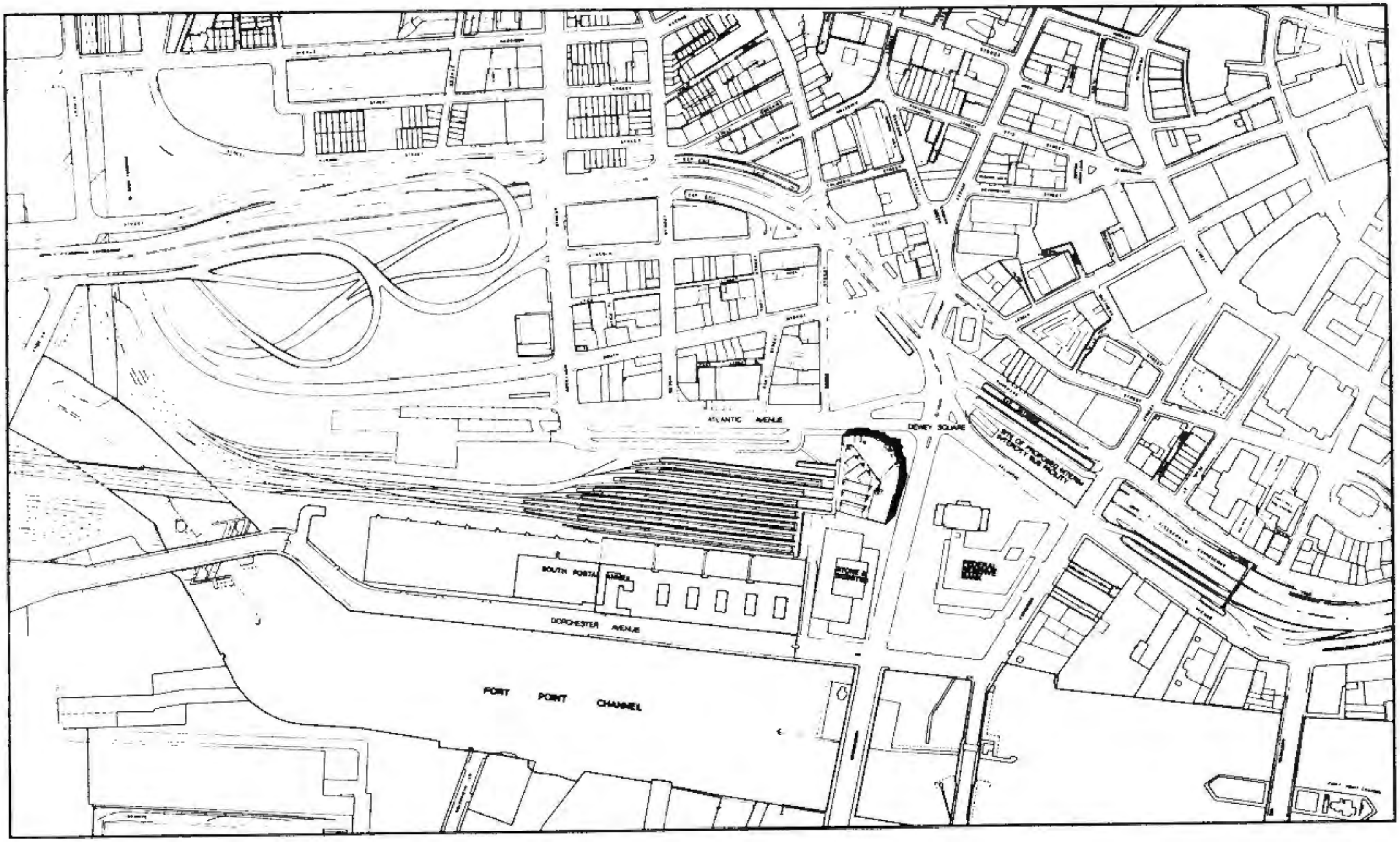


The main waiting room was 225 feet long, 65 feet wide and 28.5 feet high. Its marble mosaic floor, polished granite details and coffered ceiling made this the most richly finished space in the original structure.

The station as it exists today. The curved headhouse facade remains intact but the west wing has been almost completely removed; only 5 bays of the waiting room remain to form a fragmented east wing.



The tracks still in use today are far off to one side of the concourse which opens to a part of the train yard now used for storage. The existing commuter bus terminal and daily storage area are parallel to Atlantic Avenue.



Plan of the station and the surrounding area. The South Postal Annex and Stone & Webster headquarters offices were constructed in the 1960's and 70's on building sites created by demolition of station facilities.

completed by the FRA's consultants in early 1979. In December of 1979, after negotiation of two multi-agency agreements and transfer of the station property from the BRA to the MBTA, the consultants to the FRA began design development for rail facilities; consultants to the MBTA began design development of subway and bus facilities; and consultants to the BRA began feasibility and design studies for the air-rights commercial development. Final design of the transportation elements is now underway, with completion of construction documents scheduled for April of 1981.

DESIGN OBJECTIVES

The South Station Transportation Center will combine intercity and commuter rail, intercity and commuter bus, subway, local bus, and automobile parking in a location close to major vehicular arteries and within easy walking distance of downtown Boston. To maximize the potential of this combination of transportation facilities, the following design objectives were established:

- Provide facilities that meet the operational and support needs of the intercity, commuter, and local transportation operators and users with maximum efficiency.
- Provide an environment that meets contemporary standards for passenger safety, comfort, and enjoyment.
- Provide an overall setting, massing and image that enhance the historic Headhouse.
- Provide convenient interchange between the various transportation modes and metropolitan Boston.
- Provide transportation facilities that complement and encourage state and city plans for commercial development at South Station and the surrounding area.
- Provide barrier-free access for the physically handicapped.
- Provide a distinct identity for each transportation mode and operator.
- Provide maximum frontage along Atlantic Avenue for the competing automobile pick-up/drop-off needs of the rail and bus carriers, and potential air-rights commercial development.

- Provide clear, efficient access between the local street system and the automobile parking levels.
- Provide a network of ramps for automobiles, buses and package express trucks that allows for direct access from the air-rights levels to the turnpike and southeast expressway, and that can be implemented in two or more phases.

DESIGN CONCEPT

The NECIP has served as a catalyst for proposed improvements that will not only rehabilitate the intercity rail facilities, but with the inclusion of city and state-supported commuter rail, subway, parking and intercity and commuter bus facilities, will also create a new major intermodal transportation center rivaling the original station in its importance to the Boston Metropolitan Area. Above the air-rights bus and parking facilities the city plans extensive private development consisting of hotel, office, and trade exhibition space with additional parking. Sky lobbies for these commercial occupancies will be reached by escalators and elevators from both Atlantic Avenue and the rail and bus terminals.

A realigned track plan and reconstructed concourse are the key elements in the design. The tracks are shifted to the west and lengthened so that there is a direct relationship to the concourse. The new concourse is on axis with the headhouse main entrance from Dewey Square; its geometry is developed from the symmetry of the headhouse so that the original station's awkward joining of headhouse and concourse is corrected. The glass wall between the concourse and the trackheads is angled so that there is an exciting three-quarter view of trains in the trainroom.

Other important elements serving the rail concourse level are a pair of escalators and stairs to the Red Line subway station and another pair of escalators and stairs to the pedestrian link which bridges the trainroom and provides direct access to the air-rights bus and parking facilities.

In the old waiting room, rail ticketing and passenger support facilities are on the concourse level with a first-class restaurant occupying new mezzanine space above. The existing elevator core will be reconstructed to make upper level commercial space more attractive.

The second floor of the headhouse will become retail space; the third, fourth and fifth floors will become commercial office space. To complete the original symmetry of the headhouse facade, a new west wing containing retail and commercial office space will be rebuilt, and the east wing will be extended to accommodate a new fire stair. Both of the new wings will have facades in the neoclassical style of the original architecture.

Above the track area in a three-level, long-span post-tensioned concrete and steel structure will be a commuter and intercity bus terminal and parking for approximately 800 cars. The first air-rights level provides intercity bus passenger processing and package express areas, short term parking, and a commuter bus concourse overlooking the trainroom. A pedestrian circulation spine at this level, overlooking Atlantic Avenue, the trainroom and the rail passenger concourse, links the subway, rail and bus facilities. The second air-rights level provides an intercity bus concourse with docks for 40 buses and pull-through islands for 21 commuter buses. The third air-rights level provides approximately 600 long term parking spaces. Passengers will arrive at the bus facilities by escalator and elevator from the Atlantic Avenue auto pick-up/drop-off area and through the railroad station headhouse from Dewey Square, the Red Line subway station and the rail passenger concourse.

The parking levels are served by two single lane helices on Atlantic Avenue, which provide entry and exit. There is also an exit-only ramp for automobiles to Kneeland Street. Package express, intercity bus and commuter bus, are served by two entrance ramps, one directly from the Massachusetts Turnpike and one from Kneeland Street, and an exit ramp, also to Kneeland Street. Additional ramps, providing exiting directly to the Turnpike and the John F. Fitzgerald Expressway, are planned for the future.

AGENCY COORDINATION AND IMPLEMENTATION

Coordinaton of the overlapping or competing requirements of the FRA, the MBTA, and the BRA, the lead government agencies, is the key to the ultimate completion of the transportation center. Since December of 1979, each agency and its consultant team has endeavored to advance coordinated designs for each agency's program. This effort, which required good faith negotiations and compromise by the parties on a number of design and technical issues, has led to the preliminary designs depicted herein; it has proceeded in three primary arenas.

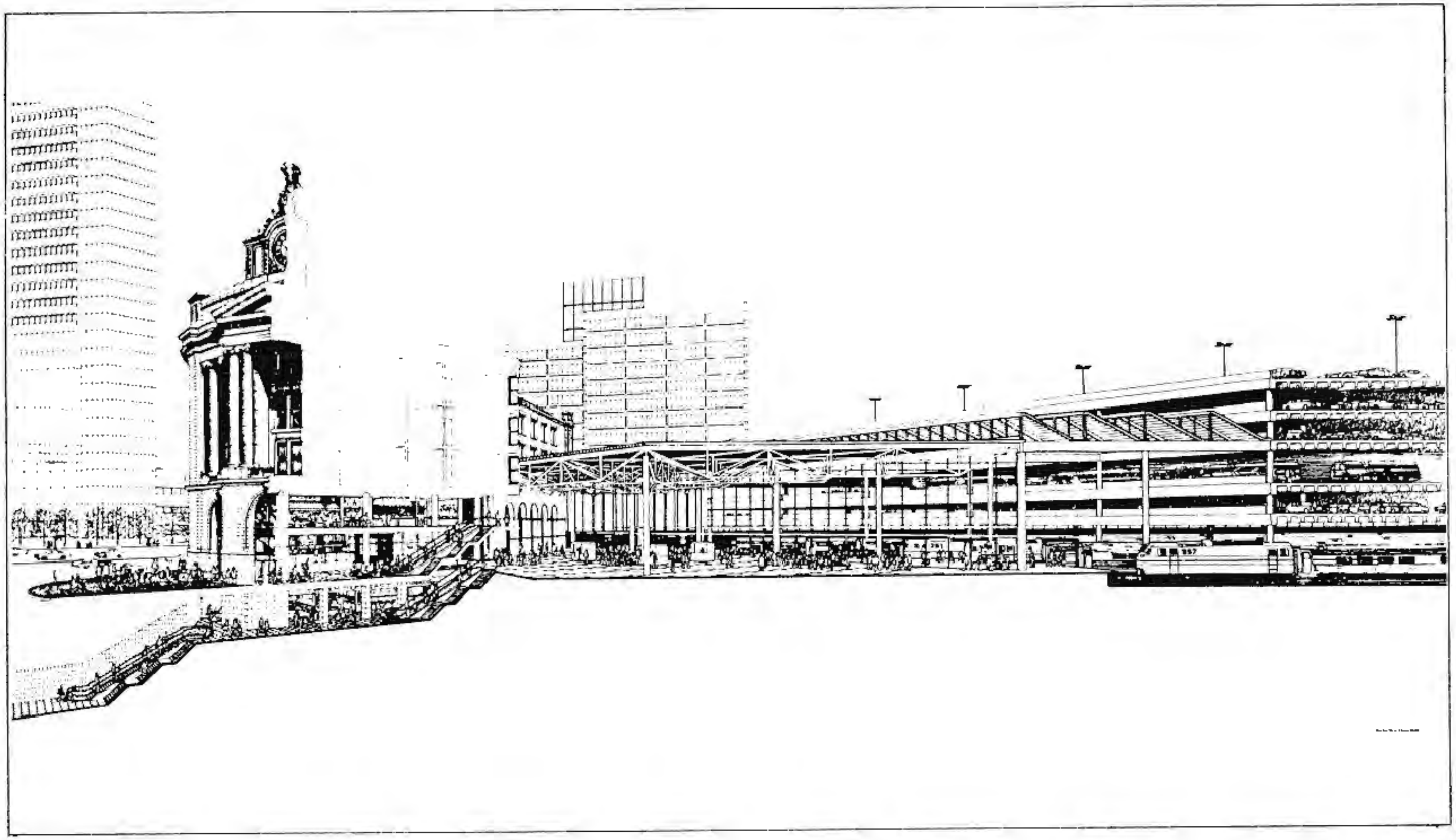
- First, bi-weekly design and technical coordination meetings have been held in Boston to provide a forum for exchange of information and discussion of issues by the agencies and their consultant teams.
- Second, detailed design and technical issue working sessions are conducted on an ad hoc basis to expedite resolution of issues. Attendance at these meetings is limited to those directly involved in resolution of the particular issues.
- Third, to coordinate with the many local agencies in addition to the BRA and MBTA, which have both a measure of jurisdiction and considerable interest in the design of the transportation center, a local interagency coordination committee was formed. The committee meets regularly to review in depth the various transportation, planning and design issues which arise. Particular attention has been given to the design of the many vehicular ramping alternatives which were developed.

The overall project is now well into final design with completion of construction bid documents presently scheduled for April 1981. By agreement among the parties, the MBTA will be responsible for bidding and constructing the transportation center. Although numerous technical and funding problems still remain to be finally resolved, the parties of interest have the common objective of moving forward with construction of the project to provide a tangible product for the diversified needs of the various users and beneficiaries of this massive public works project.

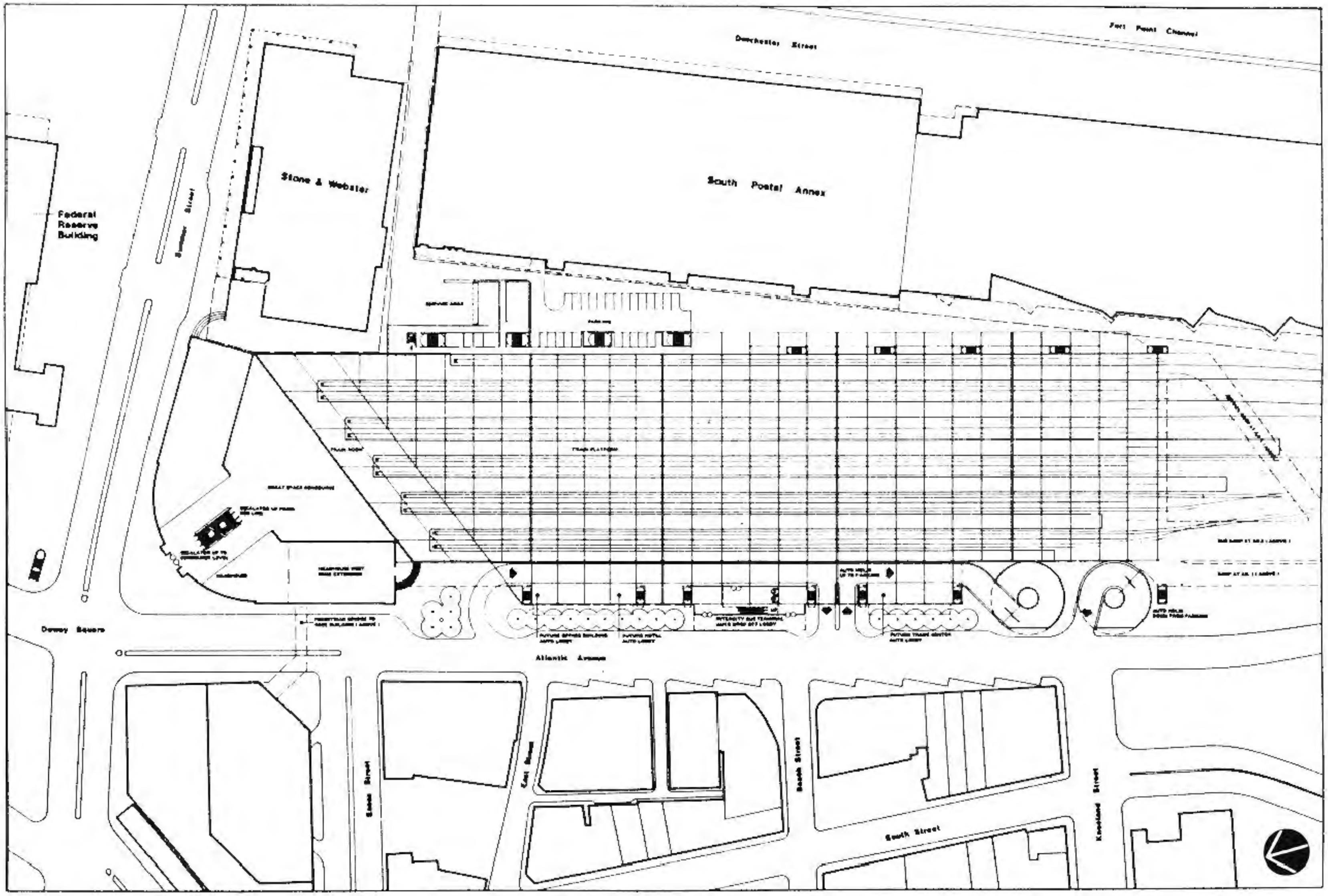
CONCLUSIONS

The South Station Transportation Center project has utilized the initiative of the Northeast Corridor Improvement Project to leverage sizeable additional Federal, state and local funds to bring to fruition a unique intermodal transportation center. Successful completion and inauguration of this facility will make a substantial contribution to solving some of the critical issues which face any large urban area today: preservation of historic resources and the urban fabric, reduction of energy consumption and air pollution, improvement of basic transportation systems, and further revitalization of the urban cores.

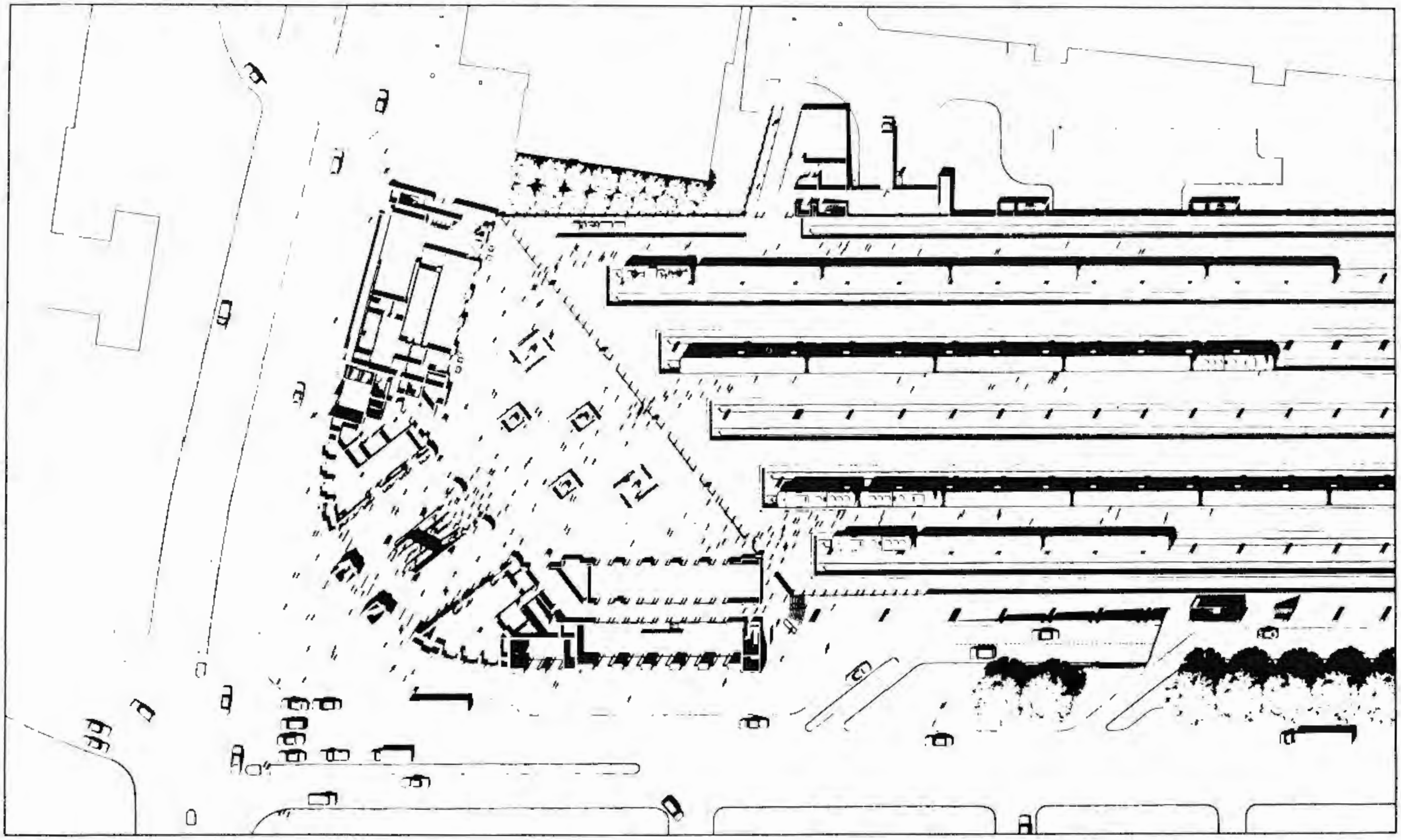
Completion of other station projects along the Corridor such as Washington Union Station, Newark Station and New Haven Station, all of which are planned to incorporate intercity bus facilities, will further demonstrate the viability of a consolidation of surface transport modes as an integral element in the improvement of urban transportation systems to foster greater use of these systems by the travelling public.



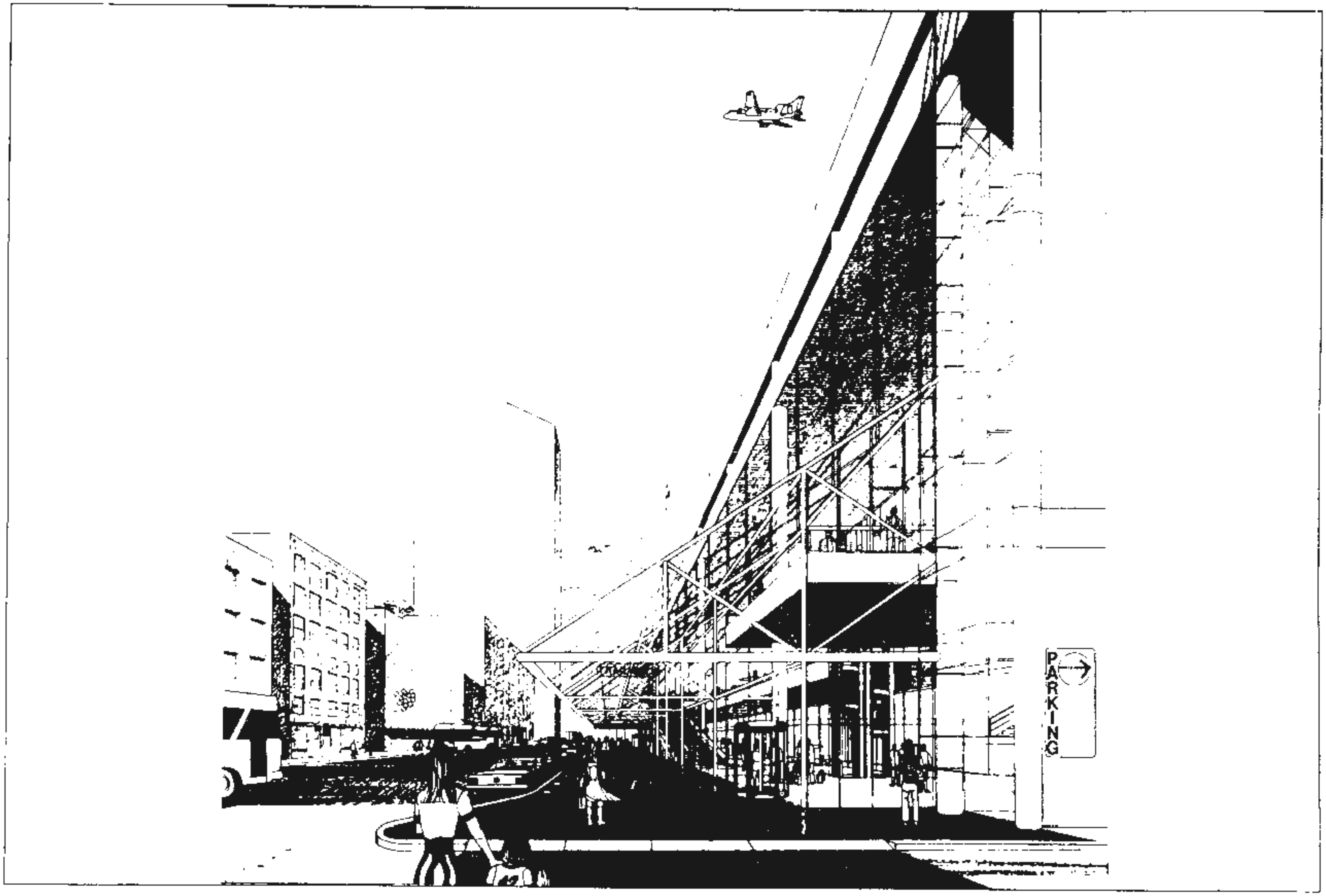
Perspective section of the concept developed by the FRA's consultants in 1978. The rail improvements are part of a comprehensive plan to create an intermodal transportation center that closely links intercity and commuter rail, intercity and commuter bus, local bus, subway and parking.



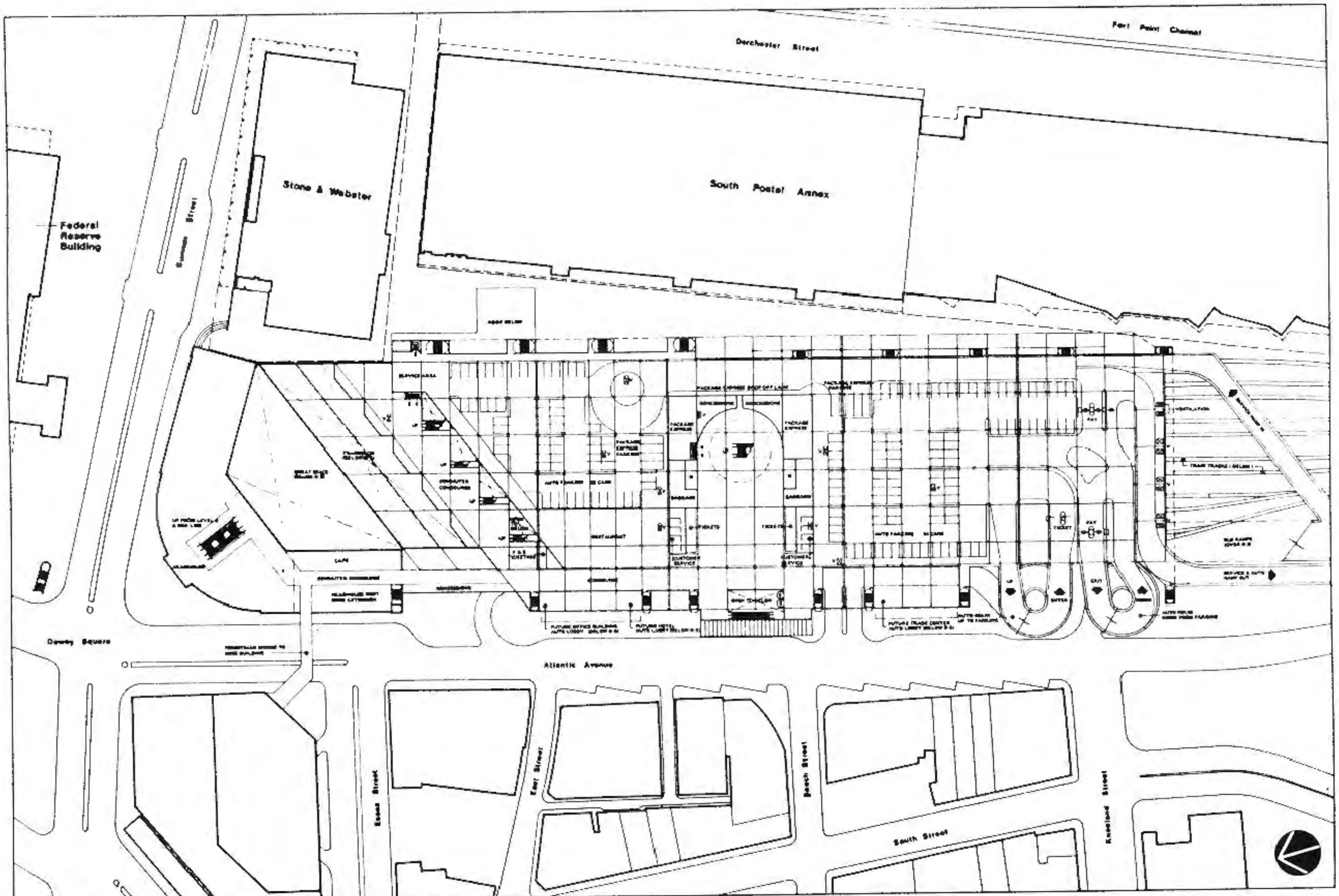
The concourse and platform level plan. A realigned track plan and a reconstructed concourse are the key elements in the design. The tracks are shifted to the west and lengthened so that there is a direct relationship to the concourse. The development along Atlantic Avenue maximizes automobile pick-up & drop-off, provides a distinct identity for the inter-city bus terminal and provides direct access to the parking levels.



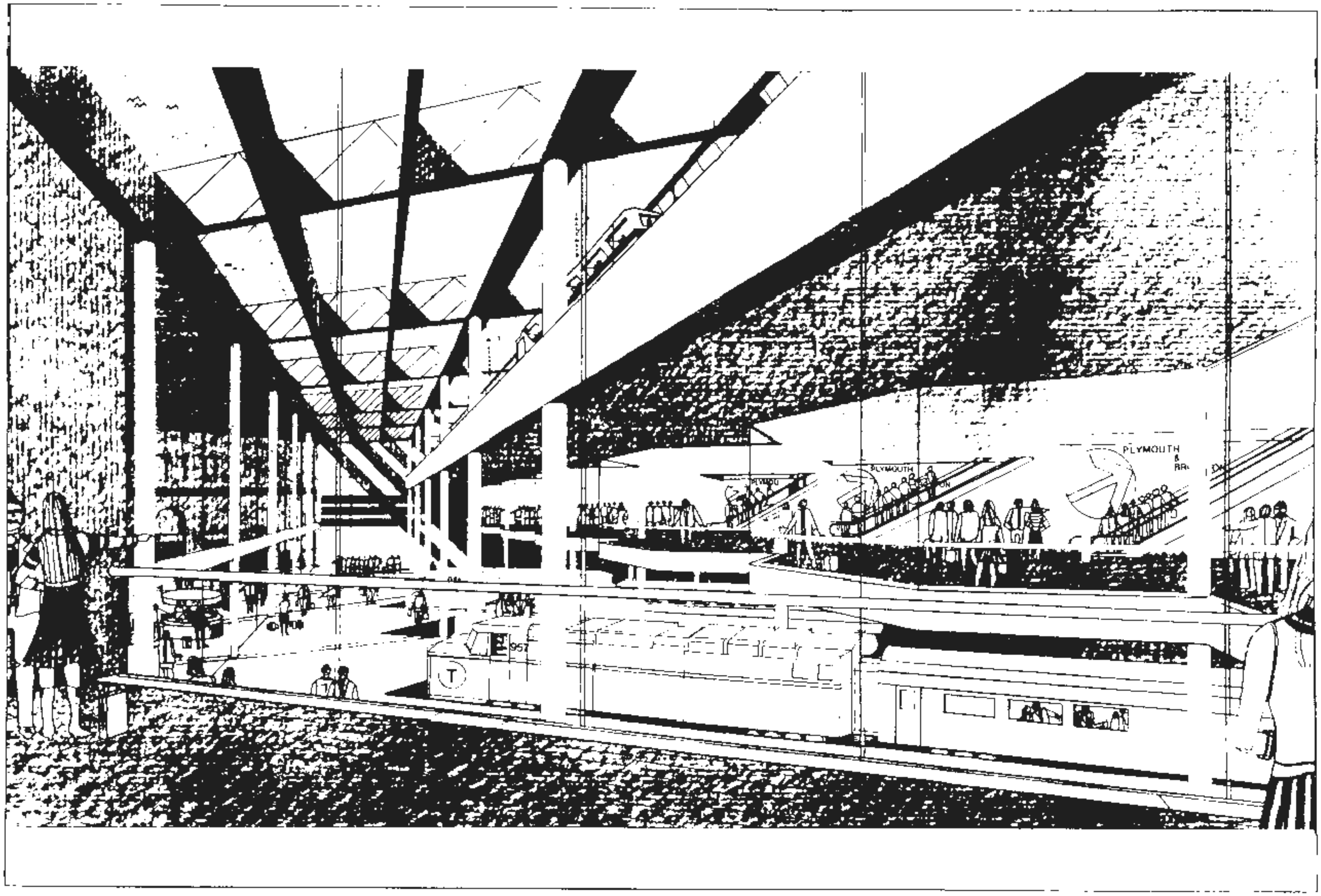
The platform and concourse level plan. The new concourse is on axis with the main entrance from Dewey Square and its geometry is developed from the symmetry of the headhouse so that the original station's awkward joining of the headhouse and concourse is converted. The new west wing and east wing cap balance the neo-classical headhouse facade.



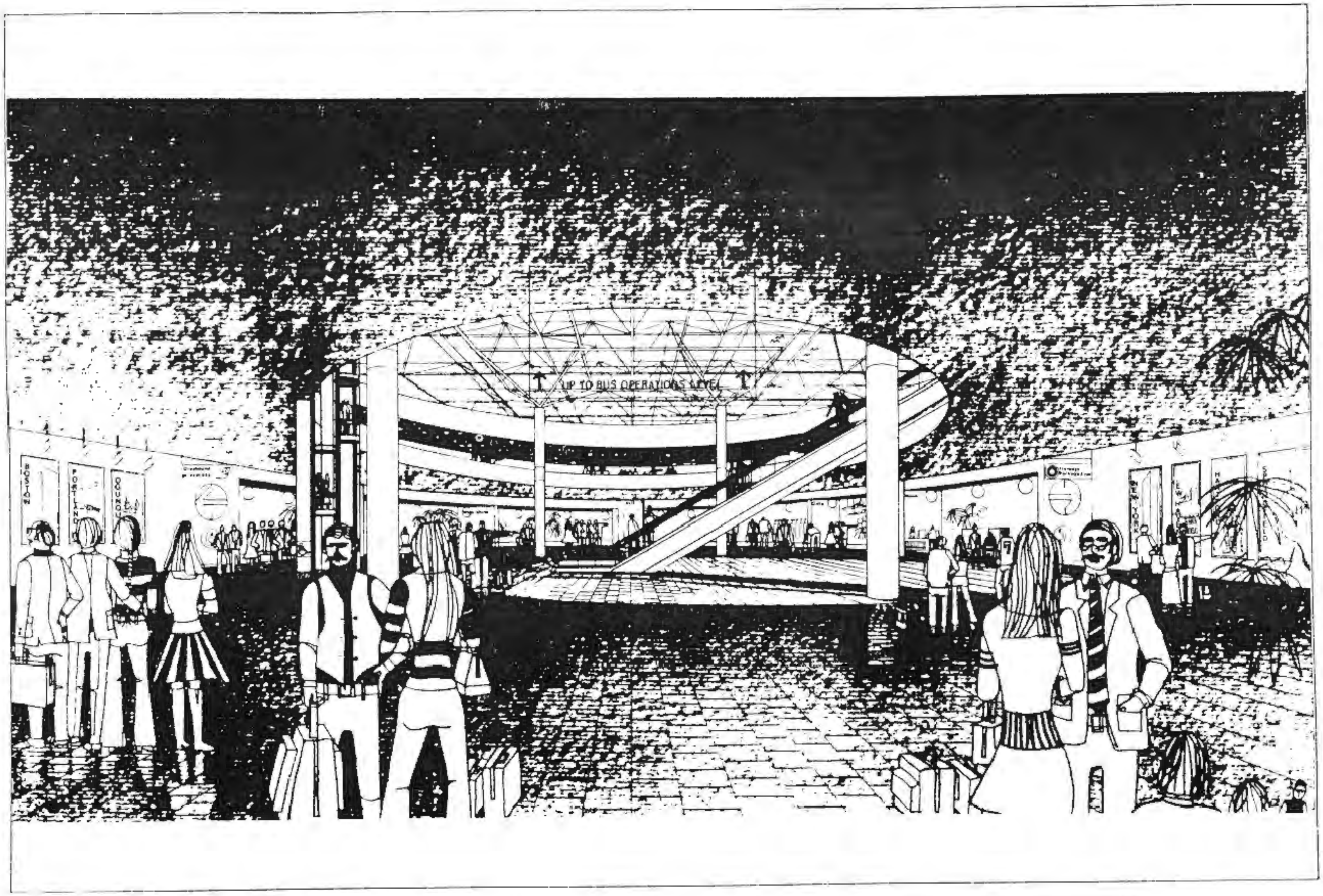
The view north on Atlantic Avenue past the bus terminal entrance.



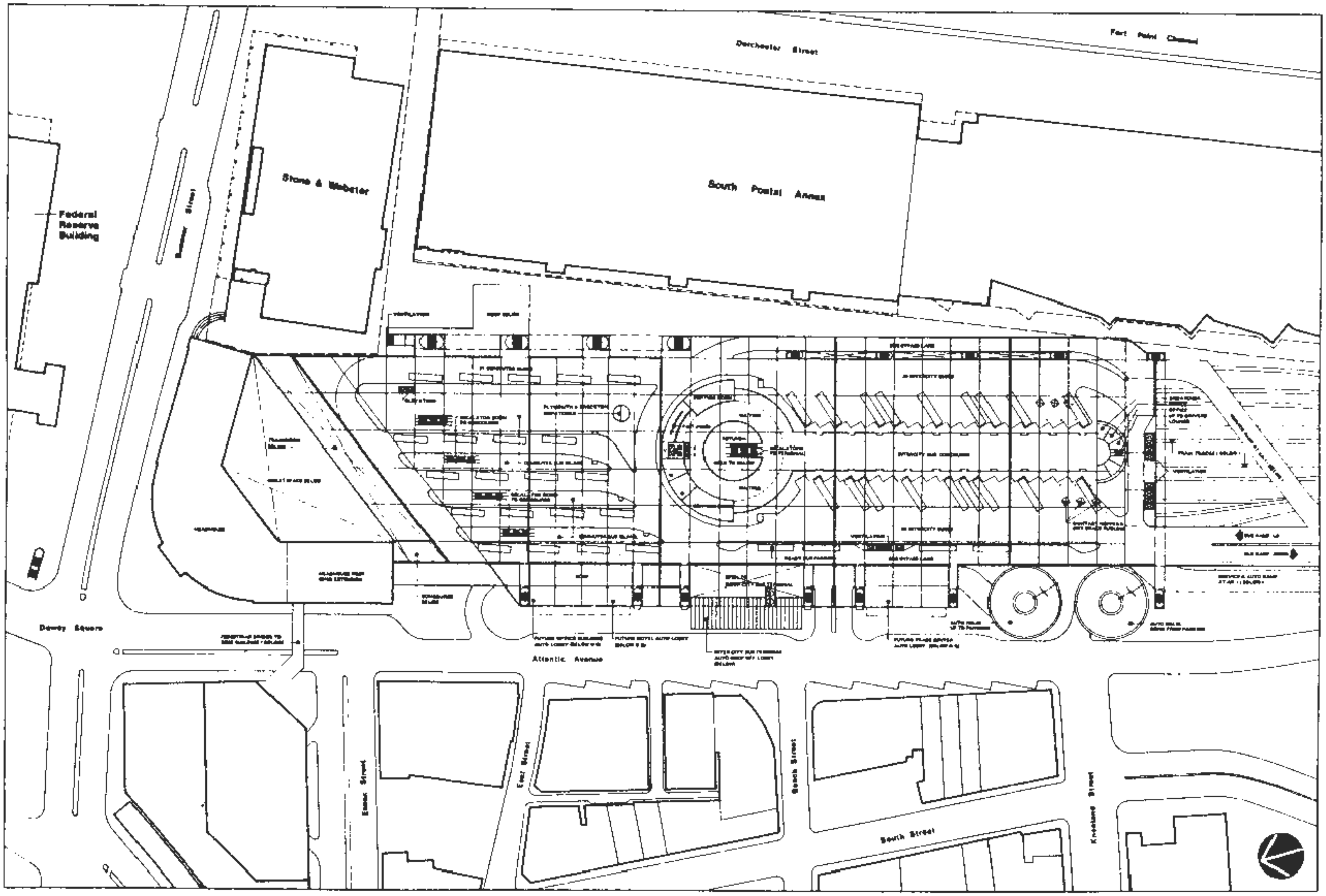
The first air-rights level plan. The commuter bus concourse, intercity bus passenger processing and package express areas, and short term parking are linked to the second floor of the headhouse by a pedestrian circulation spine overlooking Atlantic Avenue and the trainroom.



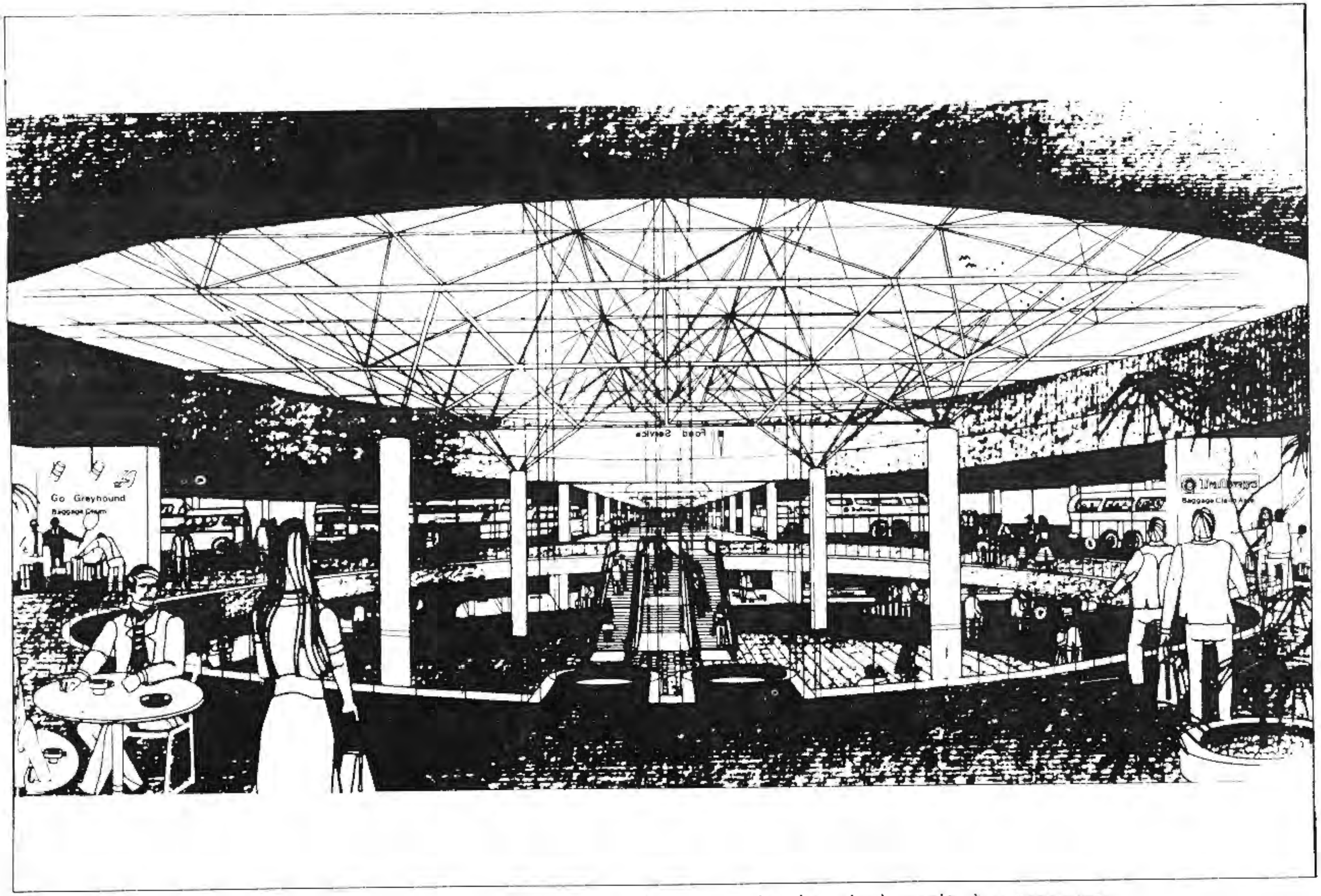
The view from the bridge linking the bus and rail terminals overlooks the trainroom to the commuter bus concourse.



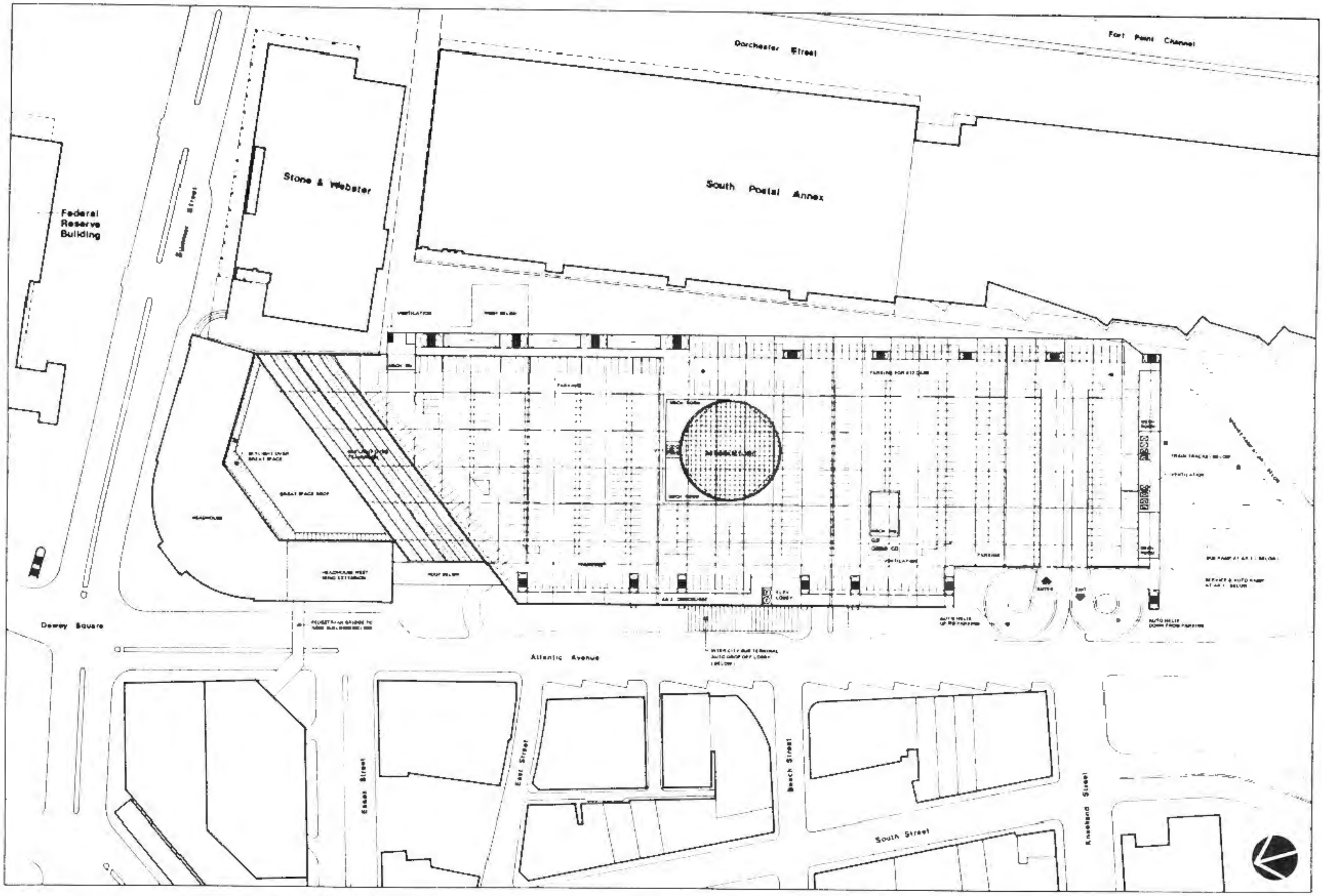
The view through the intercity bus ticketing area with escalators up to the intercity bus concourse.



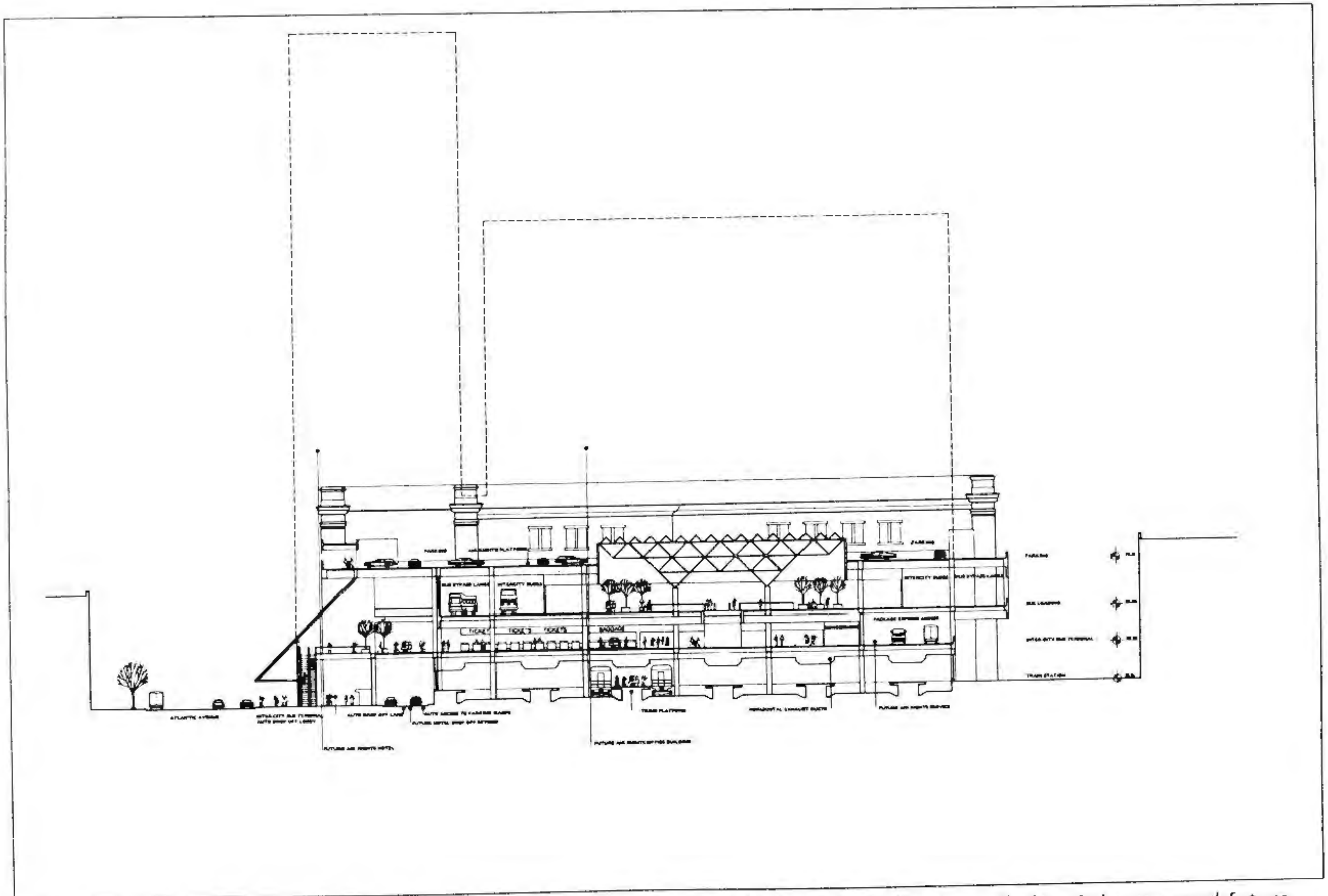
The second air-rights level plan. The intercity bus concourse has docks for 40 buses. Pull-through islands can accommodate 21 commuter buses.



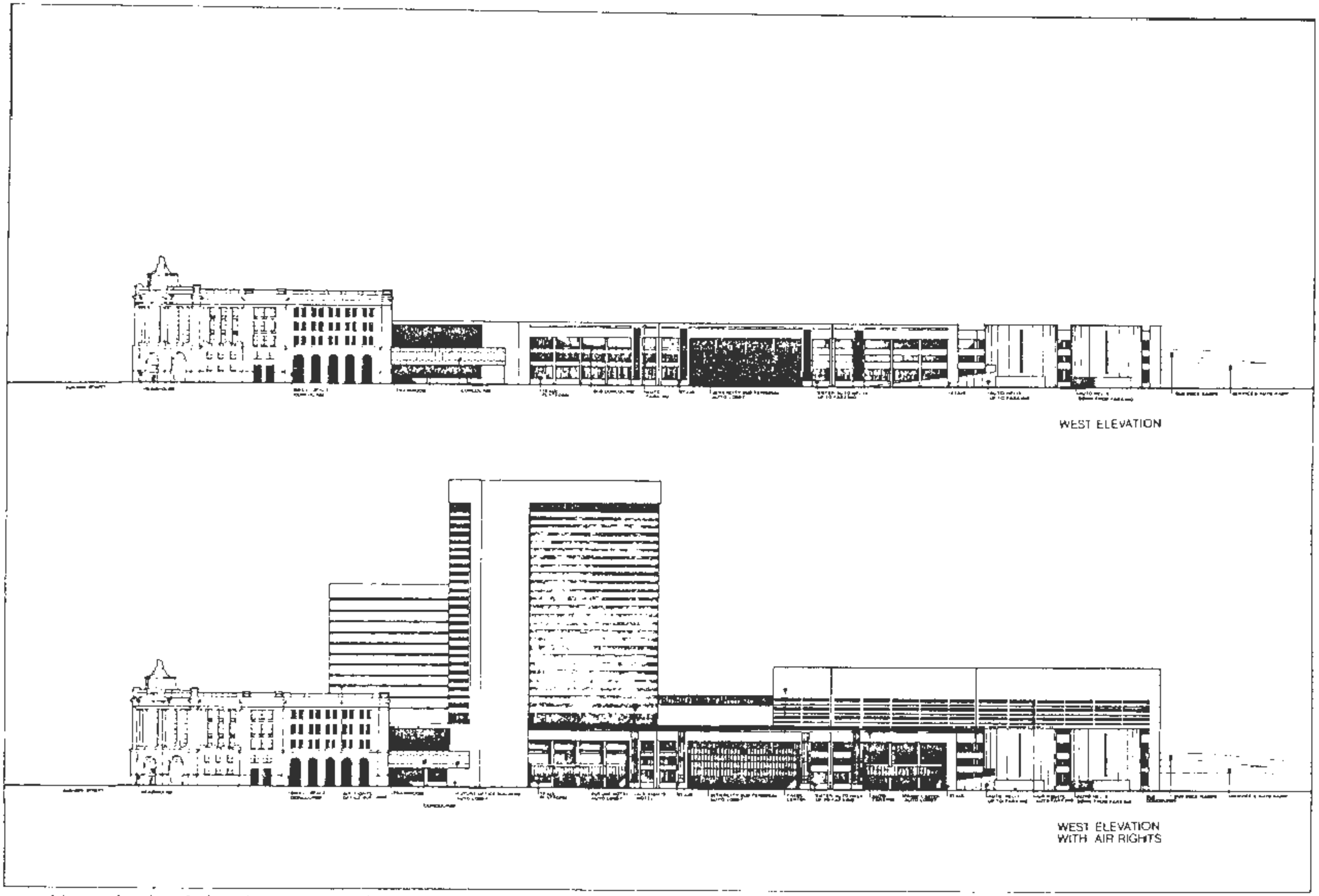
The view across the rotunda on the second air-rights level to the intercity bus concourse.



The third air-rights level plan. Parking for approximately 600 cars is provided.



Section looking north through the intercity bus ticketing area. The dashed lines indicate the limits of the proposed future hotel and office development.



Above is the Atlantic Avenue elevation of the completed transportation center. Below is the same elevation as it might appear upon completion of the proposed air-rights hotel, office, building, and trade center.

STATION RENOVATION IN OLDER RAIL RAPID TRANSIT SYSTEMS

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Assistant Director of Planning
New York Metropolitan Transportation Authority

I am here today to talk about recent experiences with station renovation in older rail rapid transit systems. Although the program mentions New York, Chicago, and Boston, I will concentrate most of my remarks on New York.

The new rapid rail systems in North America--San Francisco, Montreal, Toronto, Mexico City, Washington, Atlanta, soon Baltimore, Miami and perhaps others . . . possibly even Los Angeles, all have the luxury of being able to learn from the experiences of the older, turn-of-the-century systems and build in good design features from the beginning.

The problems in renovating stations in older systems is quite different. Renovation, especially renovation involving structural alterations or major changes in station access, are costly and what one can do is severely limited by physical and budgetary constraints, especially when one considers that the older systems also have enormous needs for capital for other rehabilitation projects . . . new cars, new track, modernized power and signal systems, etc., etc., etc. In New York City alone, some $250,000,000 a year is budgeted for ongoing improvements to the existing system, an amount generally considered to be "bare-bones". The system has an approximate replacement cost of $25 to $40 billion. A "modest" expenditure of only 4% of this amount for annual replacement of worn-out capital items indicates a need for an expenditure of well over $1 billion a year. So station renovation projects must frequently take a back seat to less glamorous projects, and so much greater is the challenge to the planner, engineer and architect designing station renovation projects to make every dollar count.

Although the first North American underground subway lines were opened at the turn of the century . . . 1898 in Boston, 1904 in New York, and 1905 in Philadelphia, the New York and Chicago systems still contain elevated stations built in the last century. New York is, in fact, right now in the process of awarding construction contracts for a $4.5 million rehabilitation of a section of elevated line, including two stations, originally built around 1885. This is a part of the Jamaica Avenue elevated, or "J" line, Norwood Avenue to Alabama Avenue.

A bit of "transit trivia" provides a clue to the vast range of design problems facing those responsible for station renovation. We are building a new underground subway terminal for the "J" Line under Archer Avenue, Queens, to replace the outer portion of the elevated which has already been torn down. Upon completion of this new subway, "J" Line trains will actually be operating through stations of many different designs built at many different times over a full <u>one hundred year</u> timespan. Specifically, starting in sequence from the new outer terminal, "J" Line trains will be operating through stations opened in <u>1985</u>, 1918, 1917, 1893, <u>1885</u>, 1916, 1908, 1913 and 1931. An $8 million improvement is planned at the Marcy Avenue Station (an 1888 station last rebuilt in 1916), and $6 million of improvements are planned at three 1893 stations.

The first New York subway line opened on October 27, 1904 (we celebrated its Diamond Jubilee last year) and the need for subway station renovation became apparent in 1905. Shortly after the first subway opened (the original "IRT" line), the IRT hired a consulting engineer to evaluate the design and operation of the system. This engineer wrote several interesting reports and made several major recommendations which became the basis for a number of modifications to the original system and its stations.

You may recall Wil Sergeant's remarks yesterday that the cheapest way to increase capacity is to make the trains and platforms longer. Starting around 1905, the old IRT did just this. The IRT was the first four track, local/express rapid transit line. It was designed for five car local trains and seven car express trains. Passenger traffic on the original IRT subway quickly exceeded projections. So what did the IRT do? It lengthened platforms and trains to accommodate six car local trains and 10 car express trains. This was the beginning of subway station renovations in New York.

Years later, mostly in the 1950's, a major station renovation program took place to further lengthen station platforms to standard lengths to accommodate both ten car local and express trains. And what was the effect of all this platform extension work? It resulted in adding the capacity equivalent of an entirely new two track subway line running the length of Manhattan Island, at far less capital and operating cost.

It is interesting to observe the evolving design of stations in older systems and New York in particular. The first stations were quickly found to be too small. In the next wave of subway building, stations were made larger and more mezzanines over the platforms were included in the design. In the next wave (the IND system in the 1920's and 1930's) enormous mezzanines were built. Most of these now have proven to be too large, creating nuisances and areas hard to police and keep clean. Vast parts of these new mezzanines have been closed off in make-shift, unattractive ways with wooden board or chain link fencing. In some of the station modernization projects we are considering today, unneeded parts of stations will be partitioned off using suitable architectural materials and the remaining portions renovated. These unneeded areas can often be put to other uses--for example, substations for the Transit Police, storerooms for the operating departments, and in one case, as the Signal Department training school, complete with signal apparatus and a section of track which doesn't go anwhere. One completely unused station, in fact, has been converted into a Transit Museum housing old, vintage trains and other exhibits.

As you can see, station renovation is not new. Much of it is not glamorous. For example, most of the old elevated stations, and we still have a large number in New York, were originally built with wooden platforms. These are difficult to maintain and become hazardous as the wood rots and splinters. Almost all of these have been replaced with precast concrete platforms. Another renovation program involves improved lighting. The older original incandescent lighting is being replaced with higher intensity flourescent lighting. In a system with 465 stations, these programs, housekeeping programs, if you will, take not only money, but lots of time. The lighting improvement program, for example, began in 1954 and is still going on.

When Montreal opened its new subway in 1967, it sparked renewed interest in upgraded architectural design of subway stations. Montreal's stations represented a major break from the "bathroom tile" appearance found in older system.

Boston was the first older system to initiate a major station renovation program. Beginning with the Arlington Street station on the Green Line in the mid-1960's, most of Boston's older stations are being modernized under a program that is still going on. Most of the clutter--old pipes, wires, randomly placed, unrelated signage, etc., was removed. New graphic standards were adopted based on a system developed by Cambridge Seven. The identifying "T" logo was adopted. New wall and flooring materials and lighting were installed.

Murals and artwork were installed. Most stations have an area map and graphics depicting landmarks in the vicinity of the station. These are on porcelain enamel panels for durability and ease of cleaning. Older stations scheduled for abandonment upon the construction of new lines are, of course, not being renovated. The appearance of the stations was greatly improved and made more inviting to the users of the systems, namely the public. In my view, many of the stations are very attractively done and holding up fairly well.

Philadelphia too has been renovating some of the older stations, particularly on the Market Street line. The renovation of the Fifth Street station adjacent to Independence Hall is, in my view, the finest example of a renovated station in the United States. Extensive use was made of porcelain enamel panels and glass, materials that transit operators normally shy away from. Use of panels provided an economical way to reshape the outline of the station and get rid of hidden nooks and corners, greatly improving the appearance and security of the station. The contrast between the original station--one of the most squalid in the country--and the renovated station, is striking. Other stations on the Market Street line are being, or have been, renovated, including some elevated stations. The renovation of the 15th Street station involved some major reconstruction in conjunction with other renewal work, including track relocation, a rarity in station renovation work. And, as you know, Les Hoel has written a paper on alternatives for reconstructing the terminal station on this line at 69th Street.

Chicago has in recent years rebuilt two terminal stations, Ashland on the Englewood line and Kimball on the Ravenswood line. These two stations and major bus-rail interchange stations and the improvements were geared to improving transfer between these two modes. Work is underway or planned at other stations. A major issue in Chicago relates to the venerable Loop. Originally it was planned to replace this old elevated line which Loops around

Chicago's historical CBD with new subways. But the high cost of these subways (Franklin Street) has led to reconsideration, so that the Loop may remain and be rehabilitated. Should it stay, major renovation of the Loop stations will be needed.

Back to New York. There has been a renewed interest in improving the appearance and functioning of our stations. In recent years, several projects have been undertaken. While some are major projects when looked at individually, they are voices in the wilderness in a system having 465 separate stations. These projects vary from the complete reconstruction of the Bowling Green subway station in the lower Manhattan business district to the refurbishment of the mezzanine of the 42nd Street station in the 6th Avenue Line.

The Bowling Green job, which cost $17 million dollars about 5 years ago, involved major structural work and excavation. A completely new northbound platform was added and new entrances and an expensive below-track concourse was built. The station walls were refinished with red tile and floors with terrazzo. (Terrazzo, incidentally, has a tendency to crack when placed on surfaces subject to vibration from trains.) New lighting and ventilating fans were put in, and a historic park on top of the station rebuilt. There will be very few modernization projects of this magnitude. For example, a proposal to reconstruct the 72nd Street station is in jeopardy because the current estimate exceeds $40 million. A less elaborate and less desirable solution may have to be adopted.

The refurbishing of the 42nd Street mezzanine on the Sixth Avenue line complemented another job, the construction of 400 foot long intermodal transfer passageway to an adjacent subway station on another line. The passageway was originally designed to older standards, but a decision was made to upgrade the design standards to include higher ceiling, terra cotta wall finish, terrazzo floor and murals depicting the history of the area. This passageway, the Bryant Park passageway, is now one of the most attractive places in the New York system. The contiguous 42nd Street Mezzanine was refurbished to similar design standards. The work was paid for by the builder of an adjacent office building, his contribution to gain a zoning variance. The funds, however, were sufficient to do but half the length of the mezzanine, and it is a stark contract to stand at the dividing line and see the old and the new!

Another early midtown project was the $2 million rufurbishing of the 49th Street station on the Broadway BMT under an UMTA grant. The objective was to test different materials and techniques that could be used on other projects. There were no structural changes. The walls were covered with brilliant orange glazed brick, and, for the first time in the New York subway, terrazzo floor was installed. An experimental abrasive warning strip was placed parallel to the platform edge to aid vision impaired passengers, a feature now being added to all stations in the system. Sound proofing panels were placed in the ceiling, baffles were added between tracks, and welded rail on rubberized tie pads was installed to reduce noise levels.

Another major midtown renovation project was undertaken to reduce congestion and to increase entrance capacity at a heavily used station complex. The solution here to the problem was to build a completely new entrance to the Lexington Avenue station at Third Avenue and 60th Street with escalators to the platform of the BMT line. This was a difficult construction job which cost over $7 million ($10-12 million now), and illustrates why new entrances are not built to subway stations except where severe conditions exist. Again, high architectural standards were applied to the design of the new entrances.

An interesting station renovation program now underway in New York is the so-called "Adopt-A-Station" program. This program uses a mixture of public funding (UMTA and local) and private local matching contributions. In essence, a neighborhood or business community "adopts" a station and provides some of the dollars to fix up the station. The community gets involved in that design of the improvements and the improvements are closely linked with neighborhood revitalization. The amounts of money are generally small so that most improvements are cosmetic and costly structural improvements, no matter how desirable, are beyond the scope of this program.

The first "Adopt-A-Station" project to go into construction is the revitalization of parts of the 14th Street-Union Square station complex, one of the most confusing and chaotic stations in the system. A local community group known as "Sweet 14" was formed to guide the design. About $1 million has been made available to Phase I of this project. The mezzanine is being refurbished, several passageways no longer needed are being closed, lighting is being upgraded, and much of the clutter is being removed. Several obnoxious concessions have been removed, and new concessions must conform to certain design standards. Unfortunately, long term leases prevent all non-conforming concessions from being removed or relocated at this time. A large mural is planned, and a new transit police district headquarters has been constructed.

Other Adopt-A-Station projects include Clark Street, Brooklyn and Wall Street, and others are under consideration.

The New York City Department of City Planning (DCP), in its role of preparing capital programs and policies for the City of New York, has recommended a greater emphasis on subway station modernization. The preface to an UMTA funded Section 8 Technical Study that the DCP prepared on Subway Station Modernization states, "The decayed conditions of most subway stations is central to the passenger's negative impression of the rail system". DCP established four goals for station modernization.

1. Improved pedestrian movement circulation;
2. Improved information systems;
3. An improved, hospitable and attractive station environment;
4. Improved safety and security.

DCP's report contains specific recommendations to achieve these goals.

Station modernization projects being undertaken or proposed in New York can generally be placed in one of three categories:

A. Renovation (minor improvement)
B. Modernization (moderate improvement)
C. Reconstruction (major structural improvement)

Renovation affects only selected portions of the station. The work could include replacement of wooden platforms, cosmetic renovation of entrance areas, new finishes where appropriate, improved lighting and improved information systems and graphics. An example is the renovation of the entrance area of the 86th Street and Lexington Avenue subway station, done in conjunction with the construction of a new department store.

Modernization affects an entire station or a significant portion of a station. Work could include modification to vertical circulation, including new or replacement escalators and/or elevators, new or revised entrances, noise abatement measures, and general upgrading of patron facilities. An example is the reconstruction of the station at 49th Street and Seventh Avenue.

Reconstruction involves major modification to a station. An example is the complete reconstruction of the Bowling Green station. An emerging possibility is the reconstruction of a few critical stations on sharp curves to eliminate gap fillers to permit the ultimate purchase of longer, more economical subway cars.

Yesterday Lillian Liburdi mentioned the Urban Initiative program. MTA received a $10 million grant awarded a year ago under that program, which was supplemented only last week with another $1.2 million, to undertake a $14 million renovation of the Grand Central subway station complex. The work includes vastly improved connections between the subway station and Grand Central Terminal, including new elevators, rehabilitation of the subway station mezzanines and platforms, linking together the north and south mezzanines for better passenger circulation, installation of elevators and escalators, widening and relocating passageways and stairs, and general improvements to lighting, signage and public address systems. Engineer/architects are at work on preliminary design concepts. The project was sparked by the significant public and private investments in the vicinity of Grand Central--the new recently opened NY Grand Hyatt Hotel, the new international headquarters building of Philip Morris, the renovation of the landmark Chrysler Building, and complete gutting and rebuilding of 466 Lexington Avenue, renamed the Park Atrium.

It is a difficult project. We want to improve the intermodal connection between the Grand Central subway station and Grand Central Terminal, a major commuter rail facility. The narrow stairways connecting the two now operate at Fruin Level-of-Service "Z". We plan new escalators, and elevators for the handicapped. These escalators must be sandwiched in between the southbound subway local track and the Grand Central Terminal loop track which imposes a tight clearance problem. We now think escalators will fit but this is a location where inches count. Joining the now separated north and south mezzanines may require the condemnation of a long term lease held by a retail store located in the basement of the new Hyatt Hotel. It also involves difficult structural problems as the connecting passageways must avoid large transfer girders which support the hotel, originally built over half a century ago as the Commodore Hotel.

MTA's urban initiative application to UMTA includes two other stations. These are the stations at 42nd Street and 8th Avenue adjacent to the Port Authority Bus Terminal, about which Sheldon Wander is going to speak and the Herald Square subway station complex which has an interface with PATH's 33rd Street terminal. Preliminary design is underway on the 42nd Street station. Improved security is a major objective as this station is located in the Times Square area and is the most crime ridden in the system. Some speakers yesterday mentioned leases. A design problem is how to treat a particularly bad entrance--which I will politely call a nuisance. A long term lease signed in the 1930's requires us to keep this entrance open and precludes us from opening up a sealed off stairway which would bypass this "nuisance". The lawyers are working on this one. Another objective of this improvement, in addition to general upgrading of this important "gateway station", which is the first introduction to New York for many out-of-towners arriving by bus, is to improve intramodal connections within the MTA system and establish a new free transfer connection with the Times Square subway station complex.

There is growing interest in attracting more private capital into transit station modernization. In addition to "Adopt-A-Station" and Urban Iniatives programs, another possibility is to lease portions of stations (e.g. mezzanine) to a private developer who will then refurbish the station and develop concessions according to an agreed upon plan. To some extent this has been done at the 50th Street Rockefeller Center Station. Another concept is to commit a developer to undertake specific station improvements in exchange for zoning variances or bonuses.

This is a quick overview of station renovation in older systems. Before closing, I'd like to mention one interesting study about to begin in New York. We call it Underground City. In the midtown area of Manhattan, we have a disconnected partial system of underground pedestrian connections and other tunnels extending from the 34th St-Penn Station area to the 42nd Grand Central area. The objective is to devise a plan to optimize the existence of these passageways and create a better, more useful underground system of pedestrian connections linking various transportation modes (subway stations, terminals) and land uses (office buildings, stores, etc.) We may even find it feasible to install Jack Fruin's accelerating walkway in one of the passageways!

I thank you.

* * *

THE PORT AUTHORITY BUS TERMINAL

New York, New York

Sheldon D. Wander, A.I.A.

The Port Authority of New York and New Jersey

The Port Authority Bus Terminal, located in the heart of New York City, has been called the world's busiest transportation center. It was constructed in 1950, expanded in 1963, and is presently nearing completion of another major expansion. This Terminal and the current 160 million dollar extension and modernization program presently underway is the subject of this paper.

The Port Authority Bus Terminal is owned and operated by the Port Authority of New York and New Jersey. This organization, created in 1921 by an act of the United States Congress, is an agency of the states of New York and New Jersey. Its purpose is to protect the welfare and commerce of the Port of New York. It presently owns and operates 26 major transportation and commercial facilities in the New York/New Jersey metropolitan area. Included among these facilities are: The Port Authority Bus Terminal; the three major airports servicing the area, Kennedy, LaGuardia and Newark; various container ship marine terminals; four interstate bridges, including the George Washington Bridge; two interstate tunnels, the Holland and the Lincoln; a passenger ship terminal; PATH, an interstate rapid transit rail system; and even another bus terminal at the George Washington Bridge. In addition the Port Authority has recently initiated an ambitious Urban Industrial Parks program which is presently in the planning stages.

The Port Authority is a completely self sufficient agency independent of public taxes as a source of revenue. Its charter allows the support of its less profitable facilities, usually mass transit oriented such as PATH and the Bus Terminal, with the revenues from more profitable facilities such as the Airports, Bridges and Tunnels. It is this aspect of the Port Authority's charter that resulted in a 1976 agreement with the states of New York and New Jersey to dedicate revenues generated from a bridge and tunnel toll increase to mass transit improvement. A large share of these monies has been allocated to the construction program presently underway at the Bus Terminal.

The Port Authority over the years has earned the reputation of being an organization which can successfully plan and implement large projects. It employs a large and competent staff of professional planners, architects and engineers who have undertaken and completed major transportation projects. Most notable of these projects is Newark International Airport. This in-house staff has the expertise to develop projects from the earliest planning stages through the completion of construction, including architectural and engineering design, contract document preparation, and construction administration. The Bus Terminal Extension and Modernization program presently underway, is a project planned and implemented by Port Authority in-house staff.

The need for a consolidated bus terminal in Manhattan was realized in the late 1930's. At that time small bus terminals were scattered throughout Manhattan's midtown area and bus loading occurred outdoors on city streets tying up traffic which was already reaching chronic levels. Passengers who wished to transfer from one bus line to another were subject to serious inconvenience. In conjunction with legislation enacted by the City, the Port Authority, in 1947, announced it would proceed with the construction of a major bus terminal in Manhattan on a one square block site bounded by 8th and 9th Avenues and 40th and 41st streets. Three years later, on December 15, 1950, at a cost of 24 million dollars, the Port Authority Bus Terminal was open to the public. It is interesting to note that this facility has remained continuously open ever since.

The Bus Terminal as constructed in 1950 consisted of a structure filling the entire square hlock site, 800' x 200', of three levels above the street and two levels below. Direct bus connection to the Lincoln Tunnel was provided via an elevated ramp system and below the street, a pedestrian connection between the Bus Terminal and the N.Y.C. Subway system was constructed. When the Bus Terminal was opened approximately 2,500 buses were removed from the streets of midtown Manhattan daily. In its first full year of operation, 1951, the Bus Terminal handled 39 million passengers. Over 130,000 riders used the Terminal each weekday.

Within a few years of the Terminal's opening, plans for an expansion of the facility were underway. By the early 1960's, over 6,000 buses and 186,000 passengers were using the Terminal each weekday. In 1963, the Port Authority completed a 30 million dollar expansion project designed to increase the Bus Terminal's capacity by 50 percent. This program added a new bus operating level on the roof of the existing building and three levels of automobile parking, with ramp connections to the Lincoln Tunnel, above.

A second expansion project is now underway to further increase the peak-hour capacity of the Terminal. This program will extend the Terminal north to 42nd Street between the former McGraw-Hill Building and Eighth Avenue and will provide 52 additional bus loading positions with the potential for 26 more positions in the future. The Lower Bus Level extension will be served by a new vehicular underpass which provides direct access between it and the Lincoln Tunnel, thus reducing the amount of bus traffic on 40th and 41st Streets. New passenger concourses with consumer service areas will give access to these loading positions. Portions of the extension became operational late in 1979, and it is expected that work in all new areas will be complete by 1981.

As part of this project, the present Terminal is being modernized to bring all facilities up to current standards and to tie it into the new construction harmoniously. Among the many features of the modernization are the enclosing with glass partitions and air conditioning of 24 "island" platforms which provide a total of 105 bus loading positions. A new ticket plaza/open lounge waiting area has been developed, storefronts are being modernized and all public concourses will be upgraded and air conditioned. Some other features include the replacement of escalators, the central air conditioning plant and the public address, fire and sprinkler alarm systems as well as the rehabilitation of elevators and public toilet facilities.

When this construction program is completed, the Bus Terminal will have been completely redone and will have facilities to support the operations of over 40 bus companies servicing all parts of the United States, Canada and Mexico. The finished building will be a fitting gateway to New York, an asset to the city, and a major influence toward positive change in the deteriorated Times Square Area.

The finished terminal will be a complex of:

- Three levels of pedestrian circulation containing public concourses, ticketing facilities, open waiting areas and over 50 different shops offering a variety of goods and services designed to satisfy the needs of the bus passenger. In addition, the street level will provide for improved entrances, widened sidewalks and expanded taxiway loading and unloading areas. The level below the street will have two direct connecting concourses to the New York City Subway system.

- Five separate bus loading areas on three levels each with exclusive access to the Lincoln Tunnel and enclosed, heated and air conditioned passenger waiting areas.

- Three levels of parking for over 1,000 automobiles, located above the Terminal with its own ramp system providing a direct connection to the Lincoln Tunnel.

- A separate ventilation building located on the south-east corner of 41st Street and 9th Avenue, housing the equipment necessary to maintain the highest level of air quality throughout the bus operating areas of the Terminal.

The building's circulation is designed to accomodate the two main categories of passengers it serves. These categories include; commuting passengers who make up somewhat less than 80% of the traffic and are daily users of the terminal, and the mid and longhaul passengers who represent the remaining 20% of the traffic and are occasional users of the Terminal.

Commuters enter the building at the street or subway level and generally take the shortest or quickest path to their bus loading areas located on the Upper and Suburban bus levels in the existing building. These users, although by far the greatest in number, need the least assistance. They are daily users and quickly learn the best ways through the Terminal and the type and locations of the services they require. They generally have prepurchased commutation tickets which are sold on a weekly or monthly basis or can buy their tickets on the bus. Access to the Upper and Suburban bus levels is through special vestibules located on the Suburban concourse. In these areas, there are escalator and stair connections to the island platforms located on the two levels above. Escalators feeding the Upper bus level transverse two floors in a single run.

The island platforms are served by a pull-through bus operation where buses are lined up and move in tandam to the platform doors where they are

PORT AUTHORITY BUS TERMINAL AND EXTENSION

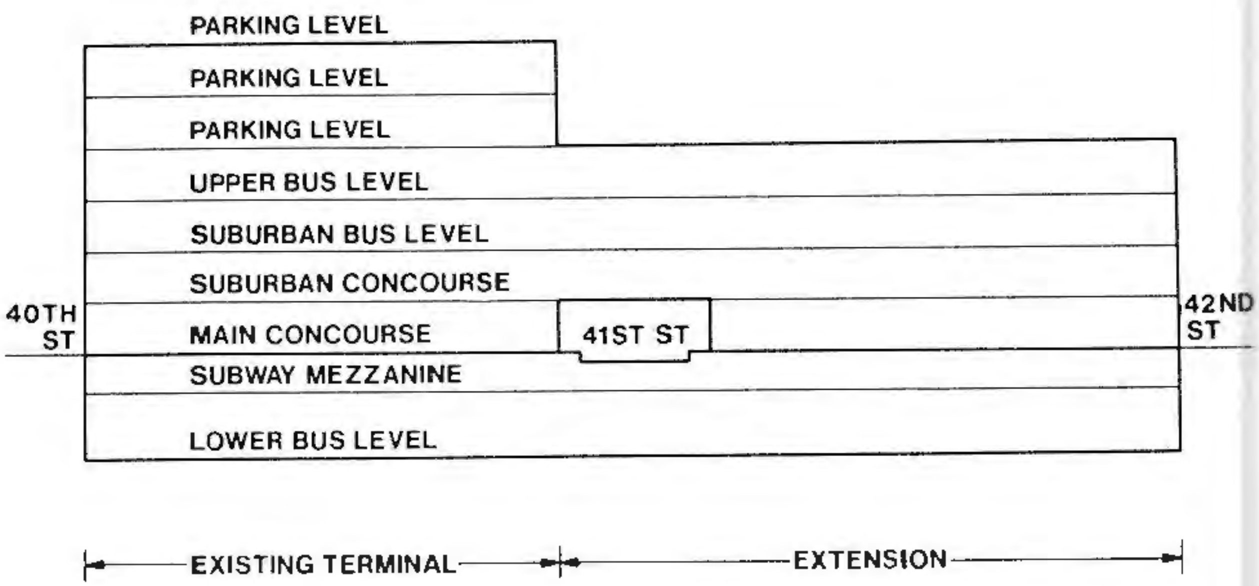

FIGURE 2

loaded with passengers. Incoming buses unload passengers at a special unloading sidewalk at the south side of each of these levels and situated adjacent to the bus entry to the building. This allows a bus to unload and proceed to an island platform to reload or to a bus storage area.

Mid and Longhaul passengers are quite different from commuters and must be assisted by public signing or other information aids to make their way through the building. These passengers are unfamiliar with the building and are generally burdened with baggage. They, like the commuters, enter the building on the street or subway level and from these points, must be directed to one of two ticketing locations. Which ticketing location is dependent on where they entered the building and the bus carrier they plan to travel on. Ticketing facilities for all bus companies are located on the street level of the existing building. In addition, supplementary ticketing facilities for Greyhound and Trailways, the largest carriers using the terminal, are also located on the subway level of the new extension. After purchasing tickets, passengers must be directed to either one of three bus loading areas. These areas are located at the lowest level of the existing building, the lowest level of the extention and on the upper level of the extension. Access to each of these areas is through different circulation routes and passengers must rely on public signing and/or directions from information agents.

Bus loading and unloading for these passengers are at sawtooth bus loading platforms boarded from wide spacious passenger waiting areas. These waiting areas are enclosed, heated and air conditioned and may have a newsstand and snack bar for the convenience of the bus patrons. Disembarking passengers are directed via public signing from these areas directly to the street or subways. Baggage is loaded and unloaded at the bus gate position.

All parts of the building will be totally accessible to the handicapped with the exception of the island platforms on the suburban and upper bus levels. Handicapped patrons using buses normally boarding at these platforms will be picked up, on call, at a special area accessible by elevator. Public toilet rooms, drinking fountains, elevators and telephones are designed for handicapped use. In addition, escalators and stairways are marked to assist patrons with impaired vision.

Architecturally the building is contemporary and designed to make the building users feel comfortable and safe. The finishing materials of brick, quarry tile, wood and bronze are warm in appearance and easy to maintain. Lighting levels are high and the interior spaces have been kept as open as possible, so circulation paths are readily visible and hidden corners are avoided. The major exterior element is a two story high 300' long steel truss supporting the bus levels and spanning from 40th Street, over 41st Street, to 42nd Street. This truss in addition to being a structural element, establishes the building's character and is a unifying design feature visually tieing the existing building with the new extension.

Several major art works are planned for the public areas of the building. A piece by the renowned sculptor George Segal has been commissioned for the main waiting area. Several other pieces are in various stages of the selection process.

At the beginning of this paper it was indicated that the Port Authority Bus Terminal was called the world's busiest transportation facility. When one cites the statistics on the Bus Terminal, it is easy to see why it has earned this title. Last year, the terminal handled over two million buses and more than 55 million patrons. On a typical weekday, approximately 6,200 buses, carrying almost 170,000 passengers use the Bus Terminal. Every morning approximately 52,000 commuters arrive at the Terminal. Since the opening of the Terminal in 1950, nearly 1.5 billion passengers have been accomodated on approximately 56 million buses.

Figure 3 Port Authority Bus Terminal

Figure 4 Port Authority Bus Terminal Extension

CANADIAN INTERCITY TERMINALS

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1. INTRODUCTION

In the allocated time today, I would like to take this opportunity to describe recent Canadian efforts in the planning and development of intercity terminals and hope to raise some issues which we may discuss at tomorrow's workshop. Although this paper is based mainly on VIA Rail project experience, experience of other carriers are also included as a significant number of terminals are expected to be shared by either bus, or in some cases, marine carriers.

The paper outlines some of the background and context of surface transportation in Canada, suggests guidelines for Canadian Terminal Development, and gives some examples of present and future intercity terminal projects.

2. BACKGROUND AND CONTEXT

VIA Rail Canada is a new actor on the Canadian Transportation scene. Since April 1st 1979, VIA, a Federal Crown Corporation, has had sole responsibility for managing in one unified system all rail passenger services in Canada formerly operated by CN and CP Rail. VIA now manages all intercity passenger rail service in Canada with minor exceptions in Northern Ontario and British Columbia. Commuter rail services, excluded from VIA's mandate, are still operated by CN and CP Rail.

VIA has been given a mandate that will have a major influence on the direction of Canadian intercity terminal development. Its two-fold corporate mandate calls for (i) providing efficient and attractive services in areas where rail is an appropriate and effective form of passenger transportation; (ii) minimizing operating losses. Specifically for terminals, we are now preparing plans to manage and control passenger terminals as an integral part of the total surface transportation system and to develop a new design standards that will promote more multifunctional and intermodal terminals.

Terminals as opposed to rolling stock are presently owned by the railways and their usage is defined under the present operating agreement between VIA and the two railways. Although there is an agreement in principle between VIA and the two railways to transfer terminals to VIA, this has not yet taken place. Consequently the pace at which Canadian intercity terminal development plans can be implemented remains to be settled.

The future direction for Canadian terminal development is unclear at the moment. Nevertheless two key elements are evident.

The first element is related to the role of the bus industry in the development process. The bus industry in Canada in contrast to intercity rail is regulated by the provinces, fragmented with some 60 plus separate companies in the business, providing mainly regional services. The only major exception is Greyhound that provides transcontinental or national service. Thus at present, joint bus and rail involvement in terminal development are unique at each location as there is no single national bus industry counterpart for the rail passenger carrier.

Past Canadian terminal development efforts were uncoordinated as there was no real incentive to combine efforts and each carrier prepared its own plans. For example in Saint-John, New Brunswick, in 1979 VIA consolidated two former CN and CP Stations located in the suburbs at one downtown location. While VIA was preparing its plans, SMT the major regional bus carrier was also preparing its own plans for their terminal at another location which is only a short distance away. This example in Saint John illustrates how we missed opportunities to improve our surface transportation system.

To take advantage of future opportunities, VIA has assigned a priority to first develop those terminals where it is possible to integrate rail facilities with other modes. There are now several projects in the planning stage and depending on the response to specific proposals, joint terminal development is expected to become more prevalent.

Joint development is likely to take place at one of three levels, where each succeeding level requires greater degree of cooperation and/or coordination.

Level One: Joint Use of Facilities

Each carrier uses the same facility and pays its pro rata share. (e.g. waiting room for passenger).

Level Two: Integration of Service

Schedules are arranged so that bus and train arrivals and departures allow convenient transfers from one mode to the other.

Level Three: Joint Operation

Daily terminal operations are fully integrated. For example, same employees carry out the same function for different carriers (e.g. baggage handling and ticketing for bus and rail services is by the same person).

The second element that is emerging is related to what role local municipalities/communities will have in terminal development and to what extent they are able to participate in the development process.

During the "great railway era" railways spent must more on station design and construction than that dictated by economic return on investment. As passenger terminals were "The gateway to the city" for either political or public image (competitive reasons) they were larger or were of better quality than that required to provide an adequate service. There are many examples in Canada as well in the U.S. where this has taken place. Today's "Gateway to the City" is the air terminal and consequently these terminals are now built to standards exceeding normal passenger needs while the rail terminal is often neglected.

As revitalization of passenger rail service is starting to take form in Canada, communities are looking once again at the rail terminal and they are not proud of what they are seeing in their community. With increasing frequency communities are requesting VIA to improve the image of the terminal in their city. However, in today's intercity transportation context, the passenger rail company cannot immediately meet all real and/or perceived terminal needs as it faces two major constraints.

First, since rail service is a national public service, it is difficult to justify any additional expenses required to meet specific local needs which go beyond some basic level of service. Second, funds allocated to terminal development must be in relation to other elements of the rail system. Thus, with tighter budgets it is more difficult to undertake immediate terminal development to counteract 25 years or so of neglect for the some 850 rail stops in Canada.

Terminals in most communities will not be developed as the community desires or it may not be developed in the time framework they desire. In most cases some positive action will be required on the part of the community to meet strictly local needs. One small example is in Kapuskasing, Ontario where the local community was a driving force in the creation of a new terminal or travel center that houses bus and rail services, limousine to the airport, and travel agents. In this case, the city, on its initiative, applied and got federal funds to cover the necessary capital costs and set up a management committee, comprised of council members and carriers, to operate the travel center. The committee establishes rental charges to terminal users which offset all operating costs. Both the travelling public and the carriers seem to be satisfied with this arrangement. Although this example is on a small scale, it illustrates how communities can have a significant role in the development of terminals. This is an isolated example and this approach remains to be tested elsewhere in Canada.

3. GUIDELINES FOR TERMINAL PLANNING

Guidelines for terminal planning must take into account that Canada is a linear country with its population centres strung out parallel to the U.S. border. The rail transportation network clearly reflect this.

Effective intercity passenger rail service on this network depends on how VIA will be able to implement convenient downtown to downtown service to maintain and attract passengers who require more favorable "door-to-door" travel times than are available at the moment. Thus a key component of future rail passenger plans is the development of terminals in central areas of major cities.

One can safely assume that future rail access to central areas of major cities will be over existing right-of-way since new routes, although technically feasible, may not be realistic due to its impact on urban development and magnitude of cost. With passenger services over existing right of way, terminals that are already in city centres will be used and terminal development will be in the form of renovation as opposed to new construction.

There are some exceptions to this in Canada, since during the mid sixties several cities have undertaken rail relocation projects from central areas as part of urban renewal projects. Consequently for cities, such as Quebec, Saskatoon and Ottawa, rail access to the central terminal has to be included in the planning process.

Major Canadian intercity rail terminals were built between 1900 to 1930 during the great railway age and in many cases the buildings have a definite historical/heritage value and often have a significant architectural value as well. This is especially evident in Western Canada where urban development centered around the passenger terminal and the building often became a major landmark.

The implications of these considerations for planners and designers are that:

1. New functional standards required to attract passengers have to be housed in an existing physical space.
2. New terminal designs have to be integrated with older architectural styles.

These two considerations, which may be conflicting at times, truly pose a challenge to planners, architects, designers and engineers to come up with plans that are modern and efficient and yet do not destroy the character of the building. We are presently involved in three major projects where we and our consultants are responding to this challenge (Vancouver, Winnipeg and Toronto).

Another factor that introduces an additional challenge to the planning process is the magnitude of a particular project. In many cases, required terminal modifications are beyond the capability of the carrier and other parties may become involved. In Quebec City, for example, where plans are begin prepared to relocate the station downtown, fifteen parties, comprised of city, regional, provincial departments and carriers are involved in the process. As in the Quebec case, major terminal plans have to be both a "selling" as well as an "information" document to people who may have different objectives and different viewpoints on the same project.

In preparing specific terminal development plans, we have found it useful to first prepare a preliminary terms of reference for the necessary work. This document is usually based on an analytical framework which considers the four major movements in and around the terminal. With this framework one can trace the sequence of passenger, equipment, baggage and on-board service movements. The framework can also be used to indicate to the planners/designers:

1. the scope of their responsibilities for which detailed plans are expected;
2. define relationships between the various terminal processing functions;
3. describe how the terminal is expected to be used based on its relative location in the city and the type of available train service.

Although intended for rail terminals, the same framework was used to develop terminal designs in Vancouver where both bus and rail are present at one location. The specific aim of this project was to assess the feasibility of accommodating a bus terminal in addition to the existing rail terminal at the Main Street terminal site and to further elaborate the intermodal concept.

Intent for intermodal coordination is shared by many individuals in both the rail and the bus industry, however, industry wide acceptance and, of course, implementation has been very slow in Canada. Carriers are hesitent to embark on intermodal projects due in part to misunderstanding and mistrust of each others motives and in part to not being able to clearly visualize how their individual operations would function together on a day-to-day basis. On the Vancouver project where some of these elements were present, steps had to be taken to create a good working environment.

The study was funded fifty percent by VIA and fifty percent by Pacific Coach Lines, a provincially owned bus company serving Vancouver Island and the lower B.C. mainland. It was realized from the outset that joint funding was an essential ingredient for getting active participation and commitment to consider and to act on project results.

Since VIA and PCL never worked together before and the respective operational requirements were unknown to the other party, the selected planning approach called for specific inputs from the people who will be using the terminal. That is PCL and VIA drivers, dispatchers, ticket sellers, on-board personnel all actively participated in the planning process. After a week long review or "Gaming Sessions" the architect/planners, who managed these sessions, were able to synthesize the relevant constraints and goals which were then used as design guidelines.

Having agreed on individual needs our consultants produced a final plan which met the requirements of all parties concerned. The results of the study showed that:

1. Joint terminal space requirements are less than that required for individual carriers. Specific benefits are that:
   - o 30% less space is required for the joint waiting room.
   - o There is a 15% increase in the available commercial space
   - o Passenger parking can be reduced from 150 to 120 spaces
2. Due to increased traffic volumes and extended hours of terminal usage there may be a perceived improvement in "personal safety" and it will be possible to attract superior quality concessions.

These results clearly indicate that there are definite incentives, both tangible and intangible, for undertaking intermodal terminal development.

The Vancouver project, is one example of what we are trying to achieve in Canada and serves as a good model for future terminal planning and development efforts.

Several other intercity terminal projects are underway and they have advanced to various stages.

A. Conceptual Stage	No financial commitments; emphasis is on integrating various functional elements. (Quebec, Moncton, Calgary, Saskatoon).
B. Preliminary Design	Used as a basis to determine project budget and to negotiate financial arrangements. (Moose Jaw, Melville, Winnipeg, Windsor).

C. Negotiations — Project organization and implementation details are defined.

(Levis, Regina, Vancouver).

D. Construction — Start of building and putting facility into operation.

(Toronto).

4. SUMMARY

In summary, project experience in planning and development terminals in Canada has indicated that:

1. Projects tend to become political issues

   As far as planners/designers are concerned there is no way to avoid this and to meet the expected challenges in an open public forum, a suitable strategy, from a technical point of view, is to prepare a sound information base for responding to political queries. This base should be mainly concerned with the rationale and basic principles of the design as opposed to specific details.

2. Projects have many participants

   Terminal development has to consider the specific needs, policies and procedures of each participant. To resolve any inconsistencies and conflicts of a project, it is preferable that a key participant such as municipal official (e.g. Planning Director) be appointed to serve as a coordinator between participants.

   With more than five or six participants as may be the case on major projects, participants tend to become passive. That is they prefer to react as opposed to generating new ideas. This will mean that planners will have to generate options for review by participants. To carry this out successfully, it will be useful to keep project data at the lowest possible level of aggregation in order to present the same options in a different format.

3. Projects are often extended beyond original target dates.

   Although many projects technically can be done in a relatively short period, it is often extended for non-technical reasons. Thus planners may have to accommodate changes in their plans in order to include new features which may not have been considered before. eleventh hour suggestions although unpopular are often valid.

Moreover, if a project is over one year in duration, the financial position of the carrier may change and force changes in the design details. Even when plans are complete, the negotiated cost-sharing arrangement for terminal development may also force changes in design details. Thus, flexibility in the proposed terminal plans to allow changes in design detail is essential to successful implementation.

5. FUTURE OUTLOOK

Future terminal development is closely linked to the success of intermodal coordination in Canada. Although potential roles for carriers are now apparent and are basically understood, specific roles for local, provincial and federal governments have not been defined as of today as this has only recently come to the forefront with the creation of VIA Rail.

TDC, the Transportation Development Center of the Federal Ministry of Transport, is planning to initiate a research program to determine the appropriate roles of the various participants and the likely federal provincial mechanisms for implementing terminal plans. The extent of this program should be known by this fall or the end of this year, and will certainly add a new dimension to the terminal development process.

In the interim we are trying to meet many of the technical and administrative challenges I mentioned today through initiating new terminal projects that underscore that future major transportation decisions must be intermodal rather than mode-by-mode as is the current practice in Canada.

SOME FUNCTIONAL ASPECTS OF EUROPEAN TRANSPORTATION TERMINALS

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Abstract

The purpose of this paper is to explore the approach Europeans have taken to planning, designing and operating transportation terminals. Terminals are examined from a functional, i.e. traffic engineering, viewpoint. Four categories of terminals are studied: 1) Railway Terminals, 2) Bus Terminals, 3) Metro Terminals and 4) Intermodal Transfer Centres.

A striking feature of all the railway stations in the Netherlands is the integration of bus and rail transportation. Bus stations for both urban and inter-urban lines are located adjacent to the railway stations. Access by bicycle is another unique characteristic of Dutch railway stations. The Dutch railways run an open system permitting anyone to enter the station platforms. This philosophy simplifes station design. The British run a closed system.

The striking feature of most European bus stations is the lack of a terminal building. These stations are laid out in the forecourts of the railway stations. Tickets can be purchased on the buses. The buses operate on the flow-through principle. They are not permitted to reverse. The platform layout is usually of the herringbone type although some stations are now using linear types. Experiments are underway in the Netherlands to reduce the size of the bus stations by "buffer" systems and computer control.

The metro stations in Europe are also highly integrated into the bus and rail networks. In the Netherlands a particularly successful integration was achieved with Amsterdam Metro and Dutch Railways. At several stations the train and metro share platforms. Another excellent example of integration was found in Hamburg. Here bus and metro are interlaced with the aid of traffic controllers.

Intermodal transfer centres are emerging in several cities in Europe. These centres have, under one roof, railway, bus, train, and metro stations.

Some have joint development in and around the station complex. Examples of such centres were found in The Hague and Utrecht. A unique computer controlled transfer centre in Lyon, France is described.

Introduction

Public Transportation in Europe is considerably more successful that it is in Canada and the U.S. Ridership volumes are greater, the level of service is much better, and the technology is much more advanced. Part of the reason for this success lies in the geographic and cultural nature of Europe. European cities are much closer together, they are more compact and have higher population densities than Canadian and American cities. Many European cities are still downtown oriented with people not only working but also shopping and living downtown. Land use is much more closely tied to transportation in Europe, automobile ownership is not as high, and gasoline costs are much higher than in Canada and the U.S.

The other part of the success story lies in the planning approach used by Europeans. The underlying philosophy of all their public transportation planning is the integration of modes. This fundamental principle means that all transportation modes should complement each other and function as an integrated system. The Europeans accomplish this on several fronts, the most visible of which is the transportation terminal. Here trains, buses, trams, metros, cars, and bicycles converge and diverge in accordance with co-ordinated schedules. Passengers transfer within minutes from one mode to another.

Another area which aids the integration of modes is ticketing. Most European transportation routes fit together in an interconnected network so that the traveler only has to use one ticket even if he has to transfer from one mode to another. As of May 8, 1980 a fare card called a "Strippen Card" was made available in the Netherlands. With this card a passenger can use any bus, tram and metro in any city in the Netherlands and transfer freely among these modes. In addition the card can also be used for trains running between Amsterdam, The Hague and Rotterdam.

The least visible area for the integration of modes is at the management level. Many European cities have set of Transportation Associations. These associations compromise numerous public and private bodies providing transportation service. These associations, working across municipal boundaries, co-ordinate time-tables, conduct research, finance projects, and keep the public informed of transportation services.

The integration of modes is a complex problem calling for multi-disciplinary solutions. This paper will focus on only one such solution - the planning and design of transportation terminals. The purpose of the paper is to examine the approach the Europeans have taken towards planning, designing, and operating their terminals.

The primary function of a transportation terminal is to facilitate the transfer of passengers and baggage from one mode of transportation to another. A secondary, albeit important function, is to provide shelter for its occupants. The focus of this paper will be on the primary function i.e. traffic, rather than on the secondary function, i.e. architecture. Four categories of terminals are discussed: 1) Railway Stations, 2) Bus Stations, 3) Metro stations, and 4) Intermodal Transfer Centres.

Railway Stations

Railway Stations in the Netherlands

Dutch railway stations are among the most functional and best integrated stations in Western Europe. There are currently (1980) 330 stations in the Netherlands as compared to 900 stations twenty five years ago. These 330 stations are served at least once every hour with most of them being served at least once every half hour. For the years 1980-1990, 30 new stations are planned.

The size of the Dutch railway stations vary from the small village stations processing a couple of thousand passengers a day to tens of thousands a day in the larger cities. The cities with the highest volumes are Amsterdam, Utrecht, Rotterdam, The Hague, and Leiden. Table 1 shows the actual volumes as well as the age and building volume of the stations.

Table 1

Size of Selected Dutch Intercity Stations

Station	Construction Year	Building Volume-m³	Daily Passenger* Volume-1977/78
Amsterdam C.S	1885	170,000	83,555
Utrecht C.S	1973	14,875	58,079
Rotterdam C.S	1958	44,500	55,055
The Hague C.S	1973	66,191	46,462
Leiden	1952	14,650	26,157

*Boarding + Alighting passengers + 30% for those not counted in surveys, per average week-day.

Most of the Dutch railway stations are located in the centre of the cities. Here these stations are physically connected to bus, tram, and metro stations. Such a central location means not only that the city centre is accessible to public transportation, but the station itself is highly accessible as well. This is particularly important for non-auto traffic. Table 2 contains the modal split for access to larger Dutch railway stations, i.e. "intercity stations", as a function of city size. Note that as city size increases, the pedestrian and bicycle access position drops, and public transport's share increases.

Table 2

Modal Split of Access Traffic to Dutch Intercity Stations

Population of City	Walk (%)	Bicycle (%)	Bus, Tram or Metro (%)	Car	Other
< 80,000	37	36	18	7	2
= 200,000	25	29	36	7	3
> 200,000	21	11	55	9	4

Source: Reference 1

The sphere of influence for a typical station is estimated by Breedveld (1) to be 800 metres for pedestrians, 2500 metres for cyclists, and 4500 metres for automobiles. For all three categories these distances represent a total travel time of 10 to 15 minutes.

Rotterdam Central Station

This station is a good example of a traditional terminal in the Netherlands. It is located in the heart of Rotterdam. On the rail side it is a through-type station with 14 elevated lines. The main terminal building is located at street level on the downtown side of the tracks. Another smaller terminal building is located on the other side of the tracks. A tunnel under the tracks connects the two buildings and also provides access to the platforms.

The integrated nature of the stations is clearly visible in Figure 1. Auto's and taxis use the frontage road between the terminal and the city tram and bus stations. Underneath the bus station is the metro station connected to the railway station with tunnels. To the east of the station is the intercity bus terminal. To the west is a short term parking lot. Long term parking is located north of the tracks. Bicycle storage with a capacity of 3100 bicycles is in the basement of the main terminal building and next to the secondary terminal building.

The layout inside the main building is functional. In the great hall are located the ticket wickets, automatic fare machines and concessions. The main pedestrian flow is through a wide tunnel leading to the 14 platforms. Access is by stairs. Escalators will be installed in the near future. Access to the trains is direct and straightforward. Access to the other modes from trains requires some searching.

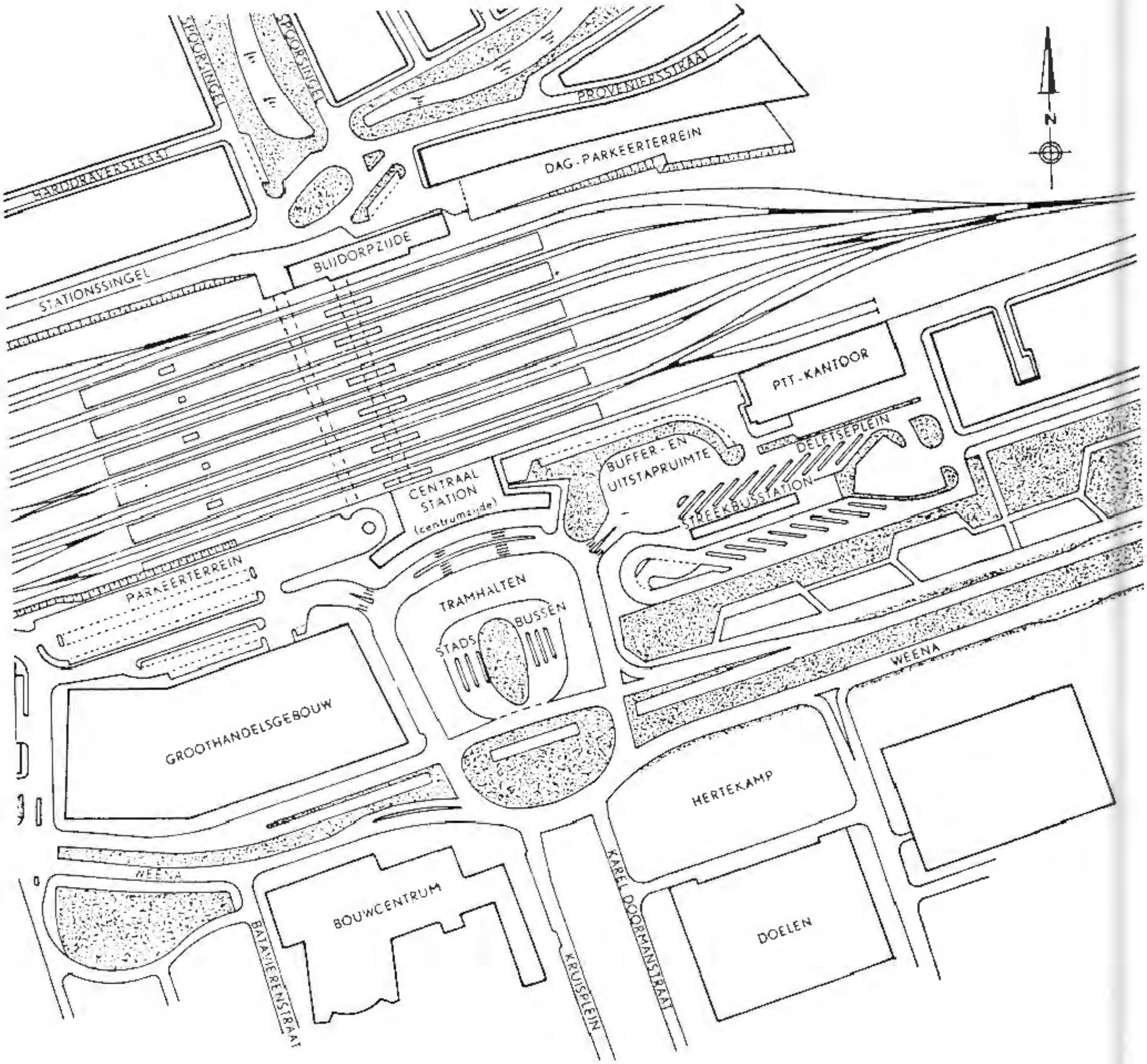
Information on train schedules and platform locations is well presented. The Netherlands is the only country in Europe where train information is given in order of destination. All other countries give train information in chronological order. In other words, in the Netherlands you select your destination first, then find a suitable departure time. In other countries you find a departure time first and select your destination.

The Dutch Railways run an "open" system so that all platforms are accessible by anyone, passengers or otherwise. This is not the case in England where British Rail runs a "closed" system whereby only people with tickets are allowed access to the platforms.

At Rotterdam a color coding system is used to assign passengers to their appropriate cars on international trains. The edge of the platform is painted

FIGURE 1

CENTRAL STATION, ROTTERDAM, THE NETHERLANDS



LEGEND:

Centraal Station =	main building of railway station
Tram Halten =	street car (tram) stops
Stads Bussen =	city buses
Streek Bus Station =	intercity bus stations
Buffer en Uitstap-Ruimte =	queuing and disembarking area
Parkeerterrein =	parking area (short term)
Dag-Parkeerterrein =	day parking area
Blijdorpzijde =	Blijdorp side of railway station

SOURCE: Dutch Railways

with different colors to indicate where the cars will stop. A display unit on the wall matches the car number with the colored sections on the platform. The German railways use overhead signs to mark off platform sectors.

The Dutch Railways also assign their trains to platforms to ensure that the majority of connecting passengers transfer by simply crossing the same platform.

Railway Stations in Great Britain

As in most countries rail travel has decreased dramatically during the past 25 years in Great Britain. In 1977 there were approximately 2,700 stations in Great Britain as opposed to 5,000 in 1962 (2). However, rail travel is on the increase again. Moss and Leake (3) report a growth rate of 2 to 4 percent per annum for intercity rail travel.

The largest and most impressive railway stations are in London. There are 16 stations located in a circle around central London. Most of them are stub, or terminating, stations. Some 14 of these stations are connected with the London Underground. These stations process immense volumes of passengers. It has been estimated that Liverpool St. Station, and London Bridge station process one million passengers a day each. London's stations are all old, dating back to the mid to late 1800's. British Rail is in the process of modernizing them. The latest station to be renovated is London Bridge station.

Integration of Transportation Facilities

Like the Dutch Railways, British Rail is very much interested in the integration of its facilities with the other modes of transportation. In London this is done very well except for regional and intercity buses which have their own terminals some distance from any railway station.

Taxi service at a number of London stations is well integrated with the rail service. In both Liverpool St. Station and Paddington Station, taxies drive into the station, parallel with the tracks, to pick up fares.

Moss and Leake (3) conducted a study on the access journey to the provincial rail terminals of Leeds, Newcastle and York. They surveyed passengers from these stations to King's Cross Station in London. Table 3 contains the results.

Table 3 shows a heavy reliance on the automobile to provide access to the railway stations. Compared to the modal split in the Netherlands, few people walk to the station and none use the bicycle.

Table 3

MODAL SPLIT OF ACCESS TRAVEL TO THREE BRITISH RAILWAY STATIONS

City	Walk (%)	Motorcycle (%)	Bus (%)	Car (%)	Other
Leeds	12	-	23	51	14
Newcastle	9	-	20	60	11
York	15	1	14	60	10

Source: Adapted from Reference 3

Ticket Barriers

Since British Rail operates a "closed" system, barriers are placed across the entrances to the platforms. Here inspectors examine the tickets of the passengers. Such a system must be well designed to avoid lengthy queueing and delays. British Rail suggests that for a reasonable degree of inspection the flow rate per inspector should not exceed 30 passengers per minute. However at the London stations during peak periods it will require a flow rate of 75 to 100 passengers per minute to clear the platform (4). Under such flow rates only a cursory inspection can be made.

Bus Stations

A bus station is defined as a collection of bus stops arranged off street (usually in some sort of courtyard) so as to enhance the visibility of the buses to the passengers, and in such a manner so as to facilitate the safe movement of pedestrians and buses. In the Netherlands a bus station is defined as a central point in a city or town where at least four bus lines meet and which has a schedule documenting the departure times of the buses (5). Many European bus stations do not have terminal buildings.

Bus Stations in the Netherlands

Location of Bus Stations

In general it is customary in the Netherlands to place a bus station adjacent to or nearby a railway station. Bus stations are usually located on the downtown side of the railway station. In a survey of the 70 bus stations, Grondelle and Polder (5) found that 84% of them were located in the front of the station, such as Haarlem, 6% of the stations were located at the rear of the stations, such as Eindhoven, and 10% were a mixture of in front, at the rear, beside, or across the street. Utrecht for example has three bus stations, two at the front and one in the rear. The preferred location of a bus station with respect to the train station is to the left when facing the station. This location minimizes bus movement and pedestrian-vehicle conflicts.

A further distinction is made between the type of bus stations. Basically there are two types: 1) city bus stations, and 2) intercity bus stations. These two types are often physically separated from each other. The layout of Rotterdam station (Figure 1) shows this separation clearly. It is important to differentiate between the two types of buses because of the dwell time of the buses. Only about 50% of the city buses begin and end their routes at the station and they stay a short time. Often the stop at the station is no different than any other city bus stop. Of the intercity buses about 85% begin and end their routes at the station and require longer time. Consequently, intercity bus stations require considerably more space than city bus stations.

Platform Layout

Two types of bus platforms are used in the Netherlands: 1) herringbone type and 2) linear or island type. The herringbone type is the most popular and is illustrated in Figure 1 for Rotterdam. Each bus line has its own platform. The result is a large area, not efficiently utilized and requiring long walking distance for passengers. Orientation is also a problem in this kind of layout as is safety where pedestrians have to cross roadways and aisles being used by buses. The visibility of the buses can be enhanced by parking them so that passengers leaving the train station see the front of the buses.

The second type, the linear or large island type, is essentially a long stretch of curb where buses park end-to-end, parallel to the curb. Passengers remain on the island, separated physically from the buses. This approach requires long walking distances and good signing to avoid disorientation. This type of layout is best suited for buses with short dwelltime, such as city buses, in order to keep the length of curb to a minimum. The traditional sawtooth layout is no longer used. This layout was abandoned in order to avoid backing up of buses.

In a recent survey (6), a sample of passengers were asked to state their preference for either the herringbone type layout or the linear island type layout at Utrecht. The results showed that 44% preferred the linear island type, 23% preferred the herringbone type and 33% had no preference. The survey also showed that the reasons for choosing the island type were greater safety and more comfort than the herringbone type. The herringbone type however did score higher in visibility and orientation than the island type.

The Buffer System

The traditional herringbone type bus terminal with each bus line being assigned to a platform was considered to be an inefficient use of land as well as creating long walking distances for the passengers. Under certain conditions of scheduling whereby for example not all bus arrivals and departures are the same time, it is possible to use a new approach to bus station design i.e. the buffer system. Here the buses arrive at a stop in front of the railway station to disembark passengers. The empty buses then are driven to a waiting area, called "buffer" to wait for their departure time. A few minutes before departure, the buses are driven to their platform to pick up passengers.

The result is a smaller area required for the buses and a better utilization of platform space. Passengers also benefit by having shorter walking distances. The design also minimizes pedestrian-vehicle conflicts. Such a bus station was designed and built at Breda.

DOVER: (Dynamic Public Transportation and Passenger Information)

Research is underway in the Netherlands to improve the buffer system by controlling bus and passenger traffic flow through information displays. All buses arriving at the bus station must be equipped with transponders, such as VETAG (Vehicle Tagging System). As a bus enters the station it is automatically identified by a computer and assigned to either a buffer area or a particular platform. If the bus is carrying passengers these are first unloaded and then the bus proceeds to the buffer or its platform. Inside the terminal, passengers are given information as to the departure time and platform number of their particular bus. At·the appropriate time, bus and passengers meet with a minimum of inconvenience.

Bus Stations in Great Britain

In Great Britain as in the Netherlands, the ideal location for a bus station is in the middle of the city centre. Britain however has not been as successful as the Netherlands in locating bus stations in the centre and/or connected to a railway station. Problems of suitable land, existing facilities, road access, and urban layout have plagued British planners. Such problems have resulted in most recent bus stations being constructed on the periphery of the city centre. Steer (7) lists such examples as Bradford, Huddersfield, Northampton and Preston. These locations, in addition to being inconvenient to the passengers, have also increased bus operating costs.

In the design of bus terminals in Britain, an attempt is made to segregate passengers and buses within the terminal. This is usually done with grade separations. The type of platform layout depends to a large degree on the maneuvering criteria for the buses. For example if reversing is permitted or required, then the sawtooth layout might be a suitable concept. Steer (7) also reported that up to now most bus stations in Britain do not separate boarding, alighting and storage functions.

Victoria Bus Station

An example of a high capacity bus station is the Victoria Bus Station in London. It is located directly across from the Victoria Railway Station in a very small area. The bus station consists of 6 platforms, with the length of the platform varying from 1 to 1 1/2 bus lengths. On the average, during one hour some 18 buses depart per platform. In comparison with the Netherlands, on the average only 2 to 3 intercity buses depart per platform per hour, and some 4 to 8 city buses per platform per hour (5).

Metro Stations in the Netherlands

Only two cities in the Netherlands have metro systems, Rotterdam and Amsterdam. The Rotterdam system was opened in 1968 and Amsterdam's metro opened in 1977. Neither system has reached its ultimate development, therefore planning, design, and construction work is still continuing.

As with any station planning in the Netherlands, every attempt is made to integrate the metro system with the other modes of transportation. In both Rotterdam and Amsterdam the metro interfaces with the train, bus, tram, and automobile.

Amsterdam has been particularly successful in achieving an excellent integration between its metro line and the lines of the Dutch Railways. Amsterdam has been able to do this because the railway infrastructure - track and stations, could accomodate the Metro. Also, metros in the Netherlands now operate on an "open" system as do the railways. This made the operation of the one compatible with the other and subsequently influenced the design of the stations, i.e. the metro station and the railway station no longer have to be physically separated, as was the case when the Rotterdam metro was designed.

When the construction of the Eastern line of the Amsterdam metro is completed it will be possible to change from the Dutch Railways trains to/from the Amsterdam Metro trains at three stations: Central Station, Amstel Station and Bylmer Station. The latter two stations exhibit a unique transfer operation in that the Metro operates from one side of the platform while the Railways operate from the other side of the same platform. To transfer, all passengers have to do is walk across the platform from one mode to the other.

Amsterdam Metro Bylmer Station

This is one of the 15 above ground stations of the East line of the Amsterdam Metro. The remaining five stations are underground. The Bylmer station is located on the Amsterdam-Utrecht railway line near the centre of the new Bylmermeer suburb of Amsterdam. On the east side of the station is a shopping and recreation centre, on the north-east and south-east are residential areas, and on the west is an industrial park. Planners estimated that the demand on the station will be 6,000 arrivals and departures during the peak hour.

Access to the station is via a pedestrian and bicycle path. These paths run underneath the station connecting the shopping centre on the east with the industrial park on the west. These paths are also connected to a kiss-and-ride area, a bus stop area, a taxi area, and a park-and-ride area. Thus this station is integrated into all the modes of transportation. There is even a bicycle storage facility inside the main building.

The station has a central entrance leading to a ticket hall under the platforms. The difference in the height between this hall and street level is 2.10 metres. There are two stairways each 3 metres wide. Due to the small difference in elevation, escalators were not deemed necessary. In this hall tickets can be purchased from a machine, (if you happen to have the correct change). In 1980, Amsterdam Metro was not permitted to sell tickets manually.

From the ticket hall the platforms can be reached by two stairs and one escalator. The height from the ticket hall to the platform is 5.30 metres. An elevator has also been installed for anyone wishing to make use of it. The Amsterdam Metro does not use any pictograms but relies on simple words like "lift".

The station has two island platforms each 11.50 metres wide. The Metro trains stop on the inner side of the platform and the Railway trains stop on the outer side, each train travelling in the same direction. Due to the different lengths of the Metro trains and the Railway trains the sides of the platforms are also of different lengths. The Railways side is 210 metres long and the Metro side is 155 metres long. This arrangement is the ultimate in intermodal transfer. See Figure 2 for a layout and profile of the station.

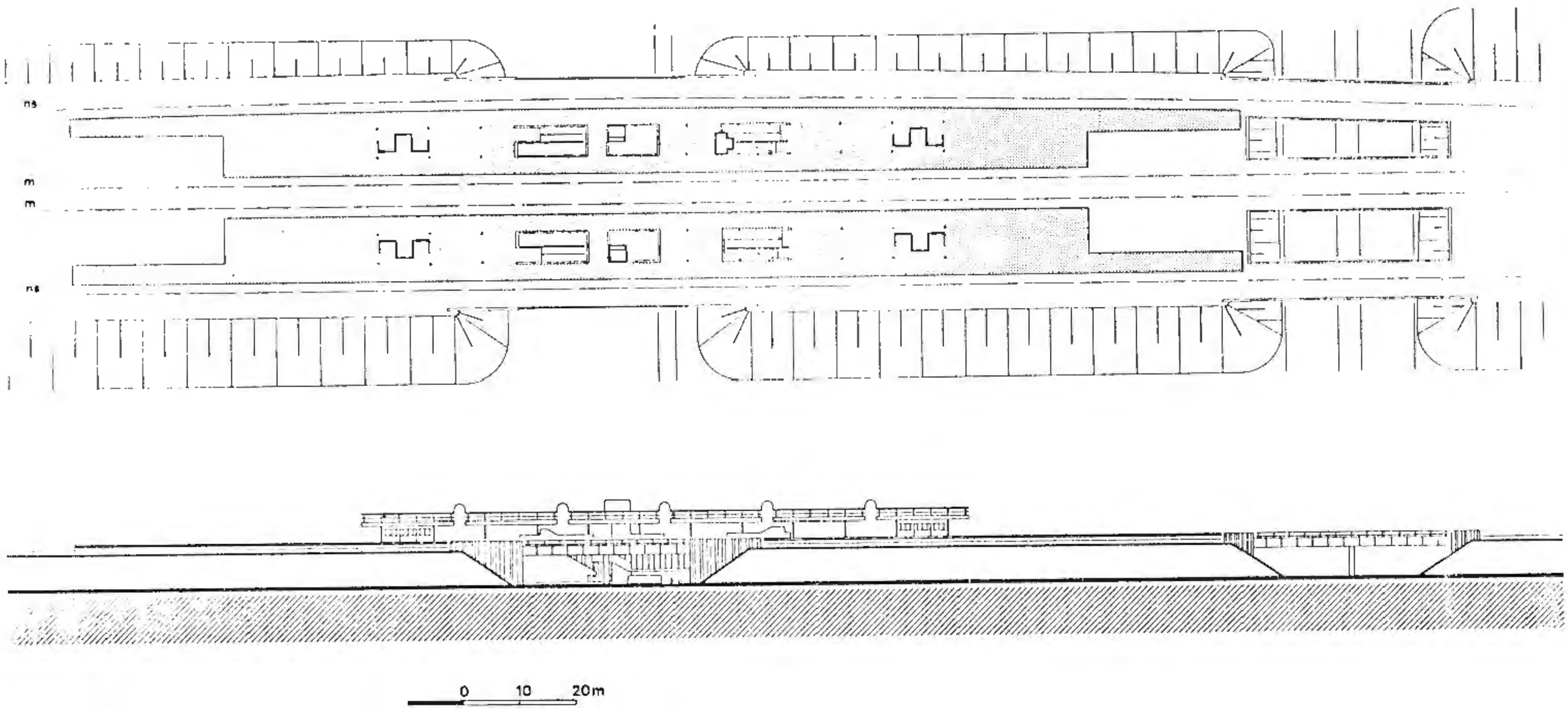
Metro Stations in Germany

The major cities of West Germany, Hamburg, Frankfurt, Munich, etc. have well developed metro systems. And like their Dutch counterparts have achieved a remarkably high degree of integration of their public transportation system. A great deal of the credit for this success goes to the "Verkehrsverbünde", or Transportation Associations. Hamburg and Munich have such associations.

The Hamburg Transportation Association (H.V.V) was founded in 1965 to coordinate and be responsible for public transportation in the Hamburg Area,

<u>FIGURE 2</u>

BYLMER METRO STATION - AMSTERDAM, THE NETHERLANDS



<u>LEGEND:</u>

ns = Dutch Railway lines
m = Amsterdam Metro lines

SOURCE: Amsterdam Metro

independent of municipal boundaries. The H.V.V. consists of nine member organizations which include the Hamburg Transit Company, the German Federal Railway, the German Post Office, and smaller bus and ferry companies. These members provide nearly 100% of the public transportation services in an area of 3,000 km². This area includes 144 municipalities. A similar Association in Munich covers 2,600 km².

The H.V.V. acts as a central planning body for public transportation in Hamburg. It is responsible for: setting fares and schedules, planning and research, layout of networks and stations, setting investment policies, distributing revenue, and performing public relations functions.

The H.V.V. transports about 2 million passengers a day on a line network of 2,800 km using 2,850 vehicles. The H.V.V. network has 2,682 stations and carries about 80% of the commuter traffic (8).

It is H.V.V. policy to assign long distance work trips to the rapid transit system (metro plus commuter rail). Its 12 lines carry 55% of the passengers. The Central Railway Station handles 100,000 passengers daily. Buses are assigned as feeders and distributors for the rapid transit network. Suburban bus lines take on a star shaped pattern as they connect with the transit stations. At the busiest interchange point between buses and metro, the Wandsbeck-Markt Station, 60,000 passengers pass through the terminal. Furthermore Park-and-Ride is encouraged. There are P & R areas at 41 stations totalling 6,100 parking spaces (8).

Hamburg Metro-Wandsbek-Markt Station

Where the Bylmer Station in Amsterdam is an excellent example of integration of metro and rail. Hamburg's Wandsbek-Markt Station is an outstanding example of the integration of metro and bus. The station is used by fourteen city bus lines, three express lines and three night lines. This represents 1100 daily bus departures. These departures have to mesh with a daily volume of 200 metro trains departing for the city center.

The bus station is accessible only by bus, or through the metro station. The metro station is a standard island platform type. From the platform, access is via stairs or escalators to a pedestrian complex consisting of intersecting tunnels. One of these tunnels leads to the centre of the bus station, a large oval shaped pedestrian area. At the periphery of this area are the bus stops, with buses parked parallel to the curb. The result is complete separation of buses and pedestrians, and short walking distances.

See Figure 3 for a layout of this station.

Bus traffic, and subsequently pedestrian traffic, is controlled by controllers in an elevated control tower in the centre of the bus station. These controllers assign buses to departure "gates" in accordance to a schedule, or if necessary in accordance with metro train arrivals and departures. Information panels of the type used at airports inform the pedestrian of the proper "gate" and time for their bus.

Intermodal Transfer Centres

An intermodal transfer centre is the ultimate in the integration of transportation. Here in one complex and under one roof, the interchange of passengers among the many modes takes place. Trains, buses, trams, and metro trains, all meet in the same building either at grade or at different levels.

Associated with these intermodal transfer centres has come joint development. This is the ultimate in the integration of land use and transportation. In and around these terminals, land is developed to enhance not only the function of the station but also of the urban area. Shopping complexes, hotels, office buildings, recreation and exhibition centres have been built around and into these terminals.

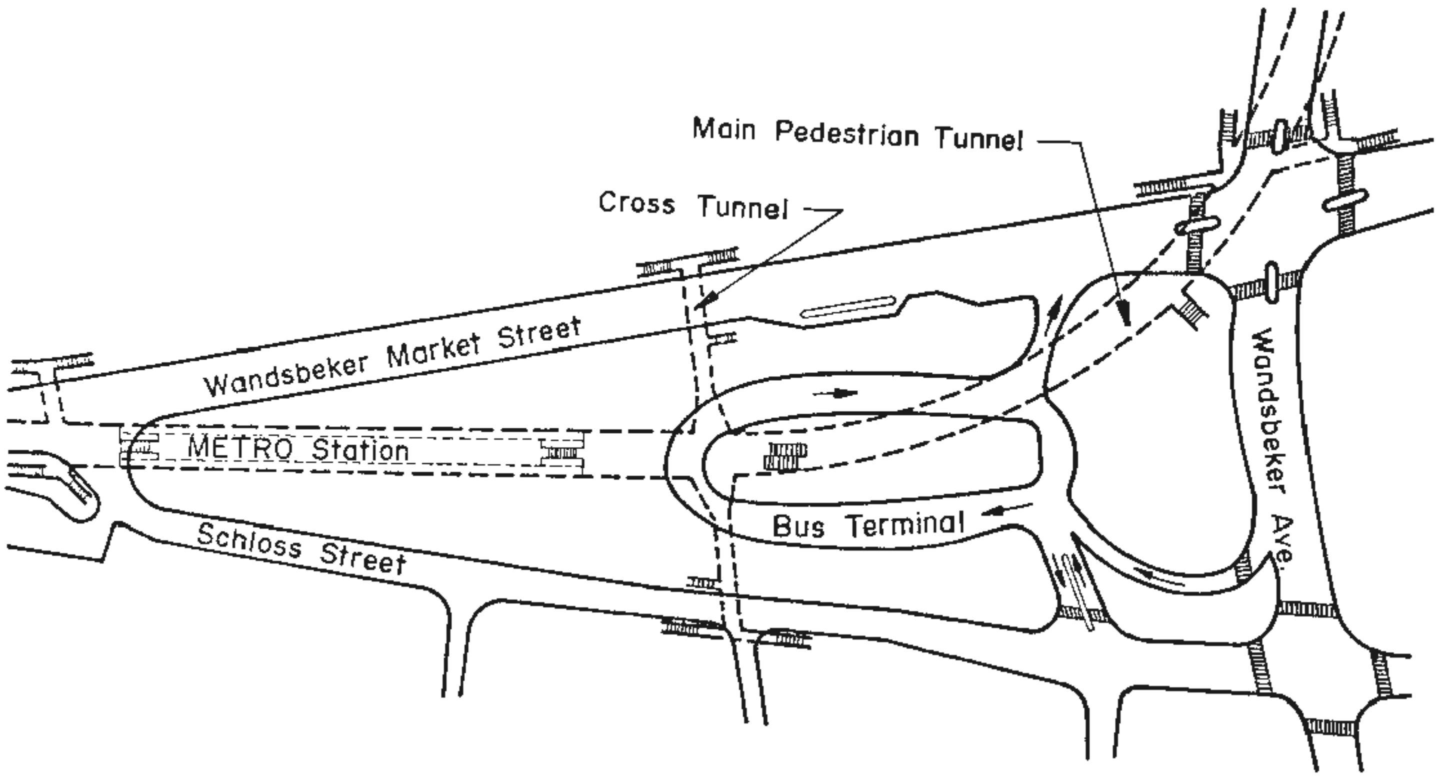
Many examples exist in Europe of intermodal transfer centres coupled with joint development. In the Netherlands, two such centres exist at Utrecht and The Hague. In France, just outside Paris, La Defense is such a centre. And further south in Lyon is the ultimate in transfer centres - Perrache. In England, London Transport has plans to turn their Hammersmith Station into a modern intermodal transfer centre.

The Central Station in The Hague, The Netherlands

The Hague Central Station opened in 1973, is located near the intersection of a major urban arterial and The Hague-Utrecht freeway. It is also located 10 minutes walking from the downtown. The railway portion of the station is a headstation or terminus for the main The Hague-Utrecht rail line. Integrated under one roof with the Dutch Railways are the bus and tram lines

FIGURE 3

WANDSBEK - MARKT METRO STATION, HAMBURG, GERMANY



SOURCE: Hamburg Metro

of the city of The Hague, the intercity bus lines, and the taxi rank. See Figure 4 for a sketch of the complex (9).

The station is essentially a two level structure. The railways operate at grade while the bus and tram station is located one level above the railway platforms. The railway station consists of 12 platforms. Ten of the platforms are for intercity trains, one platform is reserved for the commuter train to Zoetermeer a new town of 200,000 people. The last platform is reserved for the Schiphol line connecting The Hague to Schiphol Airport in Amsterdam. The platforms abut a huge hall for pedestrian interchange, ticket sales and concessions. Over the main hall is constructed an office building some eleven storys high. In front of the station at grade is a forecourt with a taxi rank and access roads. These roads are adjacent to a parking lot with a capacity of 120 cars. Additional parking space exists in a parking garage located to the east of the station. The parking garage is of three levels and has a capacity of 850 cars. The roof of the garage is level with the floor of the bus and tram station. The tram lines are elevated for some distance from the station and run over the roof of the parking garage.

The floor area of the tram and bus station is approximately 20,000 m^2. The tram station is separated from the bus station by a glass wall. The tram station has 4 platforms and the bus station has about 20 platforms. Both bus and tram station are covered, but not enclosed. Bus access/egress is via elevated roadways at the rear of the station.

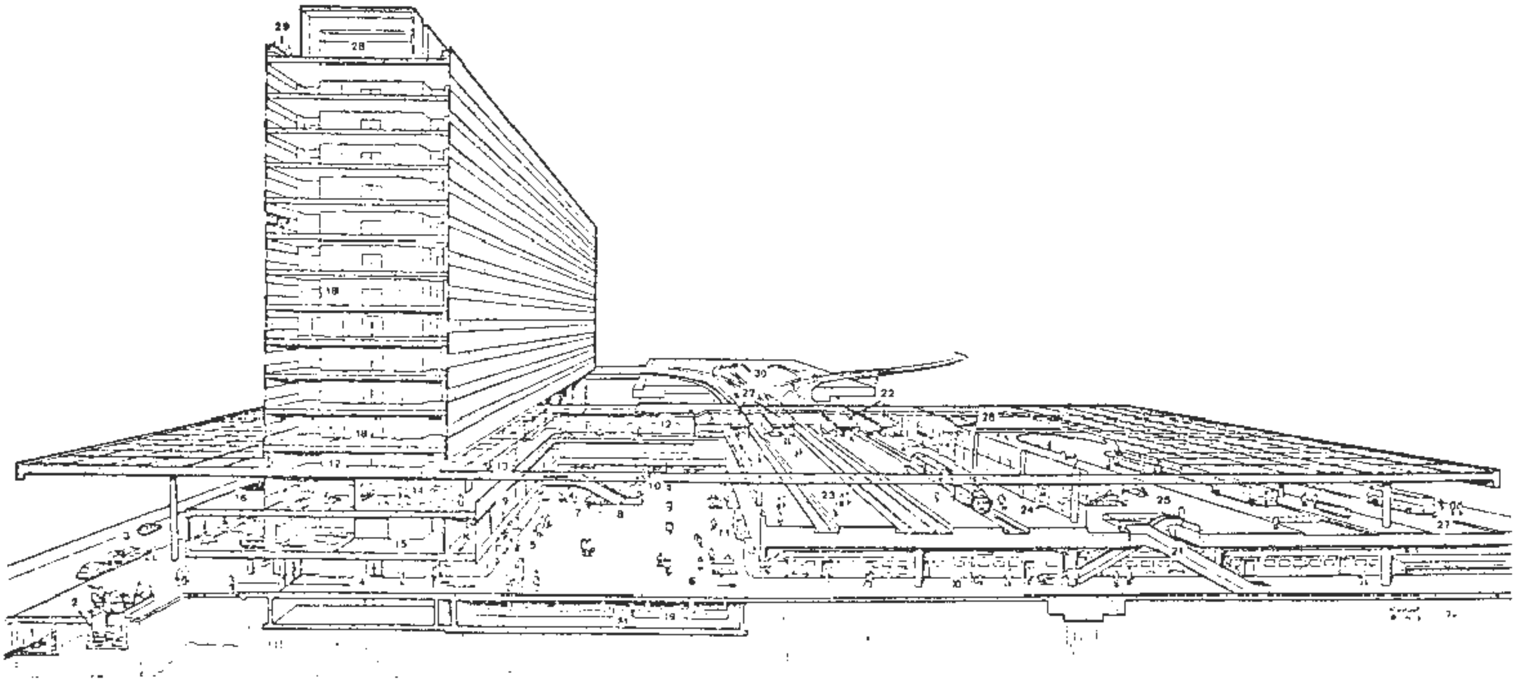
Pedestrian access to the various stations is via the main hall and stairs and escalators, or directly from/to the railway platforms to/from the bus and tram station with escalators. The station contains some 30 escalators and several elevators. Provision has been made in the design of the complex to connect it with elevated pedestrian walkways to the city centre should that ever become a reality in the future. Bicycle storage is in the basement. Adjacent to the station and physically attached to it by elevated pedestrian ways are a hotel, movie theatres, restaurants, and a shopping complex.

The Perrache Station in Lyons, France

The intermodal transfer centre of Perrache is located on an island between the rivers Rhone and Saone several kilometres from downtown Lyon. The centre stradles the main highway from Paris to Marsailles which runs

<u>FIGURE 4</u>

CENTRAL STATION, THE HAGUE, THE NETHERLANDS



<u>LEGEND</u>:

1. Tunnel for future metro
2. Escalators
3. Frontage road
4. Main entrance
5. Ticket wickets
6. Entrance to rail platforms
7. Stairs
8. Escalators
9. Corridor
10. Stairs and escalators to bus and tram station
11. Concessions
12. Offices
13. Corridor
14. Waiting Area
15. Kitchen
16. Restaurant
17. Service Area
18. Office Complex
19. Bicycle Storage
20. Railway Platforms
21. Escalators
22. Escalators
23. Tram Station
24. Glass wall
25. Bus Station
26. Escalator
27. Access road for Buses
28. Elevators
29. Roof Gardens
30. Parking Garage

SOURCE: Reference 9.

parallel with the railway from Paris to Marsailles. Currently the centre consists of two interconnected structures. One structure is the old French Railways station dating back to 1857. This station processes over 7 million passengers a year. The other structure is the bus station which houses the city and intercity buses, a metro, and a four level, 2000 car capacity parking garage. The bus station was opened in 1977. Work is currently in progress to renovate the railway station and to integrate it completely with the bus terminal.

Although the whole complex looks like and functions like a modern inter-modal transfer centre it wasn't originally designed that way. The original design was a seven story parking garage built over the depressed Paris Marsailles freeway directly across from the old railway station. The intent was to develop a large commercial centre around the parking structure. Part way into the project the public transportation people thought it would be beneficial to have buses stop at the garage, a sort of park and ride scheme. This idea expanded into a full scale bus terminal inside the parking garage. Subsequently one whole floor of the parking garage became a bus station for urban and inter-urban buses. Next came the idea to incorporate the metro station into the garage. Because of the high cost of tunnelling in the area, it was decided to raise the metro to grade level and put the metro station at the ground or first floor of the garage. The bus station was then put on the second floor. The third floor was assigned to stores, boutiques, restaurants and an exhibition hall. The remaining four floors were left for parking. The roof of the garage was turned into a mini-park with flowers, ponds and trees.

The floor developed into a bus station occupies 14,000 m^2 for the buses and 2,000 m^2 for a pedestrian interchange hall with ticket machines and information panels. The bus station is symmetrically built about a north-south line. Each half of the station is further divided into an urban station and an inter-urban station. Each inter-urban station is located in the centre of the floor with the urban bus station wrapped around it on the outside. Each inter-urban station has 12 sawtooth platforms and each urban station has one 50 m linear platform for arrivals and 5 linear departure platforms. Passenger access to these platforms is through 4 glass enclosed corridors. The corridors connect to the ticket hall and are under positive air pressure to keep the fumes out of the pedestrian area of the terminal. See Figure 5 for layout.

The bus station processes some 70,000 passengers a day of which about half transfer to and from the buses. The station accomodates 1,300 buses a day (900 urban and 400 inter-urban) or 105 buses per hour (80 urban and 25 inter-urban). These buses come from 10 urban lines of which 2 are trolley and 33 inter-city lines. During the peak period, buses operate at a frequency of 26 seconds. The station also processes 2000 small packages a day. The maximum static capacity of the station is 50 buses (10).

In order to process so many buses in such a short time and in such a limited space a dynamic computer controlled traffic control system has been installed. The system works like the DOVER system described previously. Some 350 buses are now equipped with VETAG transponders and are assigned to their gates automatically by the computer. Passengers are advised of gate, time, and bus number via solari type panels in the ticket hall. The entire terminal functions as efficiently as a major airport terminal.

Conclusions

From this brief overview of the planning, design, and operation of European transportation terminals the following conclusions were drawn:

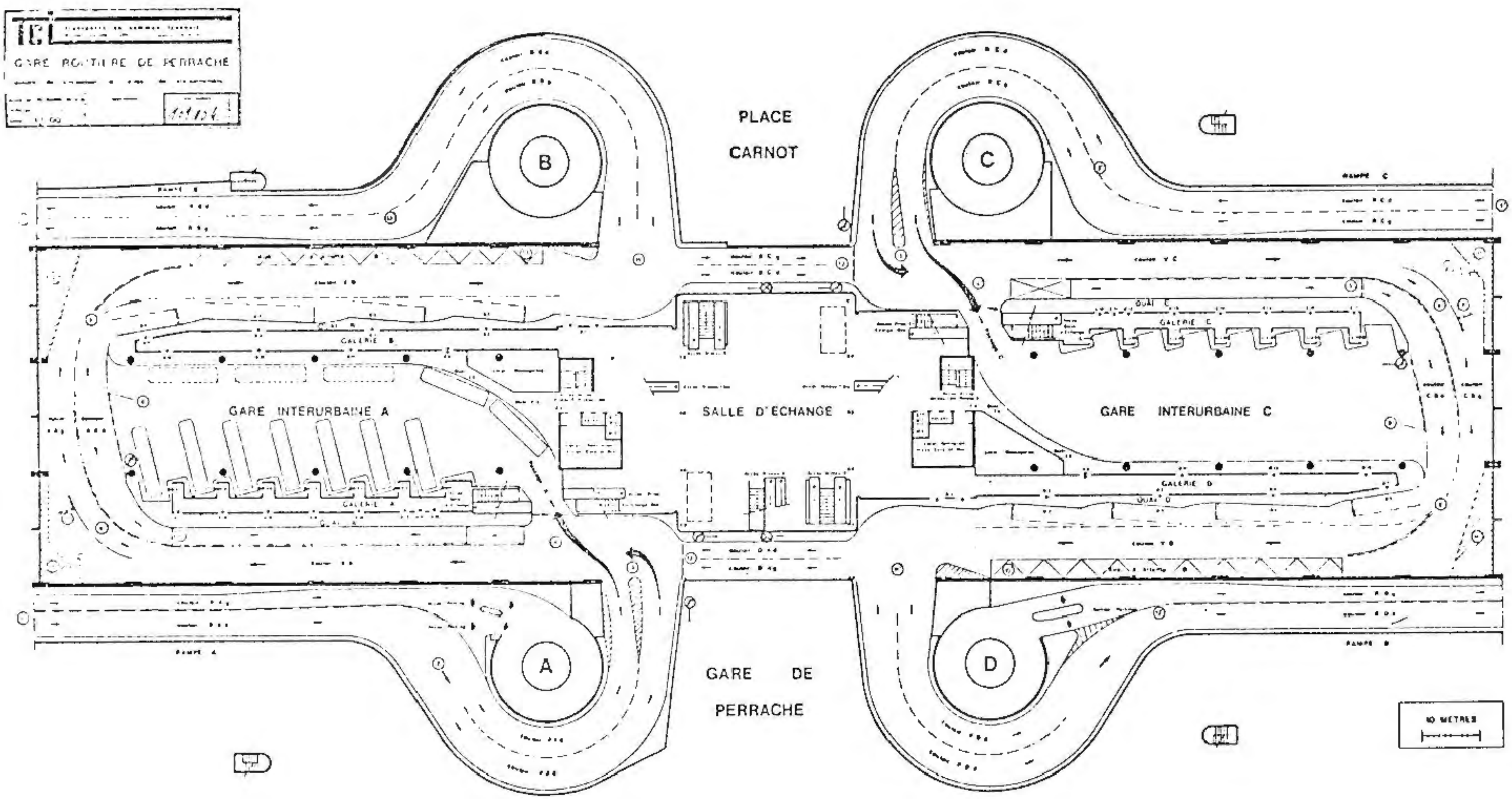
1. In order to maintain and perhaps increase ridership on public transportation it is essential that a good level of service be provided. This not only applies to the vehicles and way but also to the terminal. For it is here that the user makes his first contact with public transportation.

2. Throughout Western Europe emphasis is on the integration of public transportation. Terminals are designed to accomodate trains, buses, trams, metros, taxis, cars, bicycles, and above all pedestrians. This integration is further reinforced through common ticketing, interlaced schedules, and co-ordinated management.

3. Joint development of land on or near transportation terminals is a trend for the future. Encouraging private enterprise to develop land adjacent to transportation terminals enhances the transportation system, stimulates urban development and helps to finance the infrastructure.

FIGURE 5

PERRACHE BUS STATION, LYON, FRANCE



LEGEND:

Gare Interurbaine	=	interurban bus station
Place Carnot	=	pedestrian mall
Salle D'Exchange	=	ticket hall
Gare de Perrache	=	railway station

SOURCE: Lyon Transportation

4. With the maturing of public transportation systems in Europe have come complicated problems. These problems are being solved with sophisticated techniques. The experiments with "buffer" type bus stations in the Netherlands shows promise in designing better stations. Research in the DOVER type of traffic control in the Netherlands shows promise. The computerized bus traffic control in the Perrache bus terminal in Lyon is a model of ingenuity. Solutions used in airport terminals could find application in other transportation terminals.

5. The purpose of this paper was to present the European approach to terminal design and to see if we in Canada and the U.S. can benefit from their experience. It is obvious that we can but what is perhaps not so clear is how. Europe and European cities have their own characteristics which may or may not be compatible with our own cities. Therefore we must be careful and not simply transplant European solutions into Canadian and American cities. However what we can and ought to do is examine their philosophies, approaches and methodologies. For even though the characteristics of our cities might differ, the characteristics of the transportation problems do not. We can learn a great deal from each other.

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STATION DESIGN METHODOLOGY

by

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During the past day and a half we have been given first, an overview of developments regarding passenger transportation interface facilities including specific reference to the purposes of transit stations, the associated operations and maintenance problems, and passenger access and movement in the facility; and second, vivid descriptions of experiences with new station designs and renovations in North America and Europe. These discussions provide an overview of the state of the practice in the design of major passenger transportation interface facilities.

We will now review a methodological approach to transit station design developed at the University of Virginia over the past 5 years. This work was initiated to try to overcome a major shortcoming of transit station design practice, namely the inability to investigate a wide range of meaningful design alternatives. Consequently, in many cases, only a limited number of spatial configurations and mixes of different components would be considered in selecting the final station design. In addition, no comprehensive framework was available to evaluate and compare recent design experiences.

Today, we will discuss the role that the University of Virginia methodology can play in the development of better transit station designs. This discussion will include: 1) the rationale and background for the methodology, 2) an overview of the methodology, 3) an example application, and 4) the role of this conference in evaluating and revising the methodology.

BACKGROUND AND RATIONALE

An early seminar on transit station design (1) brought together representatives from both the private sector (architectural, planning and engineering consultants) and the public sector (transit agencies and authorities). These various professional interest groups agreed that a common design methodology did not exist, that transportation interface design was an art and that a systematic approach for evaluating suggested designs was lacking. A large number of different procedures were employed by planners, architects and engineering consultants engaged in transit station design.

Of all available documentation in the literature at the time, only a small portion dealt directly with urban interface design. Most of that literature concerned related areas of transit station impact, parking facilities, location factors and berthing configurations. Advanced station design methodology was predominantly concerned with airline terminals. Many design studies were not described in sufficient detail for general application and others were proprietary in nature.

In response to these problems, the University of Virginia Department of Civil Engineering has conducted a research program with the following objectives.

1. To provide a comprehensive conceptual definition of the components of an interchange facility,
2. To recommend criteria for evaluating alternative transit station designs,
3. To provide an evaluation framework for comparing the effectiveness of alternative facility designs for the given criteria,
4. To develop a methodology for providing measures for each of the evaluation criteria, and
5. To apply the proposed methodology in specific applications and establish guidelines for selecting components for new and renovated stations.

Conference participants have received copies of reports that document the methodology (2,3,4,5,6,7) and its applications. At present, we are developing a decision model for transit station evaluation that will weight different decision variables and establish the priority of different policy and design considerations. The proceedings of this conference will also be published by the U. S. Department of Transportation.

OVERVIEW OF METHODOLOGY

The transit station design methodology is a series of tasks which, when combined, give a systematic method for planning, designing and/or evaluating transit stations. Categories of information about the transportation system that establish requirements for the station design include the technology of the interfacing modes, the route alignment and operating policy; the station location, line-haul modal demands; and access mode volumes. The design methodology translates this information into an acceptable station plan. The primary considerations that guided the development of the methodology included the following subproducts that were ultimately fused into an implementable method.

1. Definition of system components,
2. Statement of objectives,
3. Definition of design criteria,
4. Differentiation between policy elements and measures or performance and cost,
5. Formulation of a general evaluation model,
6. Development of the analysis framework (design process), and
7. Specification of techniques for measurement of performance and cost.

Definition of System Components

The transportation interface facility includes functional facility components that are furnished to accomodate tripmakers, elements that enhance the quality of the station environment such as amenities, safety and security measures, and special facilities available to meet the needs of the physically handicapped and elderly.

Functional Facility Components

Functional facility components are those elements provided to meet the operational objectives of the station. They serve to establish the effective passenger capacity of the facility. The major functional components are:

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

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

5. Special provisions for the elderly and handicapped.

The amount and arrangement of pedestrian travel facilities and space in terminals will affect different measures of aggregate travel times, distances, and queueing.

The Station Environment, Amenities, Safety, and Security

The environmental quality of a transit station is represented by those features which the pedestrian associates with his or her personal comfort, convenience, safety, and security. These considerations are not directly associated with the movement of people but pertain to the physical environment through which they move. Amenities are difficult to assess but produce subtle effects on people's attitudes. Typical environment-amenity concerns include the following:

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

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

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

4. Weather protection.

5. Other.

The terminal environment also affects both actual and perceived safety and security. The combined performance of subsystems for the passenger processing and environmental conditions account for the overall effectiveness of a station design.

Provisions for Special Users

Recent transportation systems design reflects an increased concern for special users, especially those handicapped and elderly individuals whose ambulatory functions are impaired. Devices, design features, and policies which aid these groups are included in the passenger processing subsystem. Typical provisions for special users include lanes for movement outside of crowds and special level change devices such as elevators. Many minimum standards are now required by law.

Statement of Objectives

Having a typology of components for the station of interest, a generalized list of transit station objectives was derived. These station design objectives must reflect the points of view of the general user, the special user (elderly and handicapped), and the operator.

Passenger Processing Objectives

General User

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

Special User

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

Operator

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

Environmental Objectives

User and Special User

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

Operator

1. Provide adequate security
2. Provide adequate safety

In addition to the performance objectives, cost objectives must be considered. The following objectives concern economy of the operation and the potential for expanding the facility.

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

Definition of Design Criteria

The terminal planning, design, and economy objectives that are given for the interest groups are translated into a set of criteria categories in Table 1. Specific criteria are then derived for each of these general objectives and performance measures are established for each.

Statement of Policy and Measures of Performance and Cost

The criteria given in Table 1 were selected by considering the physical elements of the station and the affected interest groups. To show the roles of station components within a procedural design methodology, a further classification scheme was developed in which the terminal performance criteria are classified according to the manner by which they enter the terminal design process, i.e., as a result of an initial policy decision or as measures of performance and economic efficiency. The former category reflects contemporary community values, while the latter two provide physical measures of the operational efficiency of a terminal function. It is useful to make this distinction because different decision processes govern the two areas. Table 2 illustrates examples of typical station components as classified under this scheme.

The interrelationships among the analytical measures and categories used in the development of station criteria are summarized in Figure 1. This diagram shows the steps involved in defining the elements for an evaluation model. The physical terminal components are identified and those interest groups affected by their performance are considered when developing a set of objectives that apply to the general station design problem. These objectives (e.g., minimize travel impedance) are used to develop a set of criteria (e.g., walk time required) which establish a set of performance measures (e.g., minutes required). The performance parameters are then categorized as either results of policy decisions, measures of the performance of functional elements, or measures of the cost of construction, operation and maintenance.

Formulation of a General Evaluation Model

Once performance measures are identified with an impact group(s), an evaluation matrix can be constructed such as shown by Table 3. This evaluation matrix provides the decision-maker with a summary of all performance parameters according to their role in the design methodology, and their impacts on the appropriate interest groups. Explicit measures of performance or numerical indices derived from subjective rating schemes comprise the entries to the matrix cells.

This tabulation shows raw criteria measures in a decisionmaking framework. For example, the decisionmaker can review Table 3 for dominances and tradeoffs and select a "best" design or, at least refine the total set of criteria by eliminating those which do not show significant variance among the alternatives. The various tradeoffs may be considered among the impacts, interests, and alternatives. The total information is presented for the decisionmaker so that the plan can be selected which best suits the represented interests.

Development of The Analysis Framework (Design Process)

A comprehensive framework for analysis based on use of policy, performance, and cost categories for the design criteria, is shown in Figure 2. The two primary applications of the analytic methodology are the renovation of existing terminal structures, and the construction of new modal interchange facilities, respectively.

The renovation problem initially requires measures of the performance and cost parameters for an existing facility. These measures are then evaluated in relation to the current terminal management policy. Site requirements and demand measures, brought up to date, are used in conjunction with the results of the terminal evaluation as a basis for recommending improvements regarding both policy and the physical terminal facility. This renovation strategy enters the analysis framework shown in Figure 2 at nodal point 3.

The development of a new terminal design focuses on meeting stated design standards, modal and site requirements, and expected demand levels. Here, planners enter the process shown in Figure 2 at node 1 to develop policy prior to consideration of the station proper.

Alternative Designs

When appropriate policy has been established for a transit station design, alternative physical facility components and layouts can be examined. During this stage the design team generates alternative design concepts and facility plans which meet the stated requirements and objectives. Design concepts refer to those broad considerations which account for major differences in terminals such as multi-level vs. single level, underground vs. aboveground, exclusive shopping mall zones, automated pedestrian movement aids, etc. This stage generally includes estimates of environmental impacts, the incorporation of local transportation systems management plans, and public hearings to determine reaction to the alternative design concepts. After

Table 1

Evaluation Criteria Categories for Station Performance

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

Table 2

Transit Station Component Classification for Analysis

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

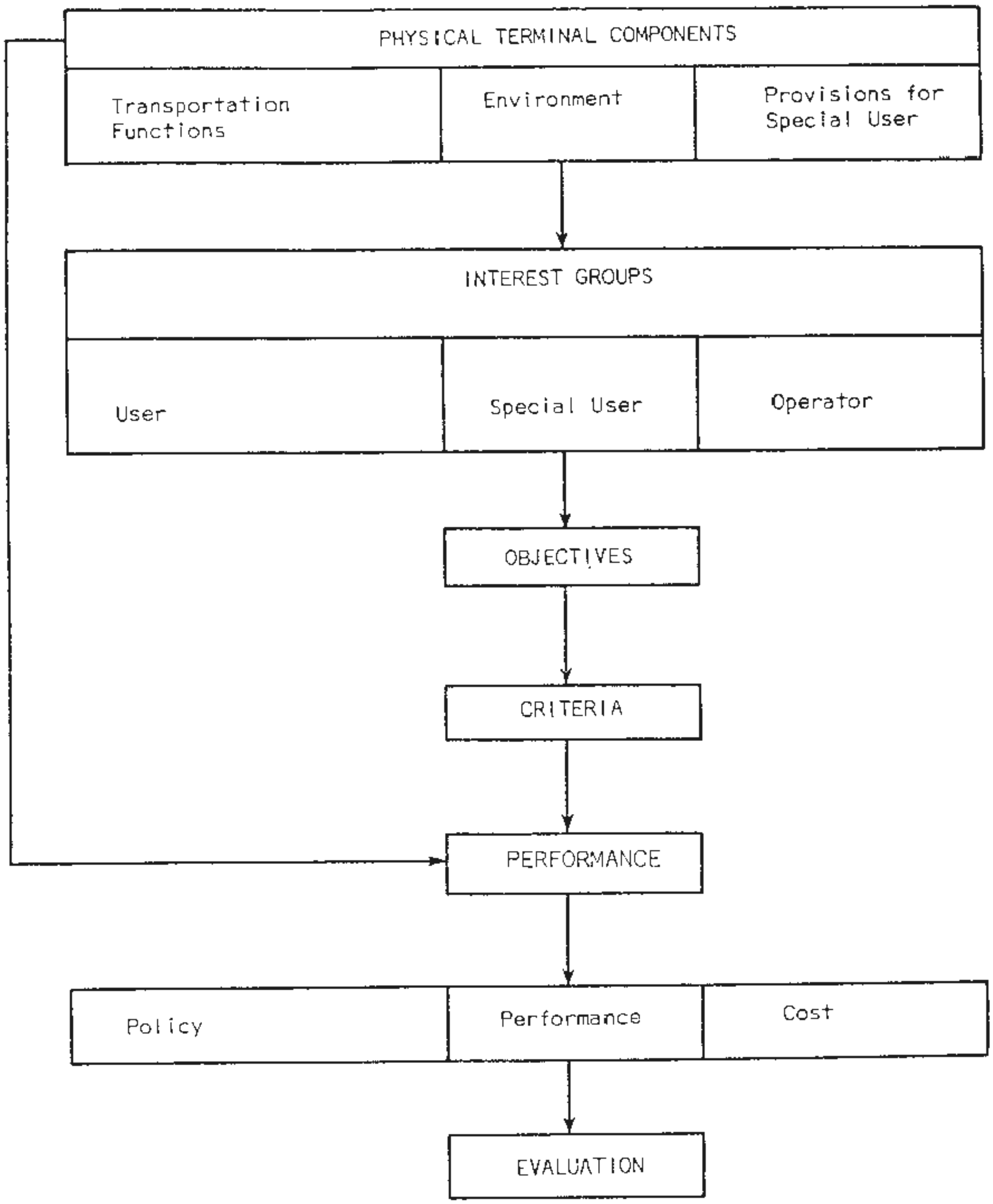
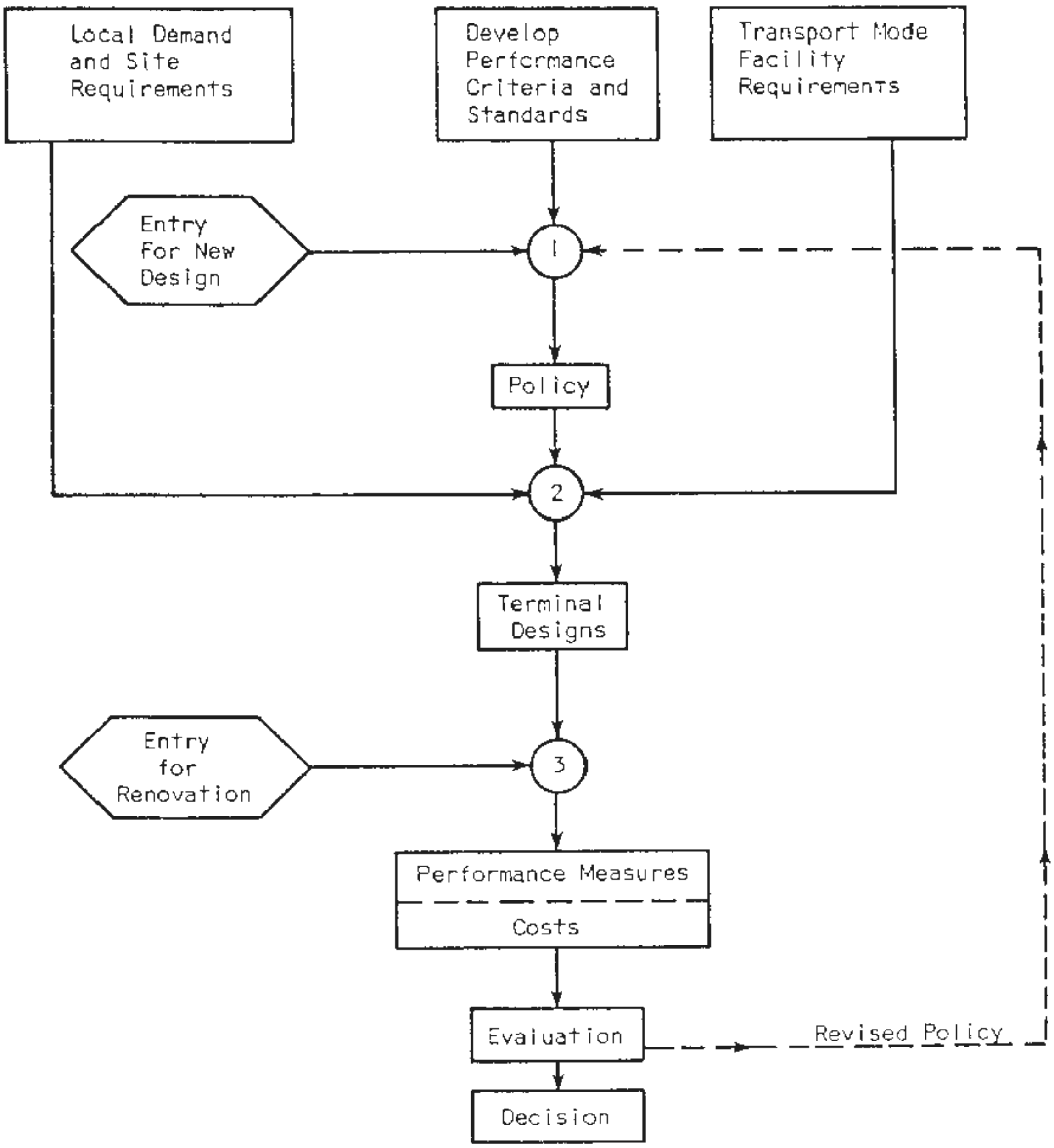


Figure 1. Definition of Station Performance Measures

Table 3

Evaluation Matrix Model

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



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

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

Figure 2. Transportation Station Design Process

specific concepts are agreed upon by the design team, detailed facility designs are prepared.

Detailed designs reflecting alternative facility components and layouts are assessed. At this point, those variables associated with optimal passenger processing and user acceptance are considered. The analyst has the option to consider variation in the design relative to the physical environment, passenger orientation aids, safety and security, if they have not already been established as a result of policy.

Techniques for Measurement of Performance and Cost

The complete design is developed using components which are selected in one of the following ways.

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

b. To meet local policy requirements (for example, considerations relating to concessions and advertising), and

c. To provide the best measured performance among a set of trial designs.

Table 4 illustrates typical station components which are established by standards or policy, or are varied by the designer and their performance measured. The listed sources of measurement range from objective measures and costs to subjective plan inspection and policy review.

In many areas, analytical techniques are available for assessing the performance of a certain station element, such as passenger processing, passenger orientation, the physical environment, security, and safety. The methodology report (2) summarizes state-of-the-art techniques for measuring the performance of different design features. For example, the UMTA station simulation model addresses one element, passenger processing. The methodology provides a perspective for using the model within a complete design process.

IMPLEMENTATION OF THE METHODOLOGY

The transit station design methodology is implemented in the steps identified in Figure 3. These tasks are described below.

Table 4

Criteria Measurement

	CRITERIA	SOURCE OF MEASUREMENT
1.	Total Walk Time	UMTA Station Simulation Model (USS)
2.	Total Time in System	USS
3.	Route Travel Times	USS
4.	Area Per Person	USS
5.	Total Delay	USS
6.	Queue Length	USS
7.	Flow Conflicts	USS, Plan Analysis
8.	Connectivity	USS, Plan Analysis, Network Analysis
9.	Orientation Aids	Inspection
10.	Safety Features	Inspection
11.	Design Hazards	Inspection
12.	Back-up Facilities	Inspection
13.	Inspection Procedures	Policy (Terminal Management)
14.	Number on Levels	Inspection of Plan & Design
15.	Mechanical and Ramp Level Change Aids	Inspection of Plan & Design
16.	Fare Collection-Entry Barrier	Inspection of Plan & Design
17.	Physical Barrier to Special Users	Inspection of Plan & Design
18.	Entry Control	Inspection of Plan & Design
19.	Station Size	Estimated Demand
20.	Odor concentration	Design Specifications
21.	Suspended Aerosols and Particulates	Design Specifications
22.	Inflow Air Rate	Design Specifications
23.	Air Discharges	Design Specifications
24.	Air Velocity	Design Specifications
25.	Pressure Changes	Design Specifications
26.	Thermal Comfort	Design Specifications
27.	Noise	Design Specifications
28.	Lighting	Design Specifications
29.	Personal Comfort Facilities	Policy
30.	Cleanliness	Design Standards, Terminal Management
31.	Pleasantness	Amenities provided, i.e., music, art, etc.
32.	Advertising	Policy
33.	Concessions	Policy
34.	Weather Exposure	Inspection
35.	Security	Policy and Plan Analysis
36.	Maintenance & Repair	Design Experience
37.	Cleaning Requirements	Design Experience
38.	Funds Available (Budget) vs Funds Required	Program, Ownership
39.	Income (Non-transport Activity)	Policy
40.	Incremental Return (Relative to Low Cost Alternative)	Cost Analysis
41.	Energy Requirements	Design Standards
42.	Joint Development Provisions	Policy Option
43.	Expansion Potential	Policy Option

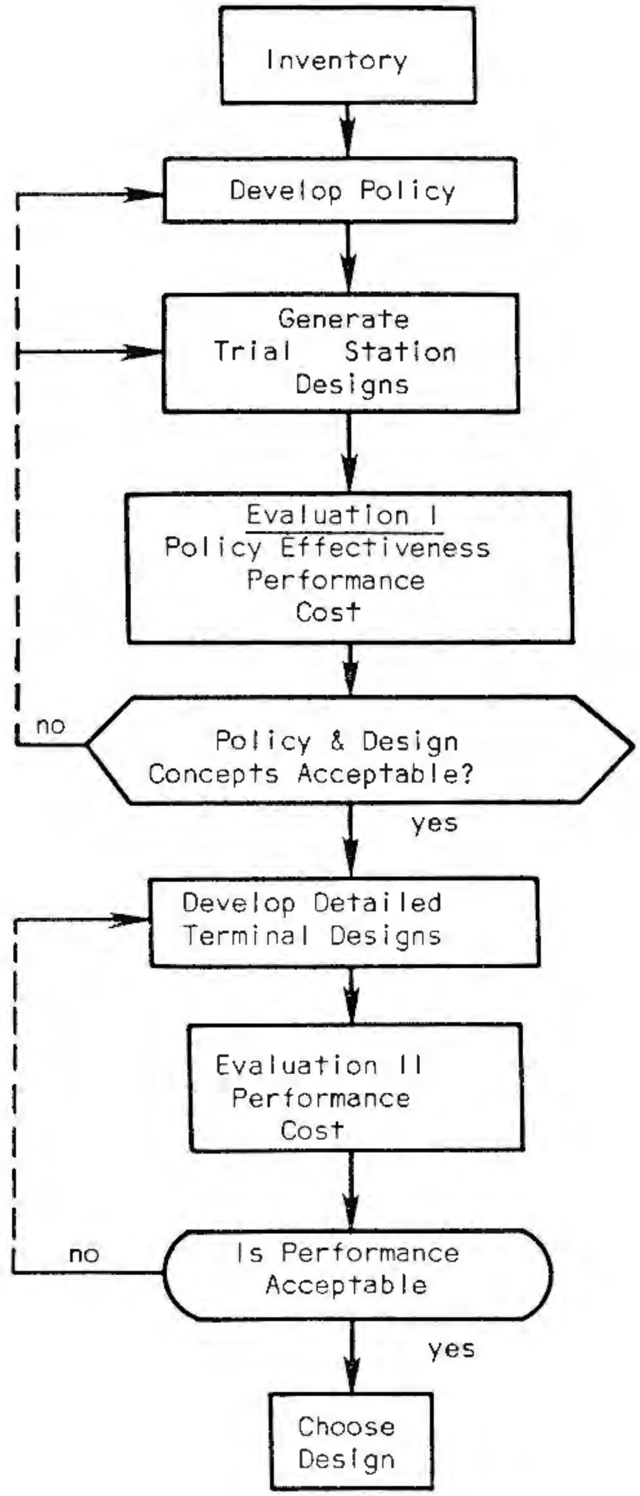


Figure 3. Stages in Transit Station Design Methodology

Inventory

Initially, input or inventory data must be secured. In the case of the transit interchange facility, the following types of data are required.

1. Exogenous Design Data

   a. Local site data

   b. Demand data
      Passenger flows
      Vehicle arrivals

   c. Supply Data
      Interchange modal technology requirements
      Access mode requirements

2. Endogenous Design Data

   a. Policy objectives (local and system)

   b. User attitudes and preferences

   c. Performance standards

   d. Cost constraints

The exogenous (or external) data reflect the loads (in terms of passengers and transit vehicles plus local land use) which the facility must sustain. The endogeous data represent further requirements that are established by the planning agency and system user prior to the investigation of actual physical station configurations. Once this preliminary design information is collected and developed, a formalized terminal design/ evaluation process is initiated.

Policy Development

The first stage in the station design process concerns the formulation of relevant policy associated with the design, operation, and maintenance of the transit station. Those specific items which comprise the nucleus of policy needs for transit stations have been identified earlier as concessions, advertising, personal care facilities, public telephones, aesthetics and cultural, environmental, construction materials, and provisions for special users (elderly and handicapped). Guidelines to assist the planning agency regarding these policy issues are available. In addition, other subsystems can be approved by policy rather than by the detailed analytical treatment described earlier.

Trial Station Design Development

During this stage, architects, planners and engineers collaborate to generate alternative design concepts and design facilities which meet the stated requirements and objectives. After specific design concepts are agreed upon by the design team, detailed facility designs can be prepared.

Evaluation I

At this stage the effectiveness of each proposed design is evaluated. This evaluation of "trial station designs" is intended primarily to resolve issues regarding policy and design concepts. Evaluation criteria mainly include cost measures but some preliminary performance analyses also apply.

Develop Detailed Terminal Design

When an acceptable design basis consisting of certain policy statements and design concepts has been established, alternative physical facility components and layouts can be examined. It is at this point that those variable details of transit stations associated with optimal passenger processing and user acceptance are considered. The analyst considers variations in the design relative to the physical environment, passenger orientation aids, safety, and security at this point, if they have not already been established as a matter of policy.

Evaluation II

The detailed terminal facility designs are evaluated in terms of performance and cost. It is in this phase that the available computerized and manual techniques associated with pedestrian flows and orientation, the physical environment, safety, and security are applied to obtain measures of effectiveness for alternative station designs. The performance and cost measures are interpreted with the effectiveness model to select the "best" alternative. When the results of the evaluation indicate where design improvements are warranted and feasible, changes are made and new designs developed. This iterative process is repeated until a specific design is selected.

Summary

Figure 4 identifies the various elements of concern at the appropriate places in the procedural method. This strategy integrates the important

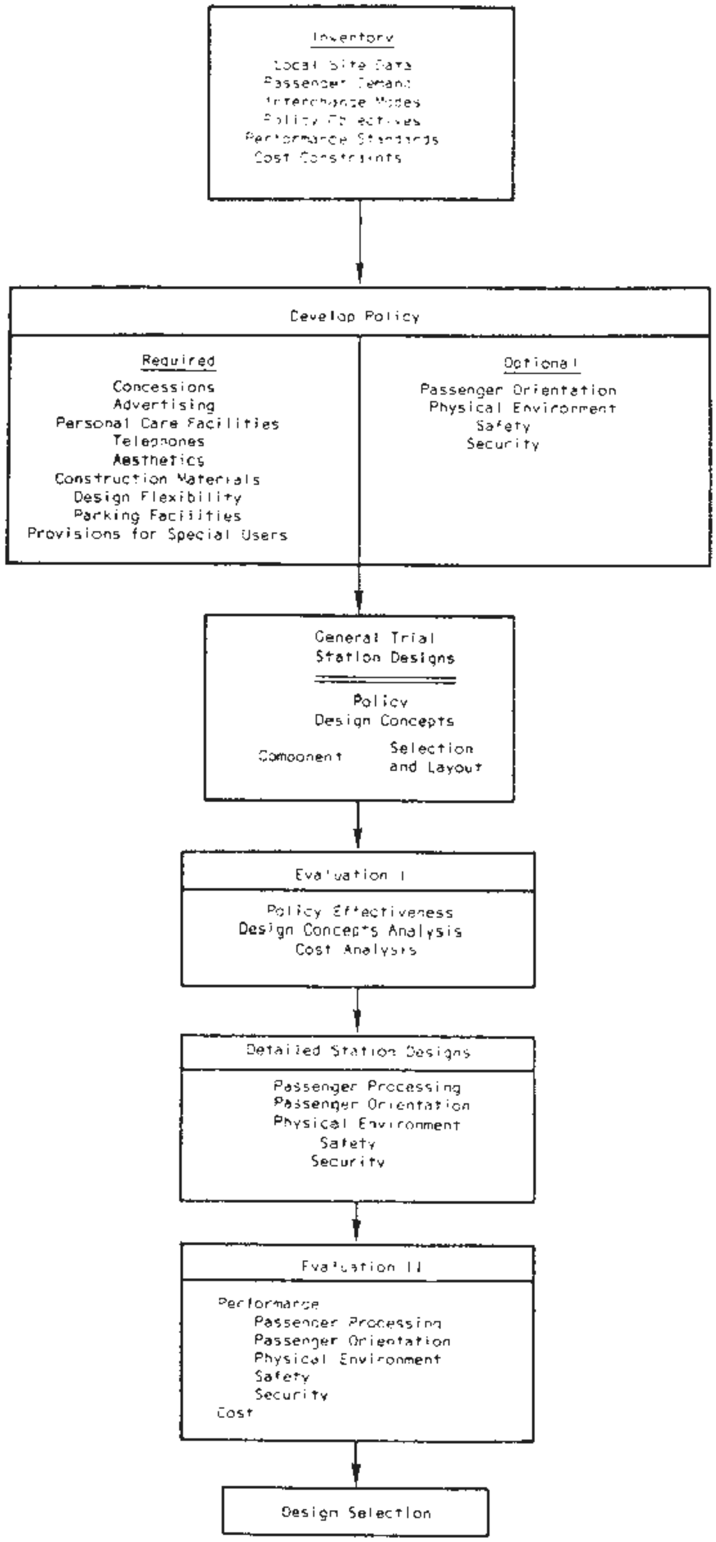


Figure 4. Elements Considered in Transit Station Design Methodology

study findings concerning design objectives, criteria and measures within an evaluation framework with the judgmental, analytical and computerized methods available for developing and analyzing various station designs.

Renovated Facilities

The procedural method for the design of new transit terminals can also be utilized for station renovation. The primary difference in these two applications is that station renovation begins with the execution of Evaluation I and Evaluation II phases given the inventory data, policy, and design detail as shown in Figure 5. Once the existing facility is evaluated, the findings are employed to develop new policy and to redesign the facility. From this point on, the standard procedure is followed.

EXAMPLE APPLICATION

In this section the transit station design methodology is illustrated in an application to the design for a central area bus terminal with intercity and commuter operations. In order to demonstrate the method, data are synthesized to establish station design objectives and requirements. Policies are established and the methodology is applied to propose and evaluate different design concepts, and to improve upon features for a specific design configuration.

Station Site

The bus terminal is located 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 a city block. The site was previously occupied by an old warehouse that was torn down as part of an urban renewal project. Presently the site is surrounded by office and retail land use.

Operating Agency Objectives

The major objectives of the operating agency with respect to this terminal are:

1. To provide a high level of service to the elderly and handicapped,
2. To encourage joint development, and

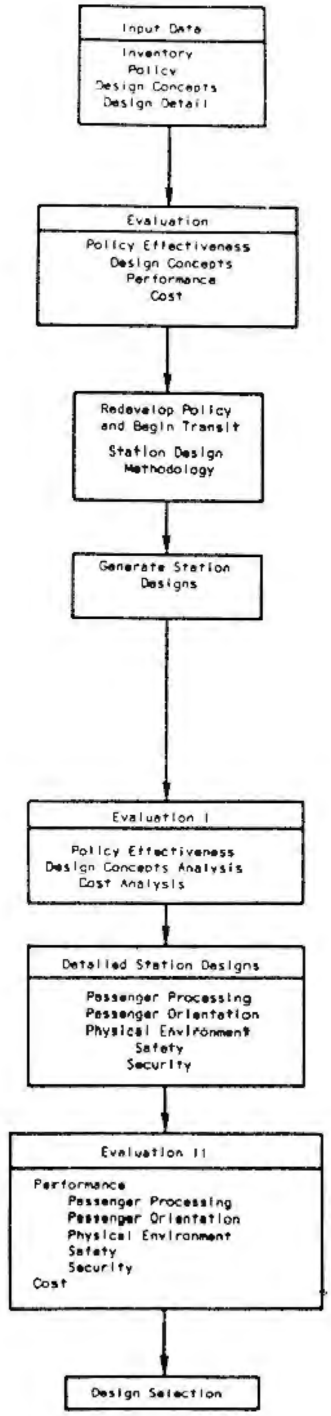


Figure 5. Preliminary Tasks for Transit Station Renovation

3. To include provisions for concessions and advertising if financially beneficial.

Objectives for the design of this downtown bus terminal were also derived for commuter and intercity users and special users as well as operators, and the corresponding criteria and performance measures were established for each set of objectives.

Policy Statements

The following policy statements governing this station were established.

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 bootb, 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.

Alternative Designs

There are many possible ways to develop 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 access points, the amount of space allocated for non-transportation purposes.

In this problem three alternative design approaches are considered which share the following common characteristics:

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

A sketch of Alternative 1 is shown in Figure 6. 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.

Alternative 2

The layout of this alternative is similar to the first except that the commuter and intercity bus areas are side-by-side on the second floor (see Figure 7). Access to these areas is provided from street level. Intercity passengers will have to travel only one floor height instead of two, but the ground area for the facility is doubled. Direct access to other modes is still provided.

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 8). 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.

Evaluation I

The performance of each of the three preliminary designs relative to the criteria is measured. This provides input for evaluating station policy, performance, and cost. It also leads to the selection of one of the alterna-

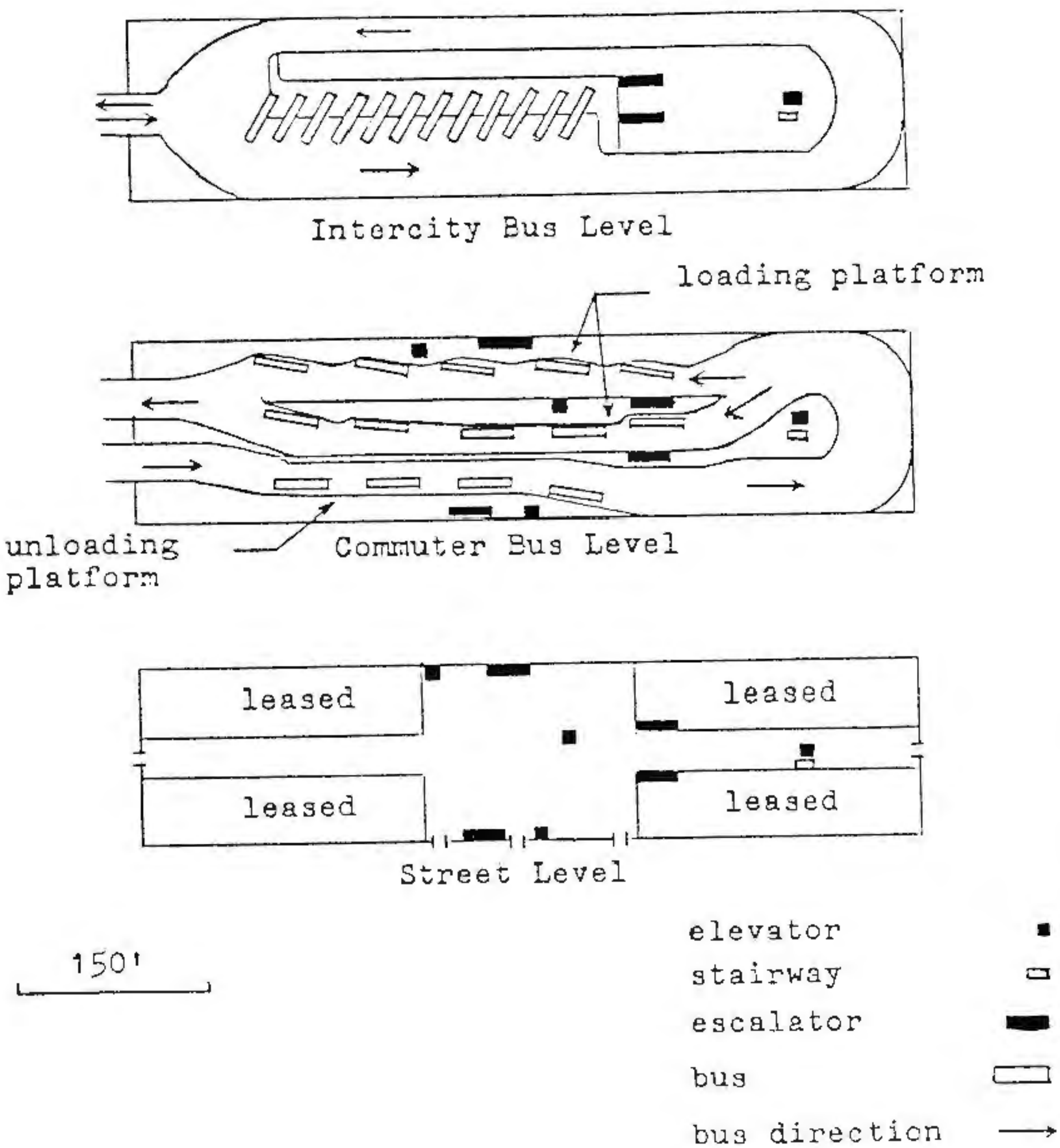


Figure 6. Bus Terminal: Alternative 1

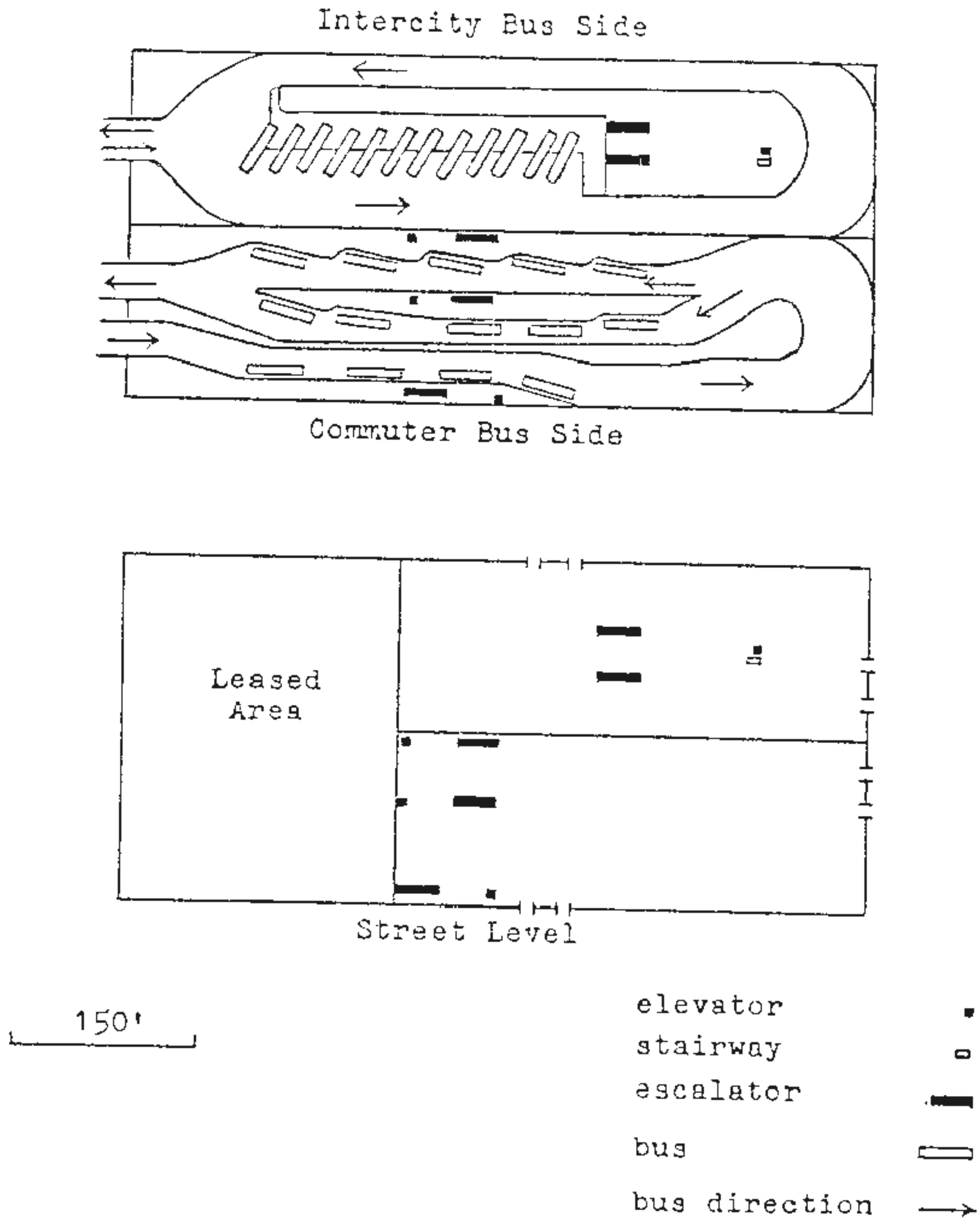


Figure 7. Bus Terminal: Alternative 2

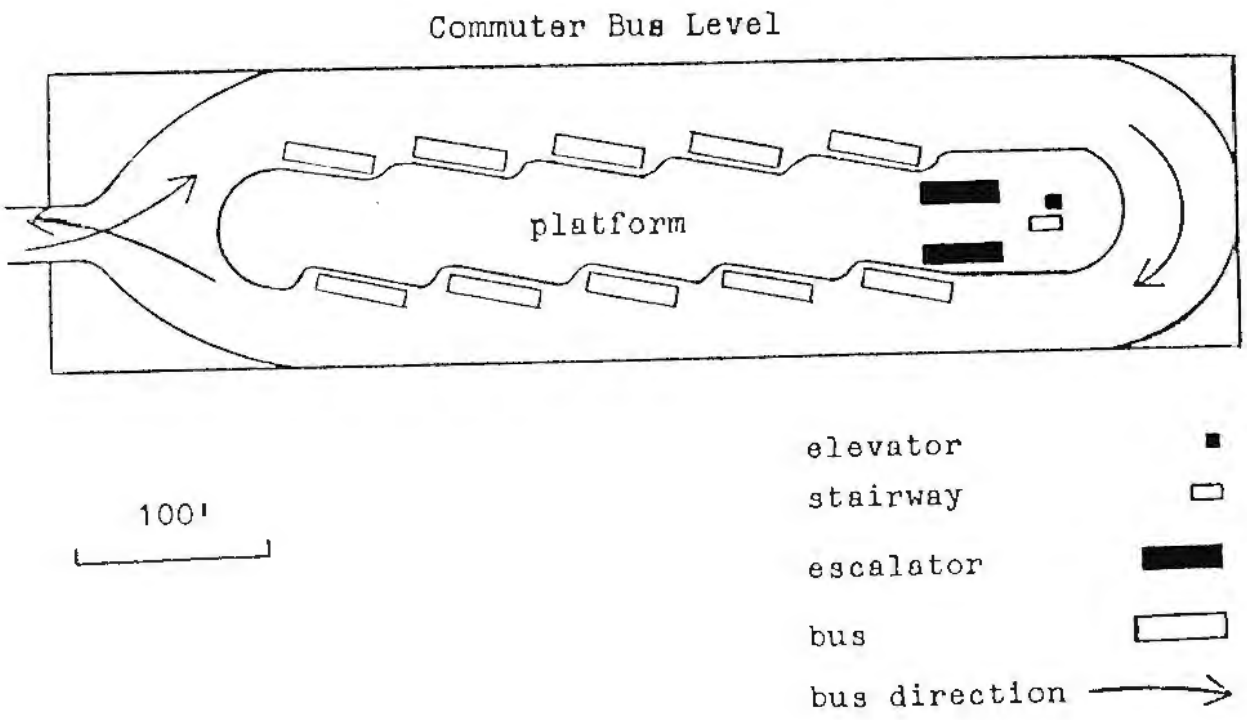


Figure 8. Bus Terminal: Alternative 3

tives for detailed design. To determine the most suitable design, an effectiveness analysis framework using data like that in Table 5 was employed. Separate tables were derived for each interest group. 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 6. Since Alternative 1 and 3 are the two least costly alternatives, they were compared first.

Comparing Alternatives 1 and 3

For intercity users the only difference between 1 and 3 is in "level of service on links". 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. Thus, Alternative 3 is superior to Alternative 1.

Comparing Alternative 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". These two groups prefer Alternative 2. Commuter users and commuter special users prefer Alternative 3 because it performs better 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 deficit 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.

Table 5
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 6

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)

Policy Review

A review of the policy statements in light of the results of this first-round evaluation was made, and no changes in policy were recommended.

Detailed Designs

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

The pedestrian level of service provided by 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 a close 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, 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 than 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.

Evaluation II

The fifteen strategies for meeting these objectives, and their expected direct and indirect effects were assessed. After the potential benefits and adverse effects of each strategy were reviewed, the following strategies were selected to develop the final design.

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 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 example illustrated how the design methodology was used to select a design concept at a relatively macroscopic level of analysis. This design was then evaluated at a micro level to ensure that an acceptable facility was constructed. The approach used is considered to be a "sufficient design" strategy rather than a strict alternative analysis. This flexibility demonstrated the generality of the procedural method to accommodate different rational approaches to choosing a design that meets particular requirements and constraints.

CRITIQUE OF THE METHODOLOGY

One of the purposes of this conference was to present and critique the University of Virginia methodology for transit station design. Each participant has received copies of the research reports documenting the methodology, we have reviewed the standard method during this session; various speakers have referred to it; and now you probably have your own thoughts on its utility and shortcomings.

As a point of clarification let me note that the transit station design methodology was never intended to be a precise blueprint giving exact specifications for site and demand characteristics. That is unrealistic. It is, rather, a framework for the planner/ designer to use to ensure that a comprehensive analysis is done and that multiple alternatives are considered so that a better design results. The methodology adds structure to the design process and insures the direct consideration of alternatives, both in concept or with features. It is a mechanism to organize data on design experiences, and to facilitate effective facility planning.

The emphasis on establishing policies which ultimately shape and constrain the station design options is really basic to the methodology. The MARTA experience as described by Richard Stanger emphasized this; there were four policies that differentiated MARTA stations from those of any other system.

1. The transit system was to be an integrated bus/rail system,
2. The stations were to be unmanned,
3. The fare collection system was to be a flat fare barrier to system, and
4. All stations were to look different.

The first policy defined the scope of the design concepts that were available, the second limited security options to off-station surveillance and the second and third helped to draw the specification for fare collection. Such policies are clearly compatible with the methodology and philosophy contained therein.

While the methodology was derived using internal station design requirements only, it can easily be expanded to consider integral external features such as parking and access mode requirements, and entrance and exit points. It is our view that the major benefit of the methodology is to serve as a mechanism for the transfer of information and experience with transit station design.

We anticipate that the transportation planning and design professions will look to the papers, discussion and workshop summaries from this conference to indicate weaknesses in the state of the practice of transit station design and to identify areas where research is needed.

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WORKSHOP #1

CRITIQUE OF DESIGN METHODOLOGY

Norman G. Paulhus, Jr., Chairman

This workshop focused primarily on the concerns associated with designing large transit stations but also considered the applicability of the University of Virginia's methodology to design of smaller stations and transfer points.

Overall, the workshop found a definite value in the standard design methodology. Its various elements were consistent with current practice in the professional community. The overall structure is more useful to experienced designers and planners, while its details are more critical to newer professionals.

The group reiterated the value of the methodology's evaluation of alternative designs from the perspectives of the user, special user, and operator. However, it found that non-user factors frequently have a substantial amount of influence as to whether a station design can actually be implemented. Three non-user issues proved to be especially important:

1. Parking, which is particularly sensitive in developed areas.
2. Aesthetics, which is a sensitive issue in suburban deployments, and
3. Access, which is important in all areas, but especially in the suburbs.

These non-user evaluations may be especially critical for stations in small properties or the central points in time transfer networks.

Community involvement is the key to resolving many of the non-user concerns. Key points to consider in the design of any community involvement plan include who should be brought into the process, who will actually become involved, and how much the various groups should actually participate in the various phases of the work.

The group stressed that in actual practice there may be more interplay between policy setting and the actual design process than the methodology may indicate. This is particularly true in the entry point for the renovation process, which assumes policy is set before the constraints of the existing physical structure are considered. This is also the case for standardization of features within individual stations. However, the group noted that while a contractor or consultant can recommend policy changes based on analytical conclusions, the setting of policy is ultimately the responsibility of the public body involved.

The University of Virginia design methodology, when applied comprehensively, generates a rather complex set of results. This full set of numerical results and evaluations is acceptable for use by planners, but is too intricate for use directly by higher level decision makers. There is therefore a special need to interpret or translate the results of any application when they have to be presented to top level staff or political leaders.

The group noted that different sets of criteria would be used for evaluation during different phases of the complete design process. As conceptualized during the session, a four step sequence is involved:

1. System Design, which establishes the general configuration and routing or alignment of the option to be deployed, and the general location of stations.

2. Area Design, which establishes the relationship of a proposed station to neighboring facilities. This step results in a site plan for the station.

3. Terminal Concept Design, which generates the features of alternative designs for a particular station. It results in the schematic for the station, and

4. Final Detailed Designs, which evolves the specific elements of a chosen station layout. This phase generates the working drawings from which the station is constructed.

As viewed by the workshop participants, the University of Virginia work addresses the last two of these four phases. However, the group emphasized that the criteria involved in the design methodology could not be applied uniformly to these phases. Some criteria were more appropriate to concept evaluation, while some were more appropriate for detailed design testing. However, the attendees could offer no hard and fast rules about separating the criteria into two sets: local conditions and policy would have much to do with those choices.

The group suggested that a few new elements could be added to the evaluation criteria, including energy impacts and life cycle costs. They also observed that some of the criteria were more highly leveraged than others, based on their experience with the actual design process. These include personal security, weather protection, and individual user orientation.

In summary, Workshop #1 found the University of Virginia methodology useful and relevant to transportation professionals, although some modifications appeared appropriate:

1. There should be more emphasis on non-user factors.
2. Procedures for insuring community involvement are needed.
3. Procedures for the presentation of results to decision makers are necessary.
4. The criteria for concept and detailed design evaluations need to be separated, and augmented slightly.

WORKSHOP #2

INTERMODAL TERMINAL PLANNING, DESIGN AND OPERATIONS

Hanan A. Kivett, Chairman

INTRODUCTION

This workshop had a wide representation of disciplines and interest groups, all of whom are either directly involved with real world intermodal terminals as designers, operators, or managers representing communities, or represent transit organizations who have an interest in developing intermodal terminals within their respective geographic areas. The Workshop discussions focused on the state of the art with regard to implementation of intermodal terminals on a variety of scales throughout the country.

In order to provide a framework for subsequent dialogue and exchange of ideas, three general subject areas were established at the outset of the Workshop as follows:

Topic A - Planning and Design Criteria

Topic B - Implementation Framework

Topic C - Operations and Maintenance

CASE STUDIES

Three intermodal terminal projects were presented in some detail to provide a perspective on the current state of the art, provide insights into opportunities for further research and development which would directly benefit the actual implementation of future intermodal terminal projects, and comment in specific terms on real-world experiences in operating and maintaining such facilities.

The Port Authority of New York and New Jersey's downtown Manhattan Consolidated Bus Terminal, presented by Mr. Sheldon Wander, provided the on-line real world perspective with regard to initial development and subsequent expansions of this country's largest consolidated bus terminal. Major problems addressed and analyzed in some detail by the Workshop included: the extent and necessity for exclusive versus preferential use of individual bus bays for intercity, commuter and local bus operations; various planning and design standards which were generated to provide the basis for undertaking actual design of the complex; the pros and cons of providing concessions within the terminal complex to help offset annual operating costs; traditional capacity problems associated with curb-side drop-off and pick-up facilities; bus entry and exit ramp capacities; and escalator and stair capacities for moving users through the complex. A discussion also took place with regard to the positive benefits of value engineering, the nature of the signing and passenger information systems and the choice of finish materials which would be highly durable and easily maintained, while still providing a suitable environment for passenger comfort, orientation, safety and security while using the complex.

The White Plains Multi-Modal Transportation Center, presented by Mr. Marvin Gerstein, focused on a smaller community's efforts to implement a consolidated bus terminal in the central business district of White Plains, New York. The presentation focused on an analysis of the alternative sites for constructing the terminal, plans to accommodate expansion at a future date, and the problems of identifying sources of funding which might be available to actually construct such a terminal complex. Through routine meetings with a so-called technical working group of representatives of the users, city officials, architects, and engineers, a number of alternative plans were developed, analyzed and then presented to the decision making bodies of each organization. Consideration of this terminal provided the Workshop with an opportunity to elaborate on the necessity for developing terminals which can be implemented in incremental segments so that the initial capital costs are manageable to the users and operators of the complex. Furthermore, landbanking for future expansion of the terminal was also recommended as a part of the site analysis.

The Boston South Station Transportation Center which had been presented in the plenary session provided an opportunity to examine how the full range of modes can be incorporated into a single complex: commuter and intercity rail; local, commuter and intercity bus; and conventional automobiles. This terminal is to be developed in air rights at an existing historic railroad station in downtown Boston. This terminal which is now in final design represents the most far-reaching example of a municipal and state government's attempt, in concert with various Federal agencies, to implement a full intermodal terminal. Although funding is not yet totally secure, the planning and design process has managed to deal effectively with contradictory objectives from the standpoint of the functional needs of rail and bus operators, owners who are concerned with minimizing long term operating and maintenance costs, and political entities who are anxious to have a fully integrated transportation center.

OVERVIEW

The Workshop participants all fully supported the concept of consolidating major ground and rail modes of transport in those communities where such systems existed and where densities of traffic and potential patronage would justify a large capital expenditure. The three case studies, which represented different stages in the development, design, and actual operations of intermodal terminals, provided the medium for the Workshop to draw specific conclusions and recommendations with regard to future research and development needs. The participants all agreed that systematic collection, organization and dissemination of existing data in this subject area is essential. The industry not only requires documentation focusing on activities leading to actual implementation of intermodal terminals but also retrospective analyses to ascertain and verify that specific planning and design assumptions were indeed the correct ones or that changes should be undertaken in future terminal planning projects in order to avoid the flaws which have since materialized in such terminals.

The participants felt particularly frustrated by lack of information in the following areas: establishing the numbers of bus bays to meet peak hour demands; the extent and nature of concessions; the choice of materials, furnishings and mechanical and electrical systems with regard to maintainability and reliability; and how to provide an equitable methodology for allocating operating and maintenance costs among the various users of the complex in order to minimize the extent of subsidy required from the owner/operator to provide such intermodal facilities.

RESEARCH NEEDS

The following topics were identified as potential areas for future research and development efforts which would be most beneficial to the diversified actors who are called upon to play a specific role in the design, implementation and eventual operation of intermodal terminals in this country and overseas.

Topic A: Planning and Design Criteria

1. Definitions of terminology used by the industry, including specific classifications for intermodal terminals and multimodal terminals in terms of types of modes accommodated, facilities provided within a particular terminal type, and volume of traffic and patronage generated in such facilities.

2. Identification of intermodal terminal characteristics and locations within major metropolitan areas in terms of specific types of configurations, phasing and staging characteristics, and the terminal's ability to respond to changing needs in capacity or modal interface requirements.

3. Development and dissemination of dimensional standards for local, commuter and intercity bus accommodations in terms of circulation, parking, loading, and unloading requirements, baggage handling procedures, ticketing, package express and special utilities and servicing requirements.

4. Development of analytical techniques based on actual case studies for optimized utilization of facilities as established in airport planning with regard to exclusive use, preferential use during peak periods and on-demand computer-controlled assignment of loading/unloading positions within an intermodal terminal.

5. Collection of existing data from actual intermodal terminal operations and its dissemination in a unified format, especially information on the nature and frequency of modal interchanges between and among modes within a given terminal.

6. Investigation and subsequent cataloging of user responses to specific operational facilities and services provided within intermodal terminals including: choice of materials for comfort and durability; the effectiveness and legibility to users of signing and graphics; and overall design of facilities for circulation, pedestrian flow and capacity for responding to peak hour demands, as perceived by users, owners, operators, and concessionnaires.

Topic B: Implementation

The workshop participants uniformly encourage undertaking a major investigative effort in order to assemble case studies of actual intermodal terminal projects so that the industry can benefit from the vast and diversified experiences of those involved with these projects. This effort would examine and systematically catalogue the specific roles for which each of the participants has been responsible in the actual implementation of intermodal terminal projects.

The perspectives and levels of responsibilities of each of the following parties need to be clearly defined based on the specific political framework, funding sources and ownership:

- Owners
- Operators (of each mode)
- Users, Passengers, Customers
- Architects, Engineers, Planners
- Builders/Constructors
- Fundings Agencies

All attendees expressed frustration as to what the most suitable roles were for each of the parties of interest. Particular emphasis was given to identifying who should design and build the facilities, what mechanisms are best suited for operating and maintaining the complex, what funding sources existed for building the facilities, and what sources of revenue proved most beneficial with regard to actual operation of the complex.

Topic C: Operations and Maintenance

Numerous questions were raised by the workshop attendees regarding the most equitable methods for allocating operating and maintenance costs among the various users of the complex. Since in almost every case, an intermodal terminal requires an annual operating subsidy, every attempt must be made to fully recover virtually all tangible costs from each of the tenants or modal carriers using the complex. Some agencies utilize user charges based on ticket sales or numbers of bus operations; others have established an annual rental fee which takes account of the overall use of facilities with a pro-rating of public facilities common to all carriers.

A major research effort is required to establish an analytical framework for identifying such costs, allocating these various costs to each of the users, and then providing a management framework for monitoring the financial viability of the overall complex. Case studies of existing intermodal terminals such as the Port Authority Bus Terminal in New York City, the New Orleans Rail and Bus Terminal, and other intermodal terminals soon coming into operation would provide a valuable resource to those agencies currently considering the operation of intermodal terminals.

Even when large amount of Federal funds is available for actual construction of intermodal terminals as is the case with Boston South Station, the owners and users of the complex must agree on a basis for allocating all costs of operating and maintaining the complex to minimize the necessity for the owner to subsidize the complex. Development of major concession and office space within the complex as well as potential air rights or value capture through the acquisition of adjacent parcels as a part of the overall project all appear to provide a basis for improving the financial viability of such projects.

WORKSHOP #3

PASSENGER PROCESSING AND INFORMATION SYSTEMS

John J. Fruin, Chairman

The workshop began with a short statement by each panel member outlining their basic interests and topics for discussion. Passenger processing was defined as the movement of the passenger through the transportation interface, including the use of turnstiles, ticketing machines, stairs, escalators, doors, platforms, or other facilities encountered by the passenger as a pedestrian. Interface information systems were described as single elements, or combinations of elements, encompassing directional signs or other information aids required for passenger processing through the interchange, and modal information such as route maps, schedules, status of service, or other trip information required by the passenger, as well as carrier information necessary for the efficient use of the interface.

Information Systems

Panel discussions of the information systems problem showed general concerns about the relative effectiveness of different types of information aids, for assisting the transit user, promoting public transportation, and being cost effective to the provider. Various types of informational aids were discussed including computer printout schedules, symbol signs, guidelines on floors or ceilings, design of the internal building space to convey direction, and public address systems. Problems associated with some of these aids included difficulty in selecting message content which the user would easily understand, the need for multi-lingual signs in some properties, and some types of novelty signs that caused user confusion. Compass point designations on signs (north, south, etc.) and vertically oriented signs were cited as some examples. The special problems of the elderly and handicapped and their impact on information systems were also discussed. The cost effectiveness of high technology systems was questioned, particularly if not properly applied or utilized.

It was the general perception of panel members that a practical, systematic, scientifically organized study of examples of both good and bad information aids and systems is lacking, but necessary. A "building block" experimental design approach was recommended in which various types of information aids were systematically evaluated, with the objective of developing both optimum means of communicating with users, and cost effectiveness for the provider. The basic human factors research used to develop highway signing was cited as good example of such a program. The Uniform Manual of Traffic Control Devices, which establishes national standards for highway signs, was discussed.

A number of transit properties have developed graphics and signing manuals, notably MBTA, CTA, and MARTA. The MBTA manual, developed by Cambridge Seven consultants, was cited as an excellent example of such a manual, providing guidelines on communication effectiveness as well as uniform signing designs. It was the consensus of workshop participants that a national, uniform transit signing and information aids manual should be developed with the assistance of the American Public Transportation Association (APTA). It was believed that national uniformity of information aids would benefit both users and providers. The new uniform system would be gradually introduced on a replacement basis as older non-uniform elements were replaced.

Passenger Processing

Workshop discussions on passenger processing dealt with the need for guidelines and examples of the dimensioning of platforms, turnstile circulation areas, stairs, locations of escalators and other pedestrian elements in stations. The UMTA Transit Station Simulation package was discussed, but there appeared to be little knowledge of its potential use for this purpose. There was a discussion of the minimum width dimensions of platforms in heavy rail rapid transit and automatic guideway transit stations. It was reported that side access platforms in the Paris Metro Subway System were approximately 10 meters (32.8 feet) wide, and center access platforms approximately 20 meters (65.5 feet) wide. U.S. practice is to design narrower platforms, and in certain unusually restricted locations, there are examples of platform widths as narrow as 3 feet. One prospective design for a guideway station platform was discussed a width of 6.5'. The passenger-holding capacity of a platform of this size, particularly under system delays, was a significant concern. Additionally, safety problems could occur where an escalator discharges onto a platform of this size, because of the constant mechanical delivery of passengers.

The potential for tapering or shortening platforms, on the basis that passenger traffic demands are lowest at the platform ends, was discussed. Tapering and/or shortening would reduce initial construction and subsequent maintenance costs. It was pointed out that a taper should only be made on the edge opposite the trainside because of the platform gap problem. Platforms shorter than the train length require that passengers walk between cars in the moving train, this is considered to be a potential safety and liability problem with some types of rail equipment. A universal problem in evaluating transit station designs are the levels of public acceptance of delay. A fully loaded train discharging passengers out of 24 wide doors produces a heavy demand on station pedestrian facilities and by necessity results in delay. Platform clearance delays of up to 12 minutes were cited where heavily loaded trains are discharged into interface systems with limited pedestrian capacity.

The workshop consensus was that research on guidelines for the design of passenger processing elements in terminals, with examples of both good and bad design, would be of value.

Workshop Recommendations

Information Systems

- Systematic research should be conducted on the effectiveness of information aids in communicating with transit users, and from the standpoint of the provider. The research should examine both good and bad examples.
- Demonstration programs and other sponsored research should be based on a "building blocks" approach of systematic improvements to the technology utilizing careful experimental design, rather than on localized, one time programs.
- A national uniform manual of transit signing and information aids should be developed in cooperation with the American Public Transit Association (APTA).

Passenger Processing

- Research should be conducted to determine levels of passenger acceptance of delay related to the use of passenger processing elements in stations.

- Guidelines should be developed for the design of passenger processing elements in terminals, showing design procedures and illustrating both good and bad examples in existing transportation systems.

WORKSHOP #4

STATION ACCESS AND TRAFFIC

Walter H. Kraft, Chairman

Dee A. Arends, Recorder

The workshop on station access and traffic commenced with a discussion of a planning issue facing many metropolitan areas with split jurisdictions. Specifically, the issue focused on the problems of planning for optimum capacity of access roads, parking lots and circulation routes for autos and buses in an area with split jurisdictions. Funding becomes even more of a critical issue in these areas.

Some areas, such as Maryland, have addressed the issue by conducting transit station access studies conducted under the auspices of traffic engineering and improvement and supported out of the highway fund as a portion of the capital improvements program. The District of Columbia has a line-item in their budget for access projects. It was felt that if funds were budgeted on a regular basis, this would not be an undue hardship on the transit system's general budget.

It was suggested that transit can be viewed as a land developer for the metropolitan area. In order for the local jurisdiction to place a high priority on transit and to fund transit development, the transit system must be seen as being able to yield a good return for the local jurisdiction's investment.

It was agreed that a set of general criteria and guidelines need to be developed, which would facilitate transit access planning for the systems. Ideally, the guidelines would consist of a minimal set of standards that must be addressed by all systems, but it should also be possible to develop alternatives to allow for system enhancement projects, as opposed to simply planning for the necessary "maintenance" items that the transit system requires.

Discussion then focused on whose responsibility it was to pay for system access improvements. One determining factor that should be considered is how much the transit station activity impacts on the overall area activity, in terms of traffic reduction, etc. It was generally agreed that each station has its own unique features and must he looked at on an individual basis in the determination of payment for station access and access improvements. It was mentioned that the Miami area assembled a diversified group of individuals representing several modes to take responsibility for bringing together the necessary funds.

The group then discussed the issue of station site selection and how much detail should be given to station access requirements in the initial planning stages. The general feeling was that, on many occasions, station access seemed to be after-thought and that more attention should be focused upon it during the early stages of the planning process. It was noted that clearly defined goals for what the system needs and wants should be determined at the onset of the process. Many times the planning process was turned into a political procedure which does not adequately address transit system needs. A suggestion was made that system planning be turned into a two-phase "order of magnitude" process: the first phase would be comprised of a general system design detailed enough to identify potential problem areas, while the second would then be the final design plan--after review and modification of the first phase by policy makers, citizens and funding agencies.

The next issue discussed by the group was how to avoid traffic jams at the stations among the incoming and outgoing traffic (bus, auto, pedestrian, etc.) and how to determine who has priority. One suggestion was that a separate bus access could be considered for peak period usage. Factors which must be addressed in making this determination included the following:

1) station size
2) lot size
3) geography and terrain
4) volume of traffic
5) size of the system
6) degree to which the area is urbanized (i.e. number of pedestrians and autos),
7) location and number of accesses
8) economy of scale (e.g. a bus can bring 50 people in), and
9) political issues.

As most transit systems have financial constraints, it is not economically feasible or possible to build the facility to handle total system demand.

Thus, it was generally agreed that transit systems should have the capability to utilize a separate bus access when the traffic flow creates problems. It was also agreed that a prioritization must be established for system access by various types of transportation. After weighing the pros and cons of the various alternatives, the group agreed upon the following priorities for system access:

1) Pedestrians
2) Bicycles
3) Bus (transit system first, then others)
4) Taxi
5) Kiss and Ride
6) High Occupancy Vehicles (require parking)
    a) bus
    b) van
    c) auto
7) Motorcycles/Mopeds
8) Park and Ride
    a) pay
    b) free
    c) off-peak
    d) peak

The group also felt that elderly and handicapped individuals should be given priority in the parking area and in the bus drop-off area as well.

The discussion then led to the question of employee parking and parking for emergency and service vehicles. It was felt that employees should be allowed to park in the lot with no designated place set aside for employee parking only. Obviously, the nature of emergency vehicles warrants their being allowed to go wherever the emergency requires; and it was determined that the space allocated for service vehicles should be contingent upon the station size and the frequency of usage (e.g., concession vendor).

On the issue of pedestrian flow, it seemed that fencing and landscaping can be very effective in channeling pedestrian flow, without adding exorbitant costs to a system's budget. It was felt that it is usually best to have pedestrians initially flow parallel to tracks or loading areas and then flow in a circular pattern to enter or exit.

One important factor which should not be overlooked is to allow for design flexibility in both bus loading arrangements and passenger flow. For example, one system representative noted with regret that the bus loading areas which were designed for 40' buses did not work quite as well as for the system's new articulated buses.

The issue of parking and the justification for parking fees was the next topic discussed by the group. At many stations there are constraints on parking for the morning peak period and this can carry over into the midday, with the result that the midday auto driver is not able to park. It was noted that in many instances, transit does subsidize auto users. The suggestion was made that the system should charge as much as the market would bear for parking fees in order to assure that spaces would be available for those willing to pay the fees. A question was raised regarding financing the lot with parking revenues. A Maryland participant noted, however, that revenues would not cover the costs and that it costs approximately $6,000 per parking space in the Maryland area.

The philosophy was brought forth that the system should not encourage auto use by fulfilling the demand for parking. Thus, it was felt that there should be some constraints on parking. Additionally, it is possible to artifically reduce the demand for parking by increasing the price. It was agreed that valid justifications for parking fees did exist, from the standpoint of

1) a control mechanism for traffic, and
2) revenue collection.

However, parking fees are a politically sensitive issue, so careful consideration should be given to some type of pricing structure--possibly peak and off-peak rates--when instituting parking fees.

The question then arose as to whether there was an optimal size for a parking stall, in view of the trend towards compact and subcompact autos. Often standard size autos will try and fit into smaller spaces so that the system may be increasing operating expenses by trying to monitor parking in the lot. A great deal of variety exists in the smaller cars. Even though the car may be smaller, the width may be comparable to a standard size automobile.

The point was made that in attempting to discriminate on the basis of vehicle size, the transit system may unknowingly discourage use of high occupancy vehicles, such as carpools and vanpools. If the system does make a determination to differentiate parking on the basis of vehicle size, design flexibility should be an important consideration.

Discussion then focused on the issue of Kiss-and-Ride facilities and whether it was better to designate areas of the parking complex for this, or to increase the width of the lanes in front of the station entrance. If the system does opt for wider lanes at the station entrance, the traffic flow is enhanced considerably by use of a modified saw-tooth design as opposed to parallel parking. A representative from Bay Area Rapid Transit noted that their system makes use of the midday parking lot, but enforcement can be a problem. In order for enforcement to be effective, there need to be clearly defined laws and authority, and adequate signs for the designated area. General consensus was that Kiss-and-Ride facilities have fewer problems if they are located in a separate area and the station entrance areas are kept open for buses.

The final topic of discussion centered on the question of who should be responsible for operating the parking lots. It was felt that contracting out to private companies would remove some of the political constraints, but could result in varied pricing policies which would not necessarily encourage transit usage. For example, a parking lot closer to a downtown area may have cheaper parking fees than one further out, which could promote increased auto driving to the cheaper lot. It was agreed that most systems would prefer to operate their own lots, simply for the sake of maintaining a greater degree of control over the operation of the parking complex.

WORKSHOP # 5

OPERATIONS AND MAINTENANCE

Colin Alter, Chairman

In the design, planning and construction of stations, the cost factor is frequently overlooked. As a matter of fact, we were advised earlier in this conference to avoid the advice of the cost-conscious engineer. The reason is simple: the Feds pay 80% of the bill. It is therefore comparatively easy to say that costs don't matter much.

In the world of operations, however, costs dominate all discussions. Federal operating assistance, while very important, still accounts for a very small proportion of the funds. Hence, the operating and maintenance managers would rather see station operating costs truly minimized than hearing and responding to various architectural theories dealing with trade-offs between various aesthetic treatments that are equally undesirable from the maintenance perspective, with no opportunity to require consideration of truly low maintenance items. There is no "free" lunch and there is no "maintenance-free" station. This issue of the cost of operation and maintenance has not received the detailed consideration it requires during this conference, and has received little attention in the literature or the documents of this study. The reason: the state-of-the-art is simply not there.

It is the first recommendation of the workshop that annual and life cycle costs of both the operation and maintenance of a station receive priority emphasis in the design. We are forced to come to this conclusion as we see beautiful designs rapidly deteriorate due to lack of adequate funds for the long-term continuing maintenance requirements. The statement by some architects and planners that money will just have to be provided is simply unrealistic. The public trough devoted to public transit is simply empty in many local governments, and is rapidly getting there in the Federal budget. (It is already there so far as operating costs are concerned.) The more dollars devoted to maintenance, the less can be devoted to service. At WMATA, 17% of the rail budget is operating costs; 22% for car maintenance; 61% + for station and system maintenance.

The second recommendation deals with research needs: more effort must go into developing the methodology for cost estimation for operations and maintenance, maintenance planning, and planning for maintenance. It is our belief that these efforts are perhaps more needed than the planning equivalents of counting the angels that can dance on the head of pin, or the definitive analysis that improves upon existing techniques of passenger flow and computer models to "guesstimate" passenger volumes. Does it really do anyone any good to sharpen these estimates by + 5-10% when our operating and maintenance costs are off 1-200%-- <u>if</u> we can even guess them?

In the Criteria volume of the study, we learn that the stations are to be designed to reduce or minimize maintenance costs. Of course, the designer never really refers his design to experienced operators and maintenance people for effective critique while there is still time in the new systems. Instead, the operator is informed that the design process has gone too far, especially to allow a change of that magnitude. Little consideration is given to the cost of that error over the total life cycle. On the other hand, the operator must understand that changes in basic operating assumptions will drastically impact the ability of the design to operate. Compare that with the experience in New York City with the TA, or PATH, or in South Jersey's PATCO where senior operating people are involved in every step of the process. In some cases, they even have the right of effective veto. Our third recommendation addresses the question of when do you (the designer/planner) involve the operational people: from the conceptual design issues identification stage. In other words, from the very beginning. It is necessary to also understand that operational people come from different disciplines, as do the engineers, architects and planners. You can no more expect the director of train or bus operations to fully evaluate mechanical or electronic systems than you can expect an architect to evaluate them. It is the experience of the members of the workshop that the money spent early on highly experienced operating and maintenance staff is an investment that will be repaid many times over during the life of the project. Perhaps more importantly from the fiscal perspective, the small, costly labor intensive errors repaired after the commencement of operations will be avoided. Getting these people involved early is a capital investment of the same nature as the testing of alternative designs, and just as important.

One additional consideration outlined in the workshop was the problem of locating these senior personnel when there is a tremendous generation gap in transit generally, and the lack of continuity in A&E firms. The problem is further amplified in terms of accountability when it is realized that the section designers and the A&E firms aren't around when the maintenance requirements (frequently considerably out of the magnitude that they estimated) become evident.

Assuming that the above recommendations have been implemented, it must then be emphasized again that there is no such animal as a "maintenance-free design". Basically, consideration must be given as to the maintainability of a given design. Low cost maintenance is relative, and any station is going to require considerable maintenance at considerable cost. For example, WMATA's stations were designed and advertised to the public as "maintenance free". In this case, "maintenance-free" is expected to cost approximately $300,000 per year per station. That completely excludes the cost of station attendants, power consumption, and any other system operating cost numbers.

Our fifth recommendation is that it is vital for the station designer, especially for the new rail operations for inter-city stations, to understand that there is a system involved. Where will the maintenance facilities be? Is there adequate room within the station perimeter to allow for the maintenance and operation of the equipment located there? Have you accounted for the standardization of the signal, fare collection, and communication systems, while ignoring the need for standardization of pumps, HVAC, controls and various other electronic, electrical, mechanical and other support systems? Have you even remembered that maintenance equipment needs maintenance?

Management has a key role in resolving disputes between the various disciplines involved in station planning. The workshop concluded that they should also be involved in the resolution of similar disputes between designers and operators. This will quickly require that the designers become more fluent in the jargon and requirements of the operator, and the operator to understand the perspective of the designer. While that improved understanding may alleviate some of the problems, it is also likely that it will exacerbate others. The debate is likely to be more meaningful, being centered on crucial issues, with more information available to the decision-maker that will allow comparison of entirely different options, each with their own capital and operating cost implications. <u>But</u> a decision must be made, and not just left to time to resolve.

A seventh issue for consideration of planners, operators, and academicians is the problem of organization of the maintenance function: will it be done in-house or contracted out? Is there sufficient flexibility for the decision to be modified? We have no recommendation (due to the significant differences relating to availability of options and existence of institutional constraints) other than the problem must be addressed.

Our eighth recommendation is to thoroughly read all documents: the leases, the warranties, the easements, the political resolutions. Limitations are frequently written in that the attorney, at first view, considers as minor that may quickly turn out to he a key stumbling block many years in the future. Again, this is just one of the many institutional issues that need to be considered.

The workshop had a final concluding recommendation: a comprehensive functional analysis of the station should be completed prior to commencement of the first conceptual design. This functional analysis is more than the passenger interaction with the facility; it must include all functions associated with that particular station as well as those nearby. To suggest a few functions that need attention:

1. Location for revenue processing or storage;
2. Employee work reporting locations; with associated requirements for locker rooms, restrooms, lunch, parking, etc.
3. Remote spare parts storage rooms;
4. Location of transit police patrol zone facilities;
5. Centralized or decentralized location of small maintenance shops, equipment rooms, dispatch facilities.
6. Office space for supervision at satellite facilities.

In reviewing the plans for the locations of these essential functions, it is also necessary to review the plans to consider the requirements of maintenance and operation of all the equipment. Let's be specific:

1. Information integration where there is intermodal interface (where do you get information on bus routes serving the rail station);

2. AC power for operation of the station;
3. DC traction power control and supply;
4. Plumbing for restrooms;
5. Plumbing for station drainage related to station leaks, storm water, or even station cleaning;
6. Window washing;
7. Luminaire maintenance; direct vs. indirect lighting; light sources ranging from incandescent to flourescent to high pressure sodium;
8. Landscape maintenance;
9. HVAC needs;
10. Fire and intrusion protection;
11. Painting and graphics (there is no such thing as a final, perfect set of graphics);
12. Floor, wall, and ceiling maintenance;
13. Alterations and routine building maintenance -- like the roofs of ancillary buildings, or the street and sidewalk grates, the station entrances and the walkways, roadways, and parking facilities associated with the total design.
14. Emergency service, with its requirements for emergency tool and part storage.
15. Trash collection and temporary storage of trash;
16. Control of metallic dusts.
17. Maintenance accessibility of the vertical mobility pathways, be they stairs, elevators, or escalators; also, consideration of even such a single consideration as location of motors, weather-proofing, and location of on-off buttons;
18. System security when the stations are closed.

For inter-city stations, the problems are the same, but the scale is different. Less specialization of mechanics is possible; more generalization of skills is required that has costs of its own associated with longer diagnostic time. I may have mentioned too many of the small things, while ignoring the big things. The reason: no one is going to ignore maintenance of the elevators and escalators; who is going to remember that sliding doors that operate on tracks that open and close stations have lots of little wheels that must be maintained, and must therefore be accessible to be maintained?

As a final personal note:

I've emphasized, perhaps excessively, the problems I've noted with the design of the WMATA stations. It is easy to note the good things; our successes are notable, and we did not always attempt to reinvent the wheel. But we have also made lots of little errors that could have been avoided, and that are being avoided in the iterative design and construction process. You can and should learn a great deal from the areas where WMATA has, perhaps, advanced the state-of-the-art. You should also be fully aware of our mistakes, and can therefore plan how to avoid them.

All persons involved in operations and maintenance know that the primary purpose of a transportation station is to help in the movement of people. But any design that solely emphasizes the movement of passengers while ignoring the needs for efficient and effective maintenance is going to result in either a design that fails or a design that people are going to be paying too much money to operate for a long time into the future.

DISCUSSION PAPER

Ralph E. Smith
Director of General Maintenance
Washington Metropolitan Area
Transit Authority

There is no such thing as a "maintenance free" transit station. If we start out with this understanding as a ground rule in our planning considerations for transit station design, we've already made some progress. Since we have now acknowledged that maintenance will exist, our system plan must include facilities to accommodate the mechanical, electronic, electrical, architectural, structural, track and custodial functions early in the program. I would encourage construction of an adequate, centrally-located facility for maintenance administration, shops and stores. Also we must recognize the need for additional remote facilities to reduce travel time for mechanics and custodians.

We can now turn our efforts toward considerations to minimize the maintenance, cleaning and replacement needs. Maybe we should take time now to stress that maintenance and operations people should be "on-board" for this process. Their input has to be solicited in the initial planning, or the preliminary design concept flies without any real consideration for maintenance and little if any for operations. I am not saying that maintenance and operations should "dictate" the total concept but their input should be considered very early in the planning states in order to have a decent chance to minimize their costs later on. Some of the concepts that come to mind from a maintenance standpoint will be covered in the following paragraphs.

Covered entrances materially reduce maintenance costs. They simplify the procedures for snow and ice protection; they reduce damage incidence to escalators from objects thrown or carried onto escalators from surrounding areas and they reduce the amount of cleaning effort.

Landscape planning should minimize the hand work involved in maintenance. Weeding is very labor intensive but essential to maintain the appearance of shrubbery beds. Landscape designs should include ample pathways for patrons because otherwise they will make their own. Thought should be given to snow and ice removal requirements.

With respect to lighting, we feel that direct lighting is preferable. The lighting should be directed at the surface to be illuminated. Florescent lighting should be used to the maximum extent possible because of longer bulb life and longer power usage. Access to the light fixture for maintenance and replacement should always be considered.

As a custodial consideration for minimizing cleaning efforts, the exposed surfaces to be cleaned should be non-porous. Floor, ceiling and wall materials and finish should all be selected with ease of cleaning in mind. Also extremely important is planning for the removal of the trash that accumulates in the stations.

Somehow, wherever possible, standardization of equipment should be considered. A lot of expensive maintenance effort could be reduced if pumps, fans, motors, transformers, chillers, sewage ejectors and so on were the same in each station. It should be obvious that the number of spares, the records, the training and basic skills required could all be reduced with success in this area.

One of the early problems we experienced was the vulnerability of our pump stations to water in case of any kind of a failure. Since our pumps were in metal containers located in sumps below the surface, they are not submersible. When the pump station is flooded for any reason, the pump motors must be pulled, dried and sometimes replaced. Our future designs now call for submersible pumps but a little thought about what happens in case of failure could have eliminated a potential problem maintenance will have to live with.

I guess at the time our design concept was established no one was concerned about energy conservation or management but it's now something that requires planning to allow separate metering, distribution panel allocation and circuit termination planning to simplify energy management efforts.

Before we leave this list of areas where maintenance costs can be reduced we've got to address leaks. I've said before in several presentations that leaks probably cause more extra unnecessary maintenance effort than any one of the above listed concerns. The objective should be to produce a dry system. Whatever extra effort is devoted to this initially will certainly pay for itself in reduction of future maintenance effort.

Even if you bring maintenance and operations folks in early in the planning cycle and have them review designs before implementation, there are still going to be things that need changes discovered after operations begin. This should be anticipated and recognized. A system for accepting these changes in design should be established and a procedure developed to implement changes as soon and as gracefully as possible. The objective again is to keep maintenance costs to a minimum.

One of the ways to accomplish this change procedure and to make these suggested changes more acceptable to the design organization might be to establish a small maintenance and operations section within the design organization to interface with the functional maintenance and operations organizations. In any event the objective again is to help reduce maintenance costs and the earlier in the program this effort is started, the more that will be saved.

DISCUSSION PAPER

Richard R. Sarles
Port Authority of NY and NJ
Rail Transportation Department

During the planning and design of major new projects or modification and rehabilitation projects, it has been the practice at the PATH Corporation to include the appropriate personnel with substantial requisite experience in operations and maintenance in the planning/design process. This is beneficial for two reasons;

(a) the designer is made aware of certain deficiencies or omissions in his design at an early stage when the cost and time to make corrections is minimized, and

(b) the operations/maintenance personnel are aware of the reasons for the choice of specific designs and participate in the decision-making leading to the final design.

During the preliminary design phase of the once-proposed extension of PATH, a small cadre of personnel with decades of railroad experience in operations and maintenance was assigned on a full time basis to participate in establishing the design criteria and to review the preliminary design as it was developed. This cadre had direct access to the project director who was also deputy director of the department which was responsible for the operation of PATH.

On smaller projects involving modifications to or rehabilitation of existing facilities, the superintendents of the various operations and maintenance divisions participate in establishing the basic criteria and are given an opportunity to review functional plans, and contract drawings. After preparation of functional plans, but prior to proceeding with contract document preparation, concurrence to proceed must be received from PATH's General Superintendent. Naturally, if a conflict is unresolvable, the final decision is made by the General Manager of PATH, but this is a very rare occurrence. While the above procedure adds some time to the design process, it can reduce the overall project time and costs by reducing the more costly and disruptive delays which could occur due to contract changes during the construction phase.

WORKSHOP #6

LAND USE, JOINT DEVELOPMENT, AND STATION IMPACTS

Wilfred Sergeant, Chairman

Hugh Manke, Recorder

Joint development is, by definition, development brought about by a joint, or cooperative, venture involving both public and private elements. For our concerns, the public element is a transit facility. The public involvement generally includes both the transit agency and local and/or regional government planners.

As a general principle, it is assumed that joint development will work only if all the participants are winners - both the public and the private sectors must gain from the venture. The developer is primarily interested in his or her return on equity. The public entity is interested in increased transit ridership, possible savings in project costs, redevelopment, the maximization of land use, and an expanded tax base.

There are various problems with joint development. The developer is often concerned about the kind of people a transit terminal attracts, especially bus terminals which are perceived as attracting undesireables. Shared lobbies in such facilities are a problem. Also, developers see delays and uncertainties in dealing with government. The developer may be concerned about conflicts in parking between customers and transit patrons for facilities located in suburban areas.

Several good examples of joint development at transit terminals were discussed. Most examples of economic development at terminals involve development projects undertaken after the completion of the terminals.

Transit malls may be easier bases for joint development than intermodal terminals. The perceived adverse effect of a bus terminal is spread out over one or two city blocks (e.g. Portland). A transit mall <u>cannot</u> be successful without joint development, whereas an intermodal terminal <u>can</u> be successful without it.

Research into the effects of joint development is needed. Case studies of joint development at inner city locations and at suburban locations should be conducted and the results compared to identify whether there are different problems in these two contexts. The purposes of these studies would be to provide the public sector with a list of pros and cons of joint development, to enable the public sector to identify tradeoffs for private developers, and to assess the legal and financial complexities of joint development projects. As a part of these case studies, it would be possible to analyze whether the negative perception of bus facilities is objectively justified.

The issues of land use and the impacts of station development were also discussed. It is important to define the objectives to be met by a new terminal. Generally transportation planners focus only on one particular transportation goal. The implementation of a land use plan for the area surrounding the station is rarely identified as an important objective.

The impacts of station construction are almost always positive: economic development follows the station construction, albeit usually in an unplanned manner. The major negative impact identified in the discussion involved parking facilities. Designers often fail to properly plan for parking at suburban terminals. The workshop felt that UMTA should consider including parking in station projects.

Research is also needed on land use and station impacts. Case histories should be developed covering examples of different stations at different locations involving various service modes. One goal of these studies would be to develop means of measuring the effectiveness of different designs in achieving stated objectives for the station. The reasons for achieving or failing to achieve the objectives should also be identified.

WORKSHOP #7

DESIGN FOR THE DISABLED, ELDERLY, AND HANDICAPPED

Robert A. Olmstead, Chairman

Larry G. Richards, Recorder

Most of the attendees were already familiar with, or directly involved in, problems of the elderly and handicapped. Three of the participants represented transit authorities (RA Olmstead, MTA, New York; Henry H. Magdziasz, MTA, Manchester, N.H.; and Chris G. Kalogeras, CTA, Chicago), and three others represented the U.S. Department of Transportation (Sally H. Cooper, Region III, USDOT, Pat Simpich, UMTA, and Dr. E. Donald Sussman, TSC). Hence, although much of the discussion was general in nature, it would often zero in on specific problems some of the participants were encountering and thus focus on the details of design and operations for the handicapped user.

The problems of elevators in transit stations were discussed. The fact that there will be more elevators in transit stations was taken as a given, due to Section 504 of the Rehabilitation Act of 1973 and other government mandates. New stations may be designed to accomodate elevators, but there are major problems with installing them in most older systems. The key problem is how to fit the elevators into the system. Additional problems involve insuring their use by the handicapped and providing high levels of safety and security for handicapped users.

What kind of technology is needed to make elevators safe and secure? A system is required whereby (1) a person can be recognized as handicapped (to insure access to the elevator), (2) door operation can be controlled (so that it opens and closes at the right times - not too soon), and (3) it can be monitored to make sure that whoever gets on the elevator eventually gets off (within a reasonable time).

The design and use of elevators should minimize security problems. Transparent elevator walls and shafts are desirable; lots of glass should be included in the design. The elevator should be located so that it is within sight of the ticket agent. Each elevator should have a home level: it should return to its home level after each use and stay there with the door open until it is used or called to another level. The home level entrance should be in sight of the ticket agent. The feasibility of video surveillance systems was discussed. To date, CCTV in elevators seems ineffectual, but better systems may be developed.

Many structural and space problems have been encountered in attempting to fit elevators into older transit stations. The USDOT Transportation Systems Center (TSC) has been looking at alternative designs for elevators. One promising configuration is a screwtype elevator.

Several general issues were discussed including (1) how many handicapped users are necessary to make a system worthwhile, and (2) are special services preferable to retrofitting existing mass transit systems? Some workshop participants weren't sure that paratransit would be a cheaper alternative than retrofitting fixed route transit. A figure of $27 per hour was cited from a Caltran's study for a 24-hour advance notice paratransit system for the elderly and handicapped.

Another major concern in accomodating users in wheelchairs is the gap problem: there is a misalignment, or gap, between transit cars and station platforms. Users in wheelchairs often have difficulties negotiating this gap. Scientists at TSC have concluded that gap filling devices must work on the platform, there is no way to put them on the train. Transit operators generally agree. TSC has contacted the Veterans Administration to test what size gap wheelchairs can cross. TSC's original estimate was 2½" horizontal and 1½" vertical. After testing, it now appears to be greater: 3½" H and 2½" V. TSC is also looking at the possibility of modifying track profiles to minimize vertical gaps and also at potential new designs for platform gap fillers. Several concepts for modifying wheelchairs to cross larger gaps are also being investigated. Several innovative wheelchair designs are being tested at the University of Virginia Rehabilitation Center.

TSC is also examining the use and design of restraining devices ("tie-downs") for wheelchairs in rail cars and buses. Similar work is being done in Canada. This work is part of the broader issues on the design of transit vehicles: what features are really necessary, what features are desirable, in transit environments?

The issue of design standards was discussed at length. One problem is that a particular system will be faced with multiple codes or sets of standards. The CTA must adhere to those set by the City of Chicago, the State of Illinois, and the federal government. ANSI (American National Standards Institute) has proposed new standards (March, 1980) which OMB (the Office of Management and the Budget) has said should be accepted by the federal government (OMB, A119). The position taken by OMB is that the government should get out of the business of setting standards. Many standards are not strictly applicable to the transit environment. It was the feeling of this group that standards should be set by the industry, not those outside the industry. It was the consensus that the transit industry should establish an ad hoc committee to assist in setting standards for the handicapped in the transit environment. Chicago pointed out that they are currently modernizing several stations which have non-conforming conditions (e.g. steep ramps at stations on the Congress Street line).

The issue of standards is also related to questions of legal liability. Law suits against transit systems are much less likely to be successful if the system meets accepted standards. The ability to state that "the station was built in accordance with the standards at the time" is a good defense against certain types of law suits.

Several other topics were briefly discussed. The problems of making transit systems accessible to visually impaired users are currently being investigated. The general concern of transit systems has been accomodating wheelchair users and those with mobility limitations. Design for persons with sensory impairments has been relatively neglected. Finally, it was noted that many problems could be alleviated by training the elderly or handicapped user on how best to use the system, and training transit personnel to deal with the handicapped and elderly.

WORKSHOP #8

TRANSIT STATION SECURITY

Dr. E. Donald Sussman, Chairman

Dr. Larry G. Richards, Recorder

Passenger security has become a major issue for urban mass transportation systems. Perceived security is a primary determinant of transit mode choice and use patterns. Fear of crime and harassment is the most significant factor preventing transit use in some of our large cities, especially those with older transit systems. Even frequent users of transit schedule their trips to avoid travel during certain time of day.

Attempts to control transit crime may involve manpower (police), technology (crime countermeasures), or design. Various police deployment strategies can have marked effects on criminal activity. Similarly, closed circuit television (CCTV), a technological solution, has proven to be very effective for reducing certain types of transit crime. Elements of station design which help eliminate the opportunities for crime have been described in one of the University of Virginia reports distributed at this conference [Richards and Hoel, Improving Transit Station Security]. Design strategies will be especially important to future transit systems, such as Automated Guideway Transit (AGT), because these systems will be characterized by low manpower - no employees will be in the stations during normal operations. However, even in some current systems, designers are ignoring the lessons to be learned from the security problems of older systems.

Various crimes common in transit environments are listed in Table 1. Most of the discussion in the workshop focused on these crimes and means of dealing with them. During the discussion, several general classes of problems related to transit crime emerged and solutions for them were proposed.

A major institutional problem is that weak or erratic law enforcement is often associated with transit crime. This is true at both the judicial and patrol levels. The prosecution of transit crimes is low in prestige. Therefore, inexperienced and/or poorly motivated prosecuters are often used. Most transit crimes are relatively minor offenses and are not taken seriously by the courts. Light sentences are common.

Table 1

TYPES OF TRANSIT CRIMES

1.1 Major crimes

1.1.1 Crimes against transit system:

1.1.1.1 Sabotage
1.1.1.2 Theft of revenues
1.1.1.3 Arson
1.1.1.4 Graffitti

1.1.2 Crimes against transit patrons

1.1.2.1 Armed robbery
1.1.2.2 Physical assault
1.1.2.3 Sexual assault
1.1.2.4 Murder

1.2.3 Other transit crimes

1.2.3.1 Trafficing in narcotics
1.2.3.2 Gambling
1.2.3.3 Prostitution
1.2.3.5 Suicide

1.2 Minor crimes

1.2.1 Crimes against transit system

1.2.1.1 Vandalism
1.2.1.2 Pilferage from vending machines
1.2.1.3 Smoking, spitting, littering
1.2.1.4 Fare evasion

1.2.2 Crimes against transit patron

1.2.2.1 Harassment: sexual, verbal, physical, or acoustical
1.2.2.2 "Horseplay"
1.2.2.3 Pick-pocketing
1.2.2.4 Exhibitionism

1.2.3 Other transit crimes

1.2.3.1 Alcoholic or narcotic intoxication
1.2.3.2 Begging or soliciting
1.2.2.3 Loittering

Civil police motivation for dealing with transit crime is low due to the lack of glamour, the perceived lack of advancement, and the low conviction rates. Transit police motivation tends to be low due to the lack of prestige and low pay.

Solutions to these institutional problems include (1) efforts to convince judicial staff that "minor" transit crime can significantly reduce the utility of public transportation, and in some cases deny use of multi-billion dollar transit facilities to the public, (2) training programs and special funding for prosecuting attorneys who specialize in transit crime, and (3) favorable media coverage ("positive press") for transit police and crime prevention programs.

Other problems are more design-oriented or architecturally based. Stations are often designed so that unused spaces become problem areas. Extensive mezzanines, which were planned for peak period overflow areas, are likely to become areas for loitering, drug dealing, illicit sexual activity, or other undesireable activities.

Concession areas are often a focus for minor crime. They are usually unprofitable; in short and medium haul urban systems, the only stores likely to be financially viable are the fast food and impulse purchase vendors - both are aesthetically questionable and usually contribute to littering. Concession areas in urban transit systems generally don't repay the capital costs associated with accomodating them.

Station entrances are sometimes located at relatively deserted areas, such as parks or monuments, or loitering areas, such as high schools or bars. Such locations expose patrons to threats and harassment, and thus use of such stations is likely to be low.

Transit authorities are reluctant to use high technology surveillance equipment, because it can potentially become a major maintenance expense. However, transit systems often have limited police manpower and are unable to maintain the levels of patrol and police visibility needed to reassure the traveling public.

Each of the above problems may be alleviated by the appropriate design strategy. (1) Unused areas of stations may be closed off, and perhaps used for offices, storage, machinery, or training areas. New stations may be planned without such areas. Flexible barriers may be used to regulate the amount of station area available, which may expand or contract for peak or off-peak passenger volumes, respectively. (2) Concessions in new stations should be limited, perhaps only to those providing newspapers and magazines. Any unused or under-used concessions should be eliminated. (3) The entrances of new stations should be carefully placed to avoid problem areas. For existing stations, additional security measures (i.e. patrols and surveillance) must be extended to the problem areas around the station. (4) Station surveillance equipment and facilities must be designed for minimum maintenance. For example, system lighting may be increased thus avoiding the need for "low light" extra-sensitive video cameras, several simple cameras may be installed to maximuze coverage rather than using electro-mechanical pan, tilt, and zoom systems, and all critical sensor and control systems may be hardened during the design phase rather than after installation.

Much of the discussion dealt with CCTV surveillance of stations. Several transit systems are either using it or are installing it. The PATH system has 30 or so cameras, mostly employed watching fare gates. All stations in PATH are unattended, but are under surveillance from a remote station. In addition to human observers, a video tape recorder may be used. New York City (NYCTA) has installed CCTV in several stations, and is currently expanding that coverage. Chicago is involved in a study of CCTV at six stations. These are all old stations with poor lighting, and the investigators are currently studying what light levels are really needed for effective surveillance.

In addition to improving CCTV surveillance, higher light levels have many positive effects: passengers like the station better, maintenance crews clean it more thoroughly, etc.

There are many unanswered questions regarding CCTV surveillance. The human factors aspects of monitoring are not well studied: what kind of person makes a good monitor? What are the best monitoring strategies? How many screens can a person watch? For how long? Basic research is needed on event perception and the detection of incidents in this context.

Finally, the special security needs of the elderly and handicapped were considered. Elevators in remote locations often provide the isolation which facilitates crime. Such elevators must be under surveillance. There should be well defined areas for the E&H within a station, and station personnel should be alert to the special needs of these travelers.

WORKSHOP #9

APPLICATION OF COMPUTER METHODS TO THE PLANNING AND DESIGN OF TRANSIT STATIONS

Jerome M. Lutin

INTRODUCTION

This paper summarizes the results of a workshop conducted on September 23-24, 1980 as a part of the National Conference on Planning and Development of Public Transportation Terminals sponsored by the U. S. Department of Transportation at Silver Springs, Md. The workshop was comprised of representatives from government, academe, and the transit industry. Participants met for the purpose of discussing the problems and potentials of using computer-aided methods in a variety of applications to the planning and design of transit stations. Included in this paper is a discussion of four major themes which emerged from the workshop deliberation.

First, the state-of-the-art in model development was discussed. A number of current applications were recounted by workshop members, including the use of simulation models for evaluating subway environmental conditions, operation of automated guideway transit system stations, the land-side and air-side capacity of air terminals, and the flow of pedestrians and pedestrian planning requirements for rapid transit terminals.

The need for computer models was then discussed in light of the various planning problems which could benefit from the use of sophisticated and more detailed planning tools. Of special concern to the workshop was the subject of barriers to the use of computer models and techniques. A number of obstacles to the effective implementation of computerized techniques were discussed. Finally, the workshop developed a series of recommendations to improve the usefulness of the models and to aid in overcoming the barriers to their implementation.

STATE-OF-THE-ART

A survey of workshop members yielded information on four computer models currently in use which can be directly applied to the design and planning of terminals. These are 1) the Subway Environmental Systems (SES) model which is used to determine heating, ventilation and air conditioning loads resulting from subway train operations in tunnels; 2) the Airport Landside Simulation Model, which models behavior and congestion of vehicular and passenger movement at airports; 3) the Detailed Station Model (DSM), used to model vehicle and passenger movement within automated guideway transit (AGT) stations; and 4) the UMTA Station Simulation (USS) program module, used to simulate and evaluate passenger movement through transit stations. Each of these models is capable of producing sophisticated analysis, and at least three of the four has been used in actual system design work.

The Subway Environmental Systems model was developed by Parsons Brinkerhoff, Quade and Douglas, Inc. under a contract from the Urban Mass Transportation Administration, as part of a four-year research and development project to examine "the problems of maintaining an acceptable environment (in terms of temperature, humidity, air velocity and pressure waves) within a subway system" (Parsons Brinkerhoff, 1978). The program analyzes aerodynamic and thermodynamic behavior of a subway system through a time-dependent simulation using four sub-models. A train performance model simulates the movement of trains through the system. An aerodynamic model is used to compute the rate of air flow through the system. Short term humidity and temperature are calculated by a thermodynamic model. And a heat sink model is used to model long term heat transfer to or from the surrounding soil.

The SES model produces output which is used to predict dynamic parameters at specified time intervals; maxima, minima and average values with air conditioning and heating load estimates; and train performance data. Extensions to the model have been developed to analyze the flow of smoke and heat in fire studies. The model was used in the analysis and design of thirteen subway systems including those in Atlanta, New York, Baltimore, Washington, D. C., Chicago, Boston, San Francisco, Montreal, Caracas, and Hong Kong

The Airport Landside Simulation Model was developed by the Transportation Systems Center for the Federal Aviation Administration. It is a modified version of a model purchased from the Bechtel Corporation (Gorstein and McCabe, 1978). The program models the behavior of persons, baggage and vehicles using the airport landside, which is defined as the area from the airport boundary to the aircraft gate. The landside simulation includes the following elements - passenger terminals, access roadways, and parking.

The model simulates the movement and processing of passengers and visitors at the following types of facilities: boarding gates, customs, immigration, ticketing and check-in, car rental, enplaning and deplaning curbsides, baggage claim areas, and parking lot exits. Reports are generated for congestion statistics - waiting times, queue lengths and occupancy; queue statistics for each facility - including number of queue entries, queue size, and time spent waiting in queues; and facility utilization - including number of patrons utilizing the facility, maximum number of agents busy, and average number of agents busy during the simulated period. Model validation data were collected at three airports, but the authors did not report results of model applications in actual design efforts.

The Detailed Station Model (DSM) was developed by the General Motors Transportation Systems Division under contract to the Transportation Systems Center of the U. S. Department of Transportation. The model was designed as part of a major sotfware development project, the Automated Guideway Transit Technology-Systems Operation Studies (AGTT-SOS) to simulate performance of entire AGT systems (R. A. Lee, et. al., 1980). The model simulates vehicle and passenger movements within a station, to evaluate control policies for demand responsive service for individuals and parties, scheduled service, probability of transfers, search and disposition of empty vehicles, and launch delay resulting from network congestion.

The model functions as a discrete event processor and simulates pedestrian movement within stations on a link network. The model produces output which is used to evaluate station performance. Performance measures reported include: vehicle load factors, vehicle arrival and departure rates, empty vehicle statistics, passengers arriving, boarding and departing, and queue statistics for passengers and vehicles. No validation procedures or actual system simulation runs were reported by the authors. However, the research effort is still continuing.

The final model discussed in the state-of-the-art of computer-aided tools is the UMTA Station Simulation Computer Module (USS). USS was developed by Barton-Aschman Associates under a contract to UMTA (Barton-Aschman, 1975). USS is a discrete event, Monte-Carlo simulation model in which the physical facilities of the station are translated into links and nodes. The user must specify areas, distances and device service times. Passenger behavior is simulated by means of a multiple path choice model which considers congested walk time and queue time in the station. The model was developed primarily to evaluate the impact of station design on congestion levels, handicapped accommodations, and time spent by passengers walking and waiting in station (Lutin, 1976).

The program produces up to twenty-two different types of reports on station operation. Basically, these reports can be broken down into eight types: 1) printouts of input data cards; 2) walk time reports; 3) queue time reports; 4) total time reports; 5) number of persons using an area or device; 6) area per person; 7) percent of area used; and 8) paths taken by individuals through the station (Lutin and Benz, 1979). Several USS case studies have been performed, and a design application was performed for the Jacksonville, Florida Downtown People-Mover (DPM) Study.

In addition to the four models described above, other computer programs which can be used to design and evaluate transit stations are known to exist in both public and private sectors. The models mentioned above are representative of the spectrum of tools available, and were discussed because they are non-proprietary and can be obtained from the sponsoring agencies at minimal cost. To date, tools such as these have found limited application, and some of the reasons for this lack of widespread use are discussed in the following sections. In the next section, the need for models to aid in design development is discussed.

NEED FOR COMPUTER MODELS-PASSENGER PROCESSING

Because the interest of most workshop participants lay in the areas of passenger processing, designing physical facilities and station configurations, needs for computer models in this area were stressed. To some extent the general needs statements can be applied to other station design activities involving other engineering and physical subsystems. Within the overall context of station design, two primary roles were seen for utilization of computerized techniques. First, it was recognized that computer models would be useful in a design role, in which their primary function would be to aid in reducing overall costs of construction. The second role is that of evaluating facility designs. In this role, the primary justification for employing computer techniques would be to reduce uncertainty about station performance. Seven areas in which computer applications may prove useful were developed by the workshop as being applicable to passenger processing, physical design and layout at stations.

Analysis of Complex Stations

In many instances, transit stations, particularly those which serve as intermodal transfer facilities linking several lines or modes are complex structures. Numerous entrances, platforms and ancillary facilities create a myriad of possible paths for pedestrians through the station. The larger and more complex the design, the more useful are analytical tools to aid the designer. Typically, the designer has little information on how a particular design will function, and must appeal to experience and intuition as the basis for design decisions. In addition, the difficulties imposed by dealing with a large number of design elements reduces the designer's ability to formulate a wide variety of alternatives solutions. Computer models can be used to provide the designer with information on the performance of a complex design, and can help in screening initial schemes, which gives the designer the opportunity to develop more alternatives.

Emergency Evacuation

An important aspect of station performance is the requirement to evacuate passengers safely and in a minimum amount of time in the event of an emergency. Although various fire codes exist to insure that designs have adequate evacuation capacity, these codes are often performance standards which cannot be tested and validated empirically. Simulation models offer the ability to test the evacuation capacity of a proposed station design under a variety of scenarios.

Sizing Stations and Components

In many cases, devices such as turnstiles and escalators produce queues during periods of maximum use, and tradeoffs are possible in the number of devices versus the amount of queue area provided. Simulation models could aid in determining optimal numbers of devices and amount of queue space, subject to cost, capacity and performance constraints (Lutin and Kornhauser, 1977).

Operating Strategies

Over the life-span of a transit terminal, changes in operating strategies on the system or within the terminal may frequently occur. Increases in train frequency, disruption of terminal operations due to maintenance or rehabilitation, and changes in fare collection procedures can all affect the capacity and performance of stations. To determine the impact of such changes, simulation models could be used.

Sensitivity Testing of Peak Loading

Transit stations may be designed to accommodate an average peak design load. However, peaking characteristics very widely, and short-term loads beyond the design peak may be encountered frequently and can cause severe congestion problems. Simulation models can aid designers in anticipating the ability of a station to accommodate short-term peaking beyond design levels.

Construction Cost Evaluation

Construction costs for transit stations, particularly subway stations, have reached extensively high levels-over one thousand dollars per linear inch in some recent systems. Components such as escalators and fare collection devices are also high capital cost items and have high maintenance and operating costs, as well. Simulation models can evaluate changes in capacity and performance resulting from reductions in area and number of devices. They can help designers in estimating the minimum space requirements needed for a given facility and reduce overdesign resulting from uncertainty about minimum space requirements.

Validation or Confirmation of Codes and Standards

In most terminal design projects, a variety of codes and standards are found to apply. In some cases, performance standards may exist. For example, a performance standard may require that fire evacuation of a station must take place in less than two minutes, or that platforms must be cleared within the operating headway interval of trains. By simulating performance of a transit station with a computer model, the designer can not only determine compliance of the station with the codes, but can evaluate effectiveness of the code and its applicability to design, as well.

BARRIERS OF THE USE OF COMPUTER MODELS

Workshop participants developed a list of six problem areas and barriers which have prevented more widespread use of computer models in station design. Among these barriers are negative attitudes among management and policy-makers, excessive time and cost requirements, difficulties in use and understanding, hardware constraints, software availability and lack of a coordinated research and development program.

Negative Management Attitudes

Among many transit program managers, there is a reluctance to use computerized tools. Often, managers have had bad prior experiences with computer models which developed cost overruns, took excessive time to use, or which produced erroneous, inaccurate or irrelevant results. Many managers mistrust such models and do not see their value.

Time and Cost

Computer models are often expensive to use. It takes a considerable amount of staff time to learn how to use them, and it is difficult to train people because of inadeqate instructional materials. Also, there is a great deal of uncertainty about the cost and time needed to obtain results. Initial investments in learning time and in acquiring appropriate computer resources are high and may not be warranted for single applications.

Output Form and Ease of Use

In many instances, computer models may require elaborate numerical transformations of designs to coded machine-readable format. In creating a numerical model, the design loses some of its information content and the designer may have difficulty in comprehending the coded model. Even more difficult is the interpretation of numerical output for what is essentially a pictorial design. Then, too, the models may require more information than the designer can supply at a particular stage in design development.

Hardware Constraints

In most cases, a particular model is designed to run on only one line of computers or require a specific size computer. For example, the USS station simulation model was designed for use on IBM 360/370 series machines. To utilize this model on other computer lines, such as Digital, Burroughs or

Honeywell will require extensive adaptation work. In some cases, modifications to computer operating systems can render program inoperable on the original machines on which they were designed to run if the models were developed for use prior to the modification. Programs which produce graphic output are often designed for use with specific display terminals and can be used on others only with extensive modification.

Availability of Programs

In general, models for use in station design have not been widely disseminated. Most have been used in a limited number of applications and do not have good documentation. With most models, it takes a considerable period of use to shake out all the problems and develop a common base of experience to share among users. With a limited number of potential applications, this common base of experience will be difficult to establish in station design.

Lack of Research and Development Coordination

Each of the four computer models mentioned earlier had its origin within a different agency or office within UMTA. One model was developed by the FAA. Although the programs were all sponsored by DOT, there seemed to be little effort to coordinate efforts in developing methods for terminal design. Consequently, individuals working on terminal design problems for a given transportation mode have little opportunity to find out about similar problems and tools developed by other modal agencies.

RECOMMENDATIONS

Based on the foregoing review of the state-of-the-art in computer-aided station design tools, and the discussion of barriers to implementation, a series of recommendations has been developed as follows:

Co-ordination of DOT research and development efforts - to aid in communicating needs and sharing design methodology and emerging techniques, it is recommended that DOT establish a coordinated program for research and development in the area of transportation terminal facilities for all modes. This program should establish coordination among the various DOT modal administrations and offices across a broad range of concerns, including design methods, standards, funding and joint development. Within this recommended program, a coordinated program of research and development for computer-aided design tools would be one element.

Need for graphic output - In the development of computer models for station design, a high priority should be placed on the use of graphics for output and data input, as well. One of the first concerns for existing models should be the incorporation of graphic output routines and routines to make the models more user-oriented. Improvements in data input formats and response time are especially important. The models must be made easier to use and to understand.

Case studies in model use - It is recommended that several case studies in model application be performed to determine the cost-effectiveness of the models in practice. Information is needed on how to budget for model use in the design process, and to demonstrate the cost-savings achievable through model use.

Case studies in model validation - For those models reported on above, which dealt with passengers movement, only limited validation has been performed. There is a need to conduct specific empirical studies of pedestrian movement in actual stations and to use this information to calibrate and validate station performance models.

Training and documentation - For existing models, efforts should be made to improve model documentation and provide better instructional materials, including user guides and training sessions.

CONCLUSIONS

The workshop participants believed, in general, that the outlook for increased use of computer-aided station design tools was bright. Most of the participants were drawn to the workshop either because they had design problems which they felt could benefit from computer-aided analysis or because they had experience in other computer applications and were interested in learning how computers could be applied to the specific area of station design. The common ground for confidence in the future of these techniques was cost. As design and construction costs for transit station have steadily risen, so too have computer costs steadily declined. With the growing use of micro-computers, more and more designers will have computers available. The potential for using cheap and powerful computer-aided design methods will inevitably lead to greater use. The recommendation set forth by this workshop should help in guiding the direction of future developments in computer-aided station design and evaluation models.

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THE NATIONAL CONFERENCE ON THE PLANNING AND DEVELOPMENT OF PUBLIC TRANSPORTATION TERMINALS

PROGRAM

Sunday, September 21

6:00 p.m.	Registration

Monday, September 22

8:00 a.m.	Registration
9:00 a.m.	Session Chairman, Lester A. Hoel Welcome to Conference, Sherwood C. Chu Introductory Remarks, Lester A. Hoel Overview Papers: What is a Station? Wilfred Sergeant Passengers: the Human Element, John J. Fruin Station Operations and Maintenance, R. S. Korach Access and Traffic, Walter H. Kraft
12:15 p.m.	Luncheon (Keynote Speaker, Lillian C. Liburdi)
2:00 p.m.	Session Chairman: John J. Fruin Recent Experiences in Station Design: MARTA, Richard Stanger WMATA, Albert J. Roohr BART, W. R. McCutchen The Design of Intermodal Stations; The Northeast Corridor Project, Hanan A. Kivett
6:00 p.m.	Reception

Tuesday, September 23

8:30 a.m.	Session Chairman: Norman G. Paulhus, Jr. Recent Experiences with Station Renovation; New York, Chicago, Boston, Robert A. Olmsted The Port Authority Bus Terminal, Sheldon Wander Canadian Intercity Terminals, Peter Strobach European Perspectives, John Braaksma
10:30 a.m.	Coffee Break
11:00 a.m.	Overview of the Design Methodology, Michael J. Demetsky
12:00 Noon	Lunch
1:30 p.m.	Workshop Sessions
4:45 p.m.	Metro Tour

Wednesday, September 24

8:00 a.m.	Workshop Sessions
10:00 a.m.	Coffee Break
10:30 a.m.	Summary of Workshop Results and Recap of Conference
Afternoon	Meeting of TRB Committee A1E03

WORKSHOP TOPICS

1. Critique of Design Methodology
2. Intermodal Terminal Planning, Design and Operations
3. Passenger Processing and Information Systems
4. Station Access and Traffic
5. Maintenance and Operations
6. Land Use, Joint Development and Station Impacts
7. Design of the Disabled, Elderly and Handicapped
8. Transit Station Security
9. Computer Methods and Transit Station Simulation

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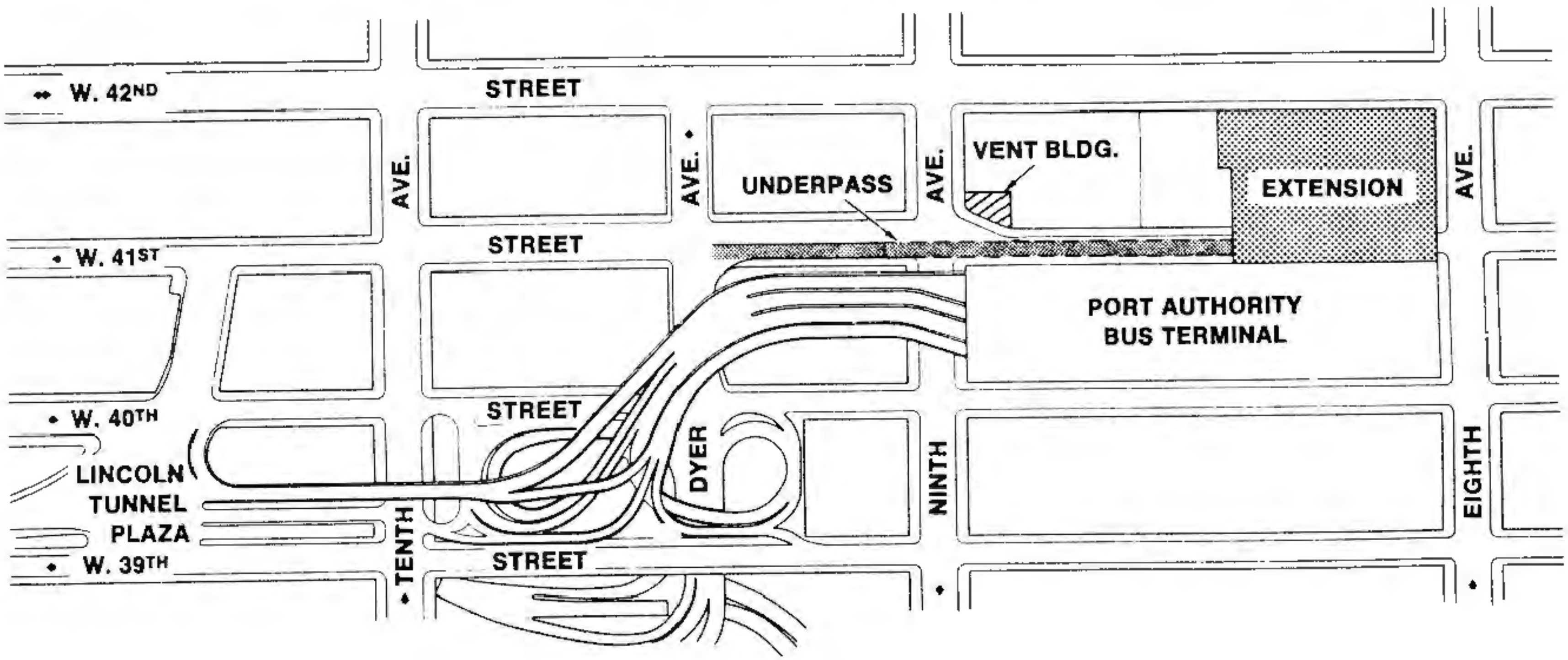

FIGURE 1