Report No. UMTA-MA-06-0048-80-7

SYSTEMS OPERATION STUDIES FOR AUTOMATED GUIDEWAY TRANSIT SYSTEMS

REPRESENTATIVE APPLICATION AREAS FOR AGT

GM Transportation Systems Division
General Motors Technical Center
Warren, MI 48090

NOVEMBER 1980
FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
URBAN MASS TRANSPORTATION ADMINISTRATION
OFFICE OF TECHNOLOGY DEVELOPMENT AND DEPLOYMENT
NEW SYSTEMS AND AUTOMATION DIVISION
WASHINGTON, D.C. 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UMTA-MA-06-0048-80-7	[illegible]	

4. Title and Subtitle	5. Report Date
Systems Operation Studies for Automated Guideway Transit Systems - REPRESENTATIVE APPLICATION AREAS FOR AGT	NOVEMBER 1980
	6. Performing Organization Code: DTS - 723
7. Author(s): R. Cowan, L. Bonderson, and F. Alberts, GM TSD	8. Performing Organization Report No.: DOT-TSC-UMTA-80-30
9. Performing Organization Name and Address: GM Transportation Systems Division* General Motors Corporation GM Technical Center Warren, Michigan 48090	10. Work Unit No. (TRAIS): UM 033/R0726
	11. Contract or Grant No.: DOT-TSC-1220
12. Sponsoring Agency Name and Address: U.S. Department of Transportation Urban Mass Transportation Administration Office of Technology Development and Deployment Office of New Systems and Automation Washington, D.C. 20590	13. Type of Report and Period Covered: FINAL REPORT NOVEMBER 1978 - MAY 1980
	14. Sponsoring Agency Code: UTD - 40

15. Supplementary Notes

*UNDER CONTRACT TO: U.S. Department of Transportation
Research and Special Programs Administration
Transportation Systems Center
Cambridge, Massachusetts 02142

16. Abstract

Results of the definition of representative Automated Guideway Transit (AGT) system deployments for analysis in the AGT Systems Operation Studies program are presented. Each deployment consists of a demand type, an AGT system type, and a guideway network type. Seven demand types (including three metropolitan areas, two CBD's, and two activity centers) are defined, and a representative locale of each type is chosen. Station-to-station demands generated after the process for generating zone-to-zone demands for the metropolitan area applications are presented. The following seven guideway network types are defined: shuttle, loop, one-way loop, two-way loop, multiple loop, partially connected grid, and fully connected grid. Ten AGT systems have been defined in another phase of the AGT-SOS program. From among the possible combinations of demands, systems, and networks, 19 representative deployments are selected, and a network is presented for each. The results of network flow analyses, in which the compatibility between the network and the station-to-station demand is evaluated, are presented for the representative SLT deployments.

17. Key Words	18. Distribution Statement
Demand Models, Networks	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	224	

Form DOT F 1700.7 (8-72)   Reproduction of completed page authorized

PREFACE

In order to examine specific Automated Guideway Transit (AGT) developments and concepts — and to build a better knowledge base for future decision-making — the Urban Mass Transportation Administration (UMTA) has undertaken a new program of studies and technology investigations called the UMTA Automated Guideway Transit Technology (AGTT) program. This program is being administered through the office of New Systems and Automation at UMTA whose director is Charles Broxmeyer. Duncan MacKinnon is the Program Manager for the AGTT program. The objectives of one segment of the AGTT program, the Systems Operation Studies (SOS), are to develop models for the analysis of systems operations, to evaluate performance and cost, and to establish guidelines for the design and operation of AGT systems. A team headed by GM Transportation Systems Division (GM TSD) has been awarded a contract by the Transportation Systems Center to pursue these objectives.

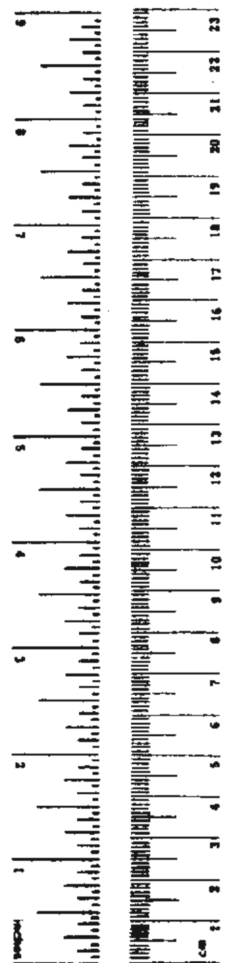
The purpose of the Application Area Definition task is to define the travel demands and guideway networks for a set of representative AGT system deployments. These demands and networks, when combined with detailed descriptions of the systems and their operating characteristics, define the representative systems to be modeled and analyzed in other tasks within the SOS program.

The report was co-authored by Robert W. Cawan, Loren S. Bonderson and Femia S. A. Alberts, all of GM TSD, who were responsible for the demand modeling, deployment definitions, and network flow analyses, respectively. Revisions were made by Gary C. Sulla. Writing and final preparation of this report were the responsibility of Ronald A. Lee, also of GM TSD.

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



Approximate Conversions from Metric Measures

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

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF ACRONYMS

ACC	Access Link
AGT	Automated Guideway Transit
ART	Automated Rail Transit
CBD	Central Business District
CC	Central City
CCR	Central City Ring
DMT	Dual Mode Transit
DPM	Downtown People Mover
EGR	Egress Link
FG	Fully Connected Grid
FSM	Feeder System Model
GM TSD	General Motors Transportation Systems Division
GRT	Group Rapid Transit
GT	Grid Transit
IGRT	Intermediate Vehicle Group Rapid Transit
L	Loop
LIN	Line-haul Link
L1	One-Way Loop
L2	Two-Way Loop
LGRT	Large Vehicle Group Rapid Transit
ML	Multiple Loop
O-D	Origin-Destination
PG	Partially Connected Grid
PRT	Personal Rapid Transit
R & SU	Rural and Scattered Urban
S	Shuttle
SEMTA	Southeastern Michigan Transportation Authority
SGRT	Small Vehicle Group Rapid Transit
SLT	Shuttle Loop Transit
SMSA	Standard Metropolitan Statistical Area
SOS	System Operations Studies
UA	Urbanized Area
UR	Urbanized Ring
UTPS	UMTA Transportation Planning System
XFR	Transfer Link

1.0 INTRODUCTION

This final report describes the formulation of representative travel demands and the definition of specific system network configurations to serve the travel demands.

1.1 OBJECTIVE

The purpose of the Application Area Definition task is to specify a set of deployment scenarios in which various AGT systems may be modeled and evaluated, where the specification of a deployment scenario includes:

1. A travel demand model for the area in which the system deployment is being analyzed

2. The selection of an AGT system class

3. A guideway network configuration suitable for the travel demand, system class, and general features of the application area.

1.2 SCOPE

The demand models developed as a result of this task are representative of general travel demand types; as such, it is not intended that they be calibrated to accurately replicate the travel patterns of any specific locales in any particular years -- even though these models are based upon data pertaining to specific areas. Furthermore, mode choice modeling is not included in the demand model formulation process except when appropriate transit demand data are already available. The demand model development task, then, includes:

1. The definition of travel demand types to be modeled

2. The acquisition and processing of data sufficient to construct the specified demand models

3. The implementation of the models in such a way that they are compatible with the needs of other analysis tasks in the AGT-SOS project.

The network configurations developed as a result of this task must be specifically tailored to the travel demand, system class, and general features of the application area. However, they must also be representative of more general network classes so that the sensitivity of system performance to network type may be clearly seen. To accomplish this, the network configuration task includes:

1. The definition of general network types based upon operational characteristics

2. The selection of specific combinations of AGT system types, general network types, and demand environments to be analyzed in the System Operations Studies project

3. The detailed specification of network configuration including station locations, merge-diverge locations, and guideway routing as a result of network flow analysis in which the compatibility of system network and demand is evaluated.

2.0 SUMMARY

This section summarizes the results of the Application Area Definition tasks performed as part of the System Operations Studies project. A top-down approach was used, and, as such, the demand models (Chapter 3.0) and network configurations (Chapter 4.0) were developed in parallel. Thus, Chapters 3.0 and 4.0 contain many cross references. Figure 2-1 presents an overview of the application area definition process as it applies to the organization of this report.

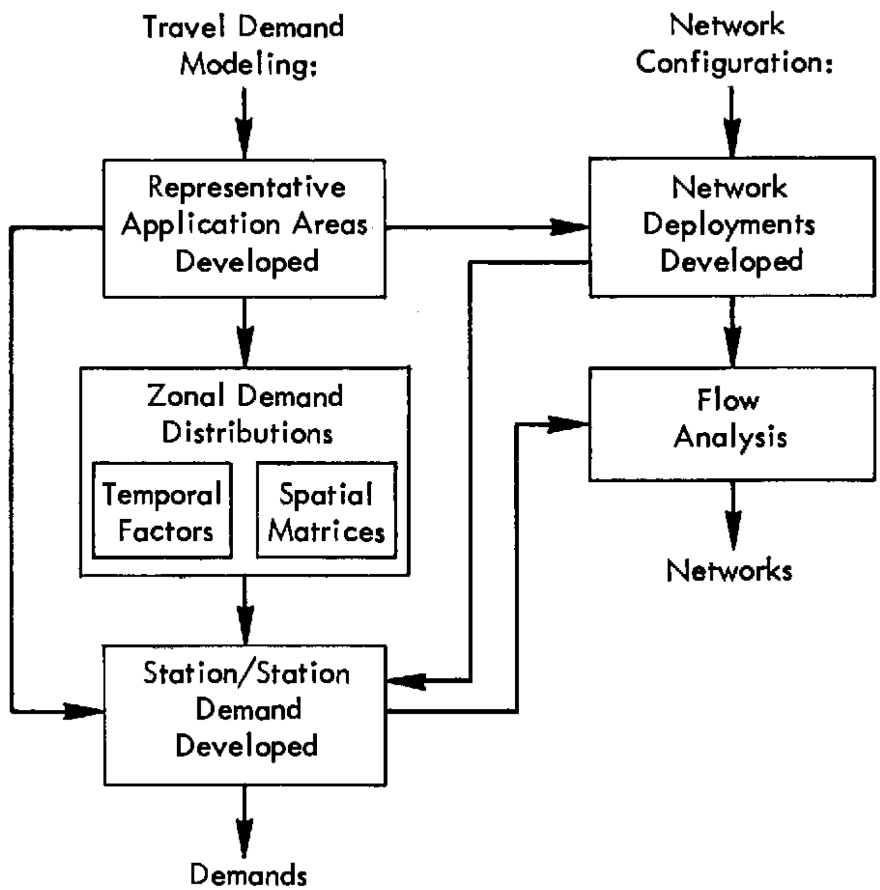


FIGURE 2-1. APPLICATION AREA DEVELOPMENT OVERVIEW

2.1 TRAVEL DEMAND MODELS

A study of travel demand characteristics and consideration of potential and existing AGT system deployments led to the definition of seven demand model types for the AGT-SOS project. In order to obtain realistic, detailed demand models, each separate model is based upon available travel demand data for a specific locale having characteristics similar to those desired of the model. The seven demand model types--each followed by the name of the representative area upon which the model is based--are listed below:

1. Metropolitan area with a relatively low CBD orientation of work trips but with high reverse commutation (travel from the Central City to outside the Central City)--Detroit, Michigan

2. Metropolitan area with high CBD orientation, but with low reverse commutation--Washington, D.C.

3. Metropolitan area with both high CBD orientation and high reverse commutation--Cincinnati, Ohio

4. CBD circulation with a relatively high projected Downtown People Mover demand--Detroit, Michigan

5. CBD Line-Haul with relatively low projected DPM demand--Houston, Texas

6. Activity Center Line-Haul--West Virginia University (Morgantown, West Virginia)

7. Activity Center Circulation--Dallas/Fort Worth Regional Airport.

Each demand model consists of a series of spatial trip matrices (one for each time interval of interest) stored in UTPS-compatible "UMTA compressed" format. Metropolitan area demand models were developed from home-interview survey data supplied by agencies in the three chosen metropolitan areas. CBD demand models are based upon data generated in the course of DPM planning in the two selected cities. The activity center line-haul demand model relies upon a combination of projected ridership data and operating data. Finally, the activity center circulation demand model was developed by estimating the distribution of trips represented by station turnstile counts.

For the activity center applications, station-to-station demand matrices were developed directly from the reference data. The process for generating zone-to-zone demand matrices for the metropolitan area applications has been developed, and the Feeder System Model (FSM) was used to generate station-to-station demand matrices from the reference zone-to-zone demand for all deployments.

2.2 NETWORK CONFIGURATION

The following general network types represent the range of significant network influences on system performance: shuttle, loop, one-way loop, two-way loop, multiple loop, fully connected grid, and partially connected grid.

A total of 19 representative system deployments have been initially selected for analysis in the AGT-SOS program. Each deployment consists of a system type, a general network type, and the demand environment. These deployments include 11 SLT deployments, two ART deployments, four GRT deployments, and two PRT deployments. These deployments satisfy all of the guidelines identified for deployment selection. Only a subset of these deployments was analyzed in detail during the program.

The specific network configurations for each deployment are presented in Section 4.0. Station locations are primarily based upon the locations used in similar systems already built or proposed. Specific measures such as guideway length, station type and number, and junction number are included in the network figures of Section 4.0.

The results of network flow analysis for the 11 SLT deployments are presented. The purpose of the network flow analysis is to evaluate the compatibility of each network/system/demand combination in terms of the capability of the system/network combination to satisfy specific service goals when deployed in the selected demand environment. The objective of the analysis is to ensure that the system deployments selected for detailed analysis during the System Operations Studies are reasonable ones.

3.0 DEMAND MODELING

3.1 TRAVEL DEMAND CHARACTERISTICS

Travel demands may be generally described in terms of several characteristics, regardless of the particular situation being considered. "Demand," in this case, is the total movement of persons within a specified analysis area, possibly including trips having only one end within the analysis area.

A significant travel demand characteristic is the size of the analysis area. For the purposes of the AGT System Operations Studies, analysis area sizes will vary from major portions of entire metropolitan areas to localized parts of small-area activity centers; that is, from hundreds of square miles to less than one square mile.

Aggregate trip-making volume is another important characteristic of a demand analysis area. The average daily number of trips in a demand analysis area, for example, is a measure of this type. Disaggregation of demand magnitude by specifying magnitudes for each of several smaller time intervals results in a third demand characteristic: temporal distribution. Disaggregation by subdividing the overall demand analysis area into smaller units and then specifying demand magnitudes between pairs of areal units, and possibly within units, allows a demand analysis area to be described in terms of spatial distribution--another major demand characteristic.

Travel demands also have several less significant characteristics when considered in the context of AGT-SOS analyses rather than conventional transportation planning. One such characteristic is the distribution of travel group sizes (that is, the number of persons traveling singly, in groups of two, in groups of three, and so on). Many additional characteristics, such as demographic and socioeconomic measures, are related to the traveler's decision to make a trip and to the choice of a travel mode; detailed analyses of those decision processes are beyond the scope of the AGT-SOS project and are not included in the formulation of travel demand models used in this project.

An examination of potential AGT system application areas, along with the characteristics discussed above, suggests a top-level classification of demands into two groups: metropolitan areas (or substantial portions of metropolitan areas) and activity centers (small areas of high travel intensity). The difference in demand analysis area size between the two groups is clear. The travel volume difference between the two groups is also great. Metropolitan areas are characterized by large numbers of trips occurring at low densities throughout large areas. Conversely, activity centers have low to moderate numbers of trips with high densities in small areas. Temporal demand distributions are expected to be somewhat uniform within the group of metropolitan areas, while the temporal distributions of activity center demands are likely to differ from both those of metropolitan area demands and those of other activity center demands. Spatial demand distributions vary greatly among demand analysis areas within each group and between the two major groups.

Since any comparison of a demand area chosen from one group with an area chosen from the other group is expected to indicate great differences in all four of the major demand characteristics, it can be judged that the basis for establishing the two groups is sound. The variations in one or more characteristics among members within each group, however, suggest that each group may be readily divided into more homogeneous subclasses.

3.2 DEMAND MODELING APPROACH

The primary function of the AGT-SOS demand models is to provide a range of travel demand environments in which a variety of AGT system deployments may be analyzed. It is the goal of each demand model to represent travel demand in such a way that realistic passenger loadings are input to the AGT system analysis process. Particularly, it is important to avoid the use of a demand model which might bias AGT system analysis results due to unrealistic patterns of trip-making. An artificially symmetric spatial distribution of travel demand, for example, might produce network trip loadings which are more easily accomodated than other loading patterns, possibly altering conclusions with regard to system capacity. Similarly, the use of demand models having unusual proportions of long and short trips, unrealistic durations or magnitudes of demand volume peaks, or other anomalies could also potentially generate misleading analysis results.

At least two alternative demand modeling approaches may be considered: abstract models of composite demand analysis areas may be formulated, or data from individual areas may be used directly with little modification.

An example of the first approach is the development and use of "Plastictown," as reported by Benjamin.[1] Plastictown is a hypothetical 1990 city which was synthesized from composite characteristics of the 30 largest urbanized areas (based upon 1990 projected populations and excluding New York, Chicago, and Los Angeles). The abstract city is circular in shape and is divided into three rings; the outer ring contains six "fingers" representing travel corridors having higher densities than the outer ring as a whole. Plastictown travel demand is defined in terms of nine large zones (four in the outer ring, four in the middle ring, and the CBD), with estimates of peak-period and daily zone interchange trip volumes. This type of demand model is quite appropriate when used for its intended purpose--macroscopic comparison of distinct transportation alternatives. It is not clear, however, that this type of demand model is adequate to produce meaningful results when used in conjunction with a detailed system simulation.

The second demand modeling approach seems to be more suitable for the types of analyses planned in the AGT-SOS project. This approach to the formulation of a particular demand model involves selecting an actual demand situation with characteristics similar to those desired, and then obtaining, modifying, and using data which describe that demand. There are at least two distinct advantages associated with this approach. First, the analyst is assured of having a model capable of representing a minimum of one "real" travel demand environment. A composite abstract demand model is unlikely to resemble any one of its constituent demands in any but the most superficial ways. Second, the averaging process used in the formulation of a composite demand model must, as a practical necessity, operate upon data sets which have been individually aggregated to a great extent. Therefore, the detailed characteristics that make each demand situation unique are obscured initially and then lost entirely during composite demand model synthesis. While it may be feasible to disaggregate a composite demand model in order to realize the necessary level of detail, the process would be cumbersome. The use of a demand model which retains the detailed information concerning an individual travel demand environment avoids the difficulties associated with aggregation and disaggregation.

For the above reasons, it was decided that the travel demand models employed in the AGT-SOS analyses would each be based upon data pertaining to a single locale. The freedom remains, of course, to choose each locale on the basis of its aggregate demand characteristics and to modify the resulting demand model as necessary to achieve other characteristics. The types of data utilized in the various demand models can be expected to differ considerably, depending upon the data source (origin-destination surveys, cordon counts, pedestrian counts, turnstile counts, analytical forecasts, or other sources) and the level of detail available (the degree of spatial and temporal aggregation relative to complete enumeration of all trips).

3.3 SELECTION OF MODEL TYPES

The analysis of a wide range of AGT system types and networks will require a variety of travel demand models. It is clear that more than one demand model for each of the two major demand classes (metropolitan areas and activity centers) will be needed. The combination of system types, network types, and demand types chosen for analysis, however, must be limited to a manageable number. These considerations indicate the need for subclassifying demands as a guide in selecting a small number of demand model types.

Within the general class of "metropolitan areas" it is possible to define many subclasses on the basis of the major demand characteristics discussed in Section 3.1 of this report. These characteristics are analysis area size, demand magnitude, temporal distribution, and spatial distribution. In order to minimize the number of basic demand models (those based upon data from separate locales), the parameters distinguishing subclasses should be restricted to those which are not readily varied after model formulation. That is, a separate demand model should not be created if similar results could be obtained by modifying an existing model. The size of a demand analysis area can be varied by simply manipulating the x-y coordinates of the area's zone centroids.

Demand magnitude variations can be accomplished by applying a constant adjustment factor to all of a model's magnitude components. Similarly, temporal distributions can be modified by applying separate adjustment factors to all magnitude components associated with corresponding time intervals. Spatial distributions are, in some respects, more difficult to vary than other demand characteristics. A city with a strong CBD orientation, for example, may have different circumferential travel patterns than is typical of less CBD-oriented cities; merely increasing the relative CBD trip attraction of a non-CBD-oriented demand model does not ensure that the resulting model resembles that of a CBD-oriented city. Therefore, spatial distribution is perhaps the most suitable characteristic for classifying metropolitan area demands.

Since the travel patterns in a metropolitan area are strongly influenced by the presence of one or more Central Business Districts, a measure of relative CBD trip attraction appears to be useful for demand classification purposes. A convenient way of expressing

CBD orientation is to calculate the percentage of all daily work trips in an urbanized area which terminate in the CBD. Another potentially useful spatial distribution measure is the relative amount of "reverse commutation;" that is, the number of persons residing in the city and working in the suburbs. This measure can be related to readily available data by computing the percentage of all daily work trips in the urbanized area represented by trips of central city residents to places of employment in the urbanized ring (the portion of the urbanized area outside the central city).

If high and low values are considered for each of the two spatial distribution measures, a total of four basic demand models are defined: low CBD orientation and low reverse commutation; low CBD orientation and high reverse commutation; high CBD orientation and low reverse commutation; and high CBD orientation and high reverse commutation. The first type, in which both measures are low, suggests a metropolitan area potentially more difficult to serve with capital-intensive transit systems than the other three types. This is due to a lack of both a high proportion of CBD trips and a strong reverse travel demand to utilize excess system capacity in that direction. Therefore, it is felt that the first demand model type can be excluded and only the other three types implemented.

Activity center demands may also be subclassified on the basis of four major characteristics. It seems more convenient, however, to subclassify activity center demands according to the nature of the associated activity. The following activity center types are among those for which AGT systems may be appropriate: Central Business District, university, airport, medical center (possibly combined with a university), zoo, shopping center, recreation area, business or industrial complex, stadium, and exposition.

One division of areas is into either CBD or other activity centers, with either line-haul or circulation systems. The analysis of CBD deployments is particularly important due to the number of cities planning Downtown People Mover systems, the potential complexity of CBD networks, and the fact that DPM riders will be less "captive" than those of most other activity centers (that is, persons considering trips within a CBD are free to choose other modes or possibly cancel their trips if they are dissatisfied with AGT service, while travelers in other activity centers may have no other practical alternative). The choice of two CBD types with different demand magnitudes enables a more complete analysis of CBD systems, while a single demand for each of the other two activity center types should be sufficient. The total of four activity center demand model types provides an interesting variety of demand magnitudes, spatial distributions, and temporal distributions for which AGT systems can be evaluated.

3.4 MODEL DATA SOURCES

Following the selection of basic demand model types, it is necessary to choose sources for the travel demand data which will be incorporated into the models. The data used in each demand model, of course, should have characteristics similar to those desired in the final model. For metropolitan area demand models, data specifying travel demands in representative metropolitan areas are needed. Similarly, activity center demand models are to be based upon data which define travel demands in representative activity centers.

Three metropolitan area demand model types have been selected for implementation:

- Low CBD orientation and high reverse commutation
- High CBD orientation and low reverse commutation
- High CBD orientation and high reverse commutation.

It was decided to choose a metropolitan area of each type from among the largest 35 Standard Metropolitan Statistical Areas (SMSAs) in the United States. The Urban Data Book[2] lists populations, land areas, and journey-to-work data (among other information) for each SMSA. Table 3-1 is a compilation of SMSA land areas, with each SMSA subdivided into smaller components. The following abbreviations are used in that and other tables:

- SMSA--Standard Metropolitan Statistical Area
- R&SU-- Rural and Scattered Urban
- UA--Urbanized Area
- UR--Urbanized Ring
- CC--Central City
- CCR--Central City Ring
- CBD--Central Business District.

As suggested in Table 3-1, the SMSA is divided into two parts, one of which is the Urbanized Area. The Urbanized Area is divided into the Central City and the remaining area, the Urbanized Ring. Finally, the Central City consists of the CBD and the Central City Ring. Table 3-2 is a similar listing of SMSA populations, based upon 1970 Census data. Next, Table 3-3 indicates work trip volumes between selected portions of each SMSA. Above each column are abbreviations for the area of residence, followed by the area of employment, for the work trips listed below. As noted on all of the preceding tables, the three largest SMSAs (Chicago, Los Angeles, and New York) are eliminated from the totals and averages presented.

Table 3-4 summarizes four important characteristics of each Urbanized Area: land area, population, CBD orientation, and reverse commutation. The 35 Urbanized Areas are ranked in descending order for each characteristic. Since CBD orientation and reverse commutation (both as defined in Section 3.3) are the major factors selected to distinguish demand model types, a list of candidate Urbanized Areas for each of the model types has been prepared.

The first list includes UAs with "low" CBD orientation and "high" reverse commutation; "high" (for this purpose) refers to a characteristic measure above the mean of all 35 UAs, while "low" refers to a value below the mean. Means of 10.06 percent for CBD orientation and 8.49 percent for reverse commutation place the first 16 UAs (in both CBD orientation and reverse commutation) in "high" categories. The following UAs satisfy the simultaneous requirements of low CBD orientation and high reverse commutation:

- San Jose
- Milwaukee
- Miami
- Los Angeles
- Detroit.

(cont. page 15)

TABLE 3-1. LAND AREAS OF 35 LARGEST SMSAs

SMSA NAME	LAND AREA (SQ. MILES)						
	TOTAL SMSA	SMSA		URBANIZED AREA		CENTRAL CITY	
		R & SU	UA	UR	CC	CCR	CBD
ATLANTA	1,727	1,292	435	303	132	130.770	1.230
BALTIMORE	2,259	1,949	310	232	78	77.473	0.527
BOSTON	987	343	644	598	46	45.000	1.000
BUFFALO	1,591	1,377	214	173	41	40.223	0.777
CHICAGO*	3,720	2,443	1,277	1,054	223	221.450	1.550
CINCINNATI	2,150	1,815	335	257	78	77.213	0.787
CLEVELAND	1,519	873	646	570	76	74.942	1.058
COLUMBUS	1,494	1,259	235	100.4	134.6	133.664	0.936
DALLAS - FT. WORTH	6,171	5,101	1,070	599	471	468.900	2.100
DAYTON	1,708	1,484	224	185.7	38.3	37.500	0.800
DENVER	3,660	3,447	213	118	95	94.094	0.906
DETROIT	1,952	1,080	872	734	138	136.880	1.120
HOUSTON	6,286	5,750	536	139	397	392.510	4.490
INDIANAPOLIS	3,080	2,699	381	29	352	349.700	2.300
KANSAS CITY	2,767	2,274	493	254	239	238.234	0.766
LOS ANGELES*	4,069	2,497	1,572	1,060	512	509.240	2.760
LOUISVILLE	908	698	210	150	60	57.650	2.350
MIAMI	2,042	1,783	259	225	34	33.605	0.395
MILWAUKEE	1,456	999	457	362	95	94.003	0.997
MINNEAPOLIS - ST. PAUL	2,107	1,386	721	614	107	105.470	1.530
NEW ORLEANS	1,975	1,791	184	98	86	84.800	1.200
NEW YORK*	2,136	--	2,425	2,125	300	295.977	4.023
PHILADELPHIA	3,553	2,801	752	624	128	125.460	2.540
PHOENIX	9,238	8,850	388	140	248	246.967	1.033
PITTSBURGH	3,049	2,453	596	541	55	54.450	0.550
PORTLAND	3,650	3,383	267	178	89	88.600	0.400
PROVIDENCE	679	435	244	182	62	61.510	0.490
ST. LOUIS	4,118	3,657	461	400	61	60.645	0.355
SAN ANTONIO	1,960	1,737	223	39	184	182.990	1.010
SAN DIEGO	4,262	3,881	381	168	213	212.675	0.325
SAN FRANCISCO - OAKL.	2,478	1,797	681	582	99	97.872	1.128
SAN JOSE	1,300	1,023	277	161	116	114.600	1.400
SEATTLE	4,229	3,816	413	300	113	112.487	0.513
TAMPA - ST. PETERSBURG	1,303	1,011	292	152	140	135.170	4.830
WASHINGTON	2,352	1,857	495	434	61	59.620	1.380
TOTAL	88,010	74,101	13,909	9,642	4,267	4,225.7	41.223
AVERAGE	2,750	2,316	435	301	133	132.1	1.288

*Excluded from Totals and Averages

TABLE 3-2. POPULATIONS OF 35 LARGEST SMSAs

SMSA NAME	POPULATION (1970)						
	TOTAL SMSA	SMSA		URBANIZED AREA		CENTRAL CITY	
		R & SU	UA	UR	CC	CCR	CBD
ATLANTA	1,390,000	217,222	1,172,778	675,778	497,000	494,571	2,429
BALTIMORE	2,071,000	491,219	1,579,781	673,781	906,000	903,431	2,569
BOSTON	2,754,000	101,425	2,652,575	2,011,575	641,000	637,300	3,700
BUFFALO	1,349,000	262,406	1,086,594	623,594	463,000	461,172	1,828
CHICAGO*	6,978,000	263,422	6,714,578	3,345,578	3,369,000	3,364,174	4,826
CINCINNATI	1,385,000	274,486	1,110,514	659,514	451,000	447,525	3,475
CLEVELAND	2,064,000	104,120	1,959,880	1,208,880	751,000	745,790	5,210
COLUMBUS	916,228	126,209	790,019	250,642	539,377	537,482	1,895
DALLAS - FT. WORTH	2,318,134	302,506	2,015,628	737,976	1,277,652	1,272,631	5,021
DAYTON	850,266	164,324	685,942	442,484	243,458	242,032	1,426
DENVER	1,230,000	182,689	1,047,311	532,311	515,000	511,880	3,120
DETROIT	4,204,000	233,416	3,970,584	2,457,584	1,513,000	1,506,572	6,428
HOUSTON	1,985,000	307,137	1,677,863	446,863	1,231,000	1,206,951	24,049
INDIANAPOLIS	1,111,000	290,741	820,259	77,259	743,000	733,298	9,702
KANSAS CITY	1,256,000	154,213	1,101,787	599,787	502,000	500,209	1,791
LOS ANGELES*	7,041,000	--	8,351,266	5,182,266	3,169,000	3,146,850	22,150
LOUISVILLE	826,553	87,157	739,396	377,943	361,453	348,292	13,161
MIAMI	1,268,000	48,339	1,219,661	884,661	335,000	331,726	3,274
MILWAUKEE	1,404,000	151,543	1,252,457	535,457	717,000	714,539	2,461
MINNEAPOLIS - ST. PAUL	1,814,000	109,577	1,704,423	960,423	744,000	738,125	5,875
NEW ORLEANS	1,046,000	84,272	961,728	369,728	592,000	586,611	5,389
NEW YORK*	11,571,883	--	16,206,841	8,310,841	7,896,000	7,705,092	190,908
PHILADELPHIA	4,822,000	800,934	4,021,066	2,071,066	1,950,000	1,906,535	43,465
PHOENIX	968,000	104,643	863,357	281,357	582,000	577,675	4,325
PITTSBURGH	2,401,000	554,958	1,846,042	1,326,042	520,000	517,056	2,944
PORTLAND	1,007,000	182,074	824,926	444,926	380,000	376,990	3,010
PROVIDENCE	914,000	118,689	795,311	455,311	340,000	338,440	1,560
ST. LOUIS	2,363,000	480,056	1,882,944	1,260,944	622,000	621,413	587
SAN ANTONIO	864,014	91,501	772,513	118,224	654,289	651,014	3,275
SAN DIEGO	1,358,000	159,677	1,198,323	504,323	694,000	690,382	3,618
SAN FRANCISCO - OAKL.	3,108,000	120,150	2,987,850	1,910,850	1,077,000	1,050,844	26,156
SAN JOSE	1,067,000	41,727	1,025,273	581,273	444,000	431,726	12,274
SEATTLE	1,425,000	186,893	1,238,107	654,107	584,000	579,951	4,049
TAMPA - ST. PETERSBURG	1,012,594	148,693	863,901	370,098	493,803	486,995	6,808
WASHINGTON	2,862,000	380,511	2,481,489	1,724,489	757,000	751,895	5,105
TOTAL	55,413,789	7,063,507	48,350,282	26,229,250	22,121,032	21,901,053	219,979
AVERAGE	1,731,681	220,735	1,510,946	819,664	691,282	684,408	6,874

*Excluded from Totals and Averages

TABLE 3-3. JOURNEY-TO-WORK DATA FOR 35 LARGEST SMSAs

SMSA NAME	DAILY WORK TRIPS WITHIN SMSA (THOUSANDS)											
	CC-CBD	CC-CCR	CC-UR	CC-UA	UR-CBD	UR-CCR	UR-UR	UR-UA	UA-CBD	UA-CCR	UA-UR	UA-UA
Atlanta	28	129	39	196	23	110	133	266	51	239	172	462
Baltimore	29	226	67	322	15	86	141	242	44	312	208	564
Boston	36	162	51	249	50	152	559	761	86	314	610	1010
Buffalo	21	98	38	157	15	55	147	217	36	153	185	374
Chicago *	160	1064	205	1429	81	277	916	1274	241	1341	1121	2703
Cincinnati	22	104	37	163	21	78	110	209	43	182	147	372
Cleveland	29	177	64	270	41	165	244	450	70	342	308	720
Columbus	29	138	38	205	12	57	42	111	41	195	80	316
Dallas-Ft. Worth	54	260	29	343	13	88	82	183	67	348	111	526
Dayton	11	60	12	83	11	55	69	135	22	115	81	218
Denver	28	147	27	202	13	75	108	196	41	222	135	398
Detroit	51	306	161	518	33	181	623	837	84	487	784	1355
Houston	84	372	34	490	17	74	51	142	101	446	85	632
Indianapolis	47	187	33	267	4	8	10	22	51	195	43	289
Kansas City	19	143	40	202	13	87	131	231	32	230	171	433
Los Angeles *	80	928	373	1381	51	445	1160	1656	131	1373	1533	3037
Louisville	26	79	25	130	16	54	70	140	42	133	95	270
Miami	10	72	57	139	12	94	217	323	22	166	274	462
Milwaukee	31	189	62	282	12	61	122	195	43	250	184	477
Minneapolis-St. Paul	52	196	57	305	35	128	207	370	87	324	264	675
New Orleans	50	126	22	198	15	35	72	122	65	161	94	320
New York *	750	2410	254	3414	100	470	1785	2355	850	2880	2039	5769
Philadelphia	79	565	74	718	37	144	540	721	116	709	614	1439
Phoenix	17	172	29	218	3	33	58	94	20	205	87	312
Pittsburgh	29	120	31	180	38	66	321	425	67	186	352	605
Portland	18	101	25	144	11	59	89	159	29	160	114	303
Providence	11	90	25	126	9	49	88	146	20	139	113	272
St. Louis	13	162	40	215	16	138	292	446	29	300	332	661
San Antonio	28	173	18	219	2	34	15	51	30	207	33	270
San Diego	16	220	37	273	4	63	116	183	20	283	153	456
San Francisco-Oakland	111	278	56	445	61	126	469	656	172	404	525	1101
San Jose	8	74	58	140	3	40	152	195	11	114	210	335
Seattle	25	181	28	234	11	96	117	224	36	277	145	458
Tampa-St. Petersburg	15	127	26	168	5	43	58	106	20	170	84	274
Washington	59	211	49	319	74	157	430	661	133	368	479	980
Col. Total	1086	5645	1389	8120	645	2691	5883	9219	1731	8336	7272	17339
Average	33.9	176.4	43.4	253.8	20.2	84.1	183.8	288.1	54.1	260.5	227.3	541.8

* Excluded from Totals and Averages

TABLE 3-4. RANKED DATA SUMMARY FOR 35 LARGEST SMSAs

Rank	Urbanized Area Size (Square Miles Land Area)		Urbanized Area Population (Thousands of Persons)		CBD Orientation (% of Urbanized Area Work Trips to CBD)		Reverse Commutation (% of Urbanized Area Work Trips Central City to Urbanized Ring)	
1	New York	2,425	New York	16,207	New Orleans	20.31	San Jose	17.31
2	Los Angeles	1,572	Los Angeles	8,351	Indianapolis	17.65	Milwaukee	13.00
3	Chicago	1,277	Chicago	6,715	Houston	15.98	Miami	12.34
4	Dallas - Ft. Worth	1,070	Philadelphia	4,021	San Francisco - Oakland	15.62	Los Angeles	12.28
5	Detroit	872	Detroit	3,971	Louisville	15.56	Columbus	12.03
6	Philadelphia	752	San Francisco - Oakland	2,988	New York	14.73	Detroit	11.88
7	Minneapolis - St. Paul	721	Boston	2,653	Washington	13.57	Baltimore	11.88
8	San Francisco - Oakland	681	Washington	2,481	Columbus	12.97	Indianapolis	11.42
9	Cleveland	646	Dallas - Ft. Worth	2,016	Minneapolis - St. Paul	12.89	Buffalo	10.16
10	Boston	644	Cleveland	1,960	Dallas - Ft. Worth	12.74	Cincinnati	9.95
11	Pittsburgh	596	St. Louis	1,883	Cincinnati	11.56	Tampa - St. Petersburg	9.49
12	Houston	536	Pittsburgh	1,846	San Antonio	11.11	Phoenix	9.29
13	Washington	495	Minneapolis - St. Paul	1,704	Pittsburgh	11.07	Louisville	9.26
14	Kansas City	493	Houston	1,678	Atlanta	11.04	Kansas City	9.24
15	St. Louis	461	Baltimore	1,580	Denver	10.30	Providence	9.19
16	Milwaukee	457	Milwaukee	1,252	Dayton	10.09	Cleveland	8.89
17	Atlanta	435	Seattle	1,238	Cleveland	9.72	Minneapolis - St. Paul	8.44
18	Seattle	413	Miami	1,220	Buffalo	9.63	Atlanta	8.44
19	Phoenix	388	San Diego	1,198	Portland	9.57	Portland	8.25
20	Indianapolis	381	Atlanta	1,173	Milwaukee	9.01	San Diego	8.11
21	San Diego	381	Cincinnati	1,111	Chicago	8.92	Chicago	7.58
22	Cincinnati	335	Kansas City	1,102	Boston	8.57	New Orleans	6.88
23	Baltimore	310	Buffalo	1,087	Philadelphia	8.06	Denver	6.78
24	Tampa - St. Petersburg	292	Denver	1,047	Seattle	7.86	San Antonio	6.67
25	San Jose	277	San Jose	1,025	Baltimore	7.80	Seattle	6.11
26	Portland	267	New Orleans	962	Kansas City	7.39	St. Louis	6.05
27	Miami	259	Tampa - St. Petersburg	864	Providence	7.35	Dallas - Ft. Worth	5.51
28	Providence	244	Phoenix	863	Tampa - St. Petersburg	7.30	Dayton	5.50
29	Columbus	235	Portland	825	Phoenix	6.41	Houston	5.38
30	Dayton	224	Indianapolis	820	Detroit	6.20	Philadelphia	5.14
31	San Antonio	223	Providence	795	Miami	4.76	Pittsburgh	5.12
32	Buffalo	214	Columbus	790	St. Louis	4.39	San Francisco - Oakland	5.09
33	Denver	213	San Antonio	773	San Diego	4.39	Boston	5.05
34	Louisville	210	Louisville	739	Los Angeles	4.31	Washington	5.00
35	New Orleans	184	Dayton	686	San Jose	3.28	New York	4.40

- Baltimore
- Tampa - St. Petersburg
- Phoenix
- Kansas City
- Providence
- Cleveland.

At this point, other considerations influence the selection of a single representative UA and two alternate UAs. Detroit is the preferred choice for this type of demand model. The Detroit CBD attracts a substantial number of work trips, even though CBD trips constitute a small percentage of all Urbanized Area work trips--providing a good demand environment for analyzing CBD-oriented AGT systems in the presence of strong reverse commutation. Furthermore, GM TSD has previously obtained and extensively used home interview survey data for the Detroit area; this will avoid the acquisition and familiarization problems which are associated with the use of a new data set of this size (approximately 300,000 records). Baltimore is the second choice for a demand model of this type, since it is lower in CBD demand, higher in CBD orientation, and slightly lower in reverse commutation, relative to Detroit. Milwaukee is a third alternative, less favored than Baltimore due to its higher CBD orientation and lower population density. San Jose and Miami can both be eliminated due to their small CBD attractions, while Tampa-St. Petersburg can be eliminated on the basis of its small CBD demand and because of the special nature of areas with multiple Central Cities. Phoenix, Kansas City, Providence, and Cleveland are low enough in reverse commutation that they need not be considered. The size of Los Angeles in terms of land area makes it less attractive computationally than other areas.

A second list of Urbanized Areas contains those with high CBD orientation and low reverse commutation. Candidates meeting those criteria are listed below:

- New Orleans
- Houston
- San Francisco-Oakland
- New York
- Washington
- Minneapolis-St. Paul
- Dallas-Fort Worth
- San Antonio
- Pittsburgh
- Denver
- Dayton.

Of the above UAs, Washington is preferred due to its high CBD orientation, very low reverse commutation, and moderately large size. Houston is a reasonable second choice, since it has a very high CBD orientation but is somewhat higher in reverse commutation and is low (relative to Washington) in CBD demand magnitude and population density. In addition, Houston has an unusually large CBD in terms of land area. This tends to make Houston less representative of this type of demand application than Washington D.C. Pittsburgh appears to be a suitable third choice due to its very low reverse commutation, moderately high CBD orientation, and medium size. New Orleans, San Antonio, and Denver can be eliminated on the basis of their small sizes and high reverse commutation; Dayton on the basis of size and low CBD orientation; New York due to its large size; and San Francisco-Oakland, Minneapolis-St. Paul, and Dallas-Fort Worth due to their dual Central Cities and CBDs.

The following cities are those with both high CBD orientation and high reverse commutation:

- Indianapolis
- Columbus
- Cincinnati
- Louisville.

For this demand model type, Cincinnati is the preferred representative area. This selection is based upon Cincinnati's relatively high population density, CBD attraction comparable to other areas, and GM TSD's possession of (and previous work with) home interview survey data for the Cincinnati area. Indianapolis is rated second due to its lower population density, while Columbus is third due to its low population and small size. Louisville, even smaller, can be eliminated from consideration.

The following four activity center demand types have been selected for use in the AGT-SOS project:

- CBD line-haul
- CBD circulation
- Activity center line-haul
- Activity center circulation.

Candidate cities for the two CBD demand models have been limited to those most likely to implement Downtown People Mover systems in the near and intermediate future. Seven cities received favorable responses to their recent DPM proposals; these cities and the projected daily riderships of their proposed systems are listed below:

• Baltimore	16,000 riders/day
• Cleveland	46,500 riders/day
• Detroit	39,450 to 65,500 riders/day
• Houston	25,601 riders/day
• Los Angeles	58,100 riders/day
• Miami	40,200 riders/day
• St. Paul	48,000 riders/day.

A CBD with low demand has been chosen by observing which of the seven CBDs has a relatively low (but not the lowest) demand. Houston's projected daily ridership of 25,601 appears to meet these conditions quite well. A high-demand CBD has been chosen in a similar fashion. That is, the highest demand has been eliminated and the second highest selected. Since Detroit CBD demand projections range from a pessimistic estimate of 39,450 to an optimistic estimate of 65,500 riders per day, an average of 52,475 has been assumed. Therefore, Detroit can be considered a representative high-demand CBD after elimination of the higher Los Angeles demand of 58,100 daily riders. In addition to these differences in daily demand magnitude, other differences make these two CBDs different from each other but representative of two types of CBD demand. The projected demand for the Houston DPM consists for the most part of primary trips which originate outside the CBD and use the people mover to reach their final destination after transferring at parking lots and bus terminals. Consequently, the peak demand periods coincide with the morning and evening rush periods. On the other hand, the projected demand for the Detroit people mover consists primarily of secondary trips which have both origin and destination within the CBD. The peak period for this demand occurs around noon. Finally, the proposed DPM for Houston is essentially a line-haul service between multimodal transfer points and employment sites while the proposed Detroit DPM is expected to serve more of a circulation function. For these reasons a CBD line-haul application, based on data from Houston, and a CBD circulation application, based on data from Detroit, have been selected to represent CBD demand applications in the AGT-SOS project. In order to permit direct comparisons of system deployments designed for different demands, three values of demand magnitude for the CBD circulation (Detroit) application and two values for the CBD line-haul (Houston) application have been specified.

For activity center travel demand models, the opportunity exists to utilize data pertaining to areas in which AGT systems are presently operating. West Virginia University at Morgantown, West Virginia has, therefore, been selected as a representative activity center line-haul travel demand situation. Dallas/Fort Worth Regional Airport has been chosen for use in the formulation of an activity center circulation demand model, since other airports with automated systems have less complex guideway network configurations.

3.5 DEMAND MODEL GENERATION

After the selection of basic demand model types and the choice of "actual" (past, present, or projected) demand situations of those types, it is necessary to obtain available demand data, process the data to produce either a transit trip matrix or a total trip matrix for each time interval of interest, and then output the trip matrices in a form usable in other stages of the analysis process.

Initial data processing and trip matrix assembly varies greatly, depending upon the particular characteristics of the data set used in the formulation of each model. Trip matrix output format, however, is uniform among all of the demand models. Furthermore, the format is compatible with computer programs in the UMTA Transportation Planning System (UTPS) package.[3] Four UTPS trip matrix formats were considered: compressed, 1-byte, 2-byte, and 4-byte. Only the compressed format allows all row-column interchanges with no trips to be omitted from the trip matrix file; other formats require that any row not deleted entirely be filled with data (zeros or otherwise) for every column. Since metropolitan area trip matrices may easily have more than one million zone interchanges, such matrices for short time intervals (perhaps one to three hours) will necessarily have many zone interchanges with no trips during an interval. To reduce storage requirements for "sparse" trip matrices, then, the UMTA compressed format has been chosen for these and other trip matrices used in the AGT-SOS project.

The demand model generation methodology, as it applies to each of the seven application areas, is described in this section. Temporal variations in total demand for each demand model and illustrative demand matrices are presented. All of the demand matrices--both zone-to-zone demand for each representative area and station-to-station demand for each deployment--are stored in the SOS data base.

3.5.1 Activity Center Line-Haul Demand

The activity center line-haul demand model is based on projected five-minute station-to-station student trip matrices for the originally planned six-station Group Rapid Transit system at West Virginia University in Morgantown. The projected data was used in conjunction with observed daily ridership totals because no actual origin-to-destination data is available for the existing Morgantown system.

The activity center line-haul application deployment to be analyzed in the SOS program consists of an alternative network linking the three stations of the existing Morgantown system. Therefore, the first step in generating the demand model for this application was to modify the projected six-station demand by eliminating trips to and from the three stations not included in the representative network defined in Section 4.3.1.1 of this report.

The magnitude of daily travel represented by the resulting three-station demand matrices was compared to existing daily ridership totals observed in recent operation of the Morgantown system. Daily ridership totals were recorded during the period between October 21, 1976 and October 27, 1976 with the highest daily total of approximately 12,700 trips being recorded on Wednesday, October 27. The demand projection, modified as described above, was found to be higher than the existing daily ridership for the three-station system. In order to more closely model the demand for the existing system configuration at Morgantown, the modified demand projection matrix was scaled by a factor of 0.675 to adjust the demand magnitude to correspond to the daily ridership observed on October 27. This resulting demand data totals 12,683 trips over the 13-hour day. Figure 3-1 illustrates the variation in demand magnitude for 15-minute intervals during a service day. It also shows the significant micropeaking which is characteristic of the university application.

As indicated previously, the approach to demand model generation is to define demand intervals over which the spatial characteristics and magnitude of demand can be considered constant. The set of separate demand matrices which define travel during each demand interval constitutes the demand model. The next step in demand model generation, then, was to define the demand intervals. In general, the unique hourly peaking characteristics illustrated in Figure 3-1, which correspond to the hourly class changes, can be adequately described by 15-minute intervals. Longer time intervals tend to veil the pronounced peaking characteristics of the university demand. Shorter intervals, on the other hand, increase the number of separate matrices required to represent the demand but fail to provide a significant amount of additional information.

The data plotted in Figure 3-1 indicate that the demand profile for each daytime off-peak hour (7:00 to 11:00 a.m. and 1:00 to 6:00 p.m.) is similar. Since variation in off-peak demand is of less importance to performance and cost modeling results than variation in

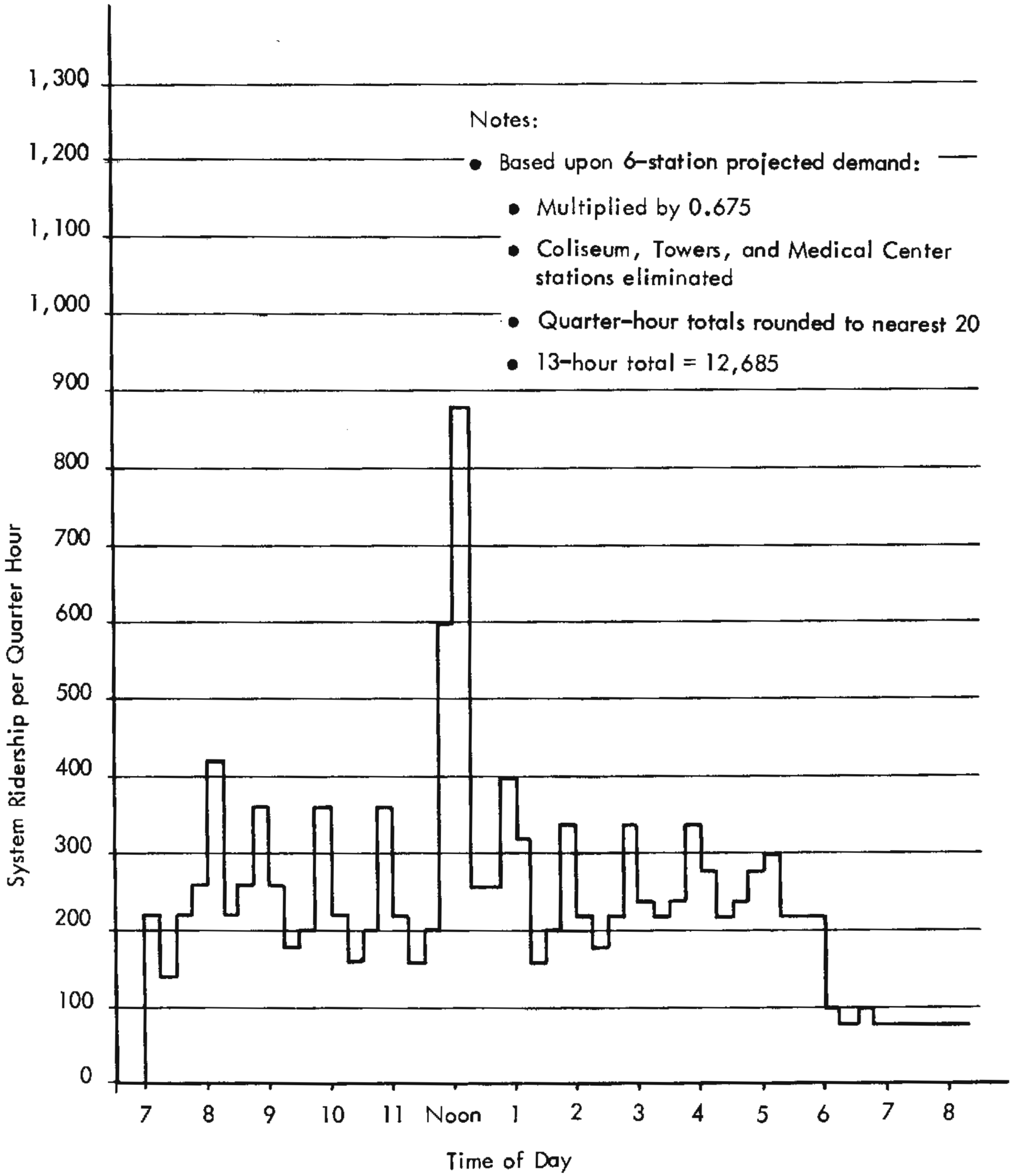


FIGURE 3-1. DEMAND PROFILE FOR THE 3-STATION MORGANTOWN AGT SYSTEM

peak demand, the demand profile and spatial distribution for each day time off-peak hour is assumed to be identical to minimize the number of distinct matrices to be stored. The data was aggregated to produce an average off-peak hour demand represented by four 15-minute matrices. The demand in each off-peak hour is modeled by the four nominal, off-peak matrices. Aggregation of the demand data to produce nominal demand matrices was accomplished using the following four steps:

1. Calculate total number of trips for all hours in a time period for each origin-destination (O-D) pair. Then sum all O-D pair totals to determine the total number of trips over the 9 off-peak hours.

2. Using the total trips figure, calculate the percent of trips for each O-D pair (O-D total trips divided by total trips).

3. Determine the total number of trips for each quarter-hour over the entire time period so that there will be four totals, one for each quarter. Divide each quarter-hour by the number of hours in the time period to obtain the average number of trips made each quarter.

4. Distribute the average quarter-hour trips to O-D pairs by applying the percentages calculated in Step 2. Multiply each quarter-hour number of trips by each O-D percent to obtain the nominal trip matrices for off-peak and evening hours. The equation for this step is:

   $$P_i \times Q_j = T_{ij} ,$$

   where

   P_i = The percent of trips each O-D pair carries (from Step 2); $i = 1$ to 6 (the number of O-D pairs)

   Q_j = The average quarter-hour trip totals (from Step 3); $j = 1$ to 4 (the number of quarters in an hour)

   T_{ij} = The number of trips for O-D pair i and quarter j .

The demand for the two evening hours (6:00 p.m. to 8:00 p.m.) shows little variation from one quarter-hour interval to another. Therefore, demand for this interval was aggregated, and the evening period is represented in the demand model as a single demand magnitude and spatial distribution. The resulting demand model for the university application is illustrated in Figure 3-2. The station-to-station demands are listed in detail in Table 3-5. The demand for the 13-hour service day is represented in the model by 13 distinct demand matrices: 4 off-peak matrices, 8 peak-period matrices, and 1 evening matrix.

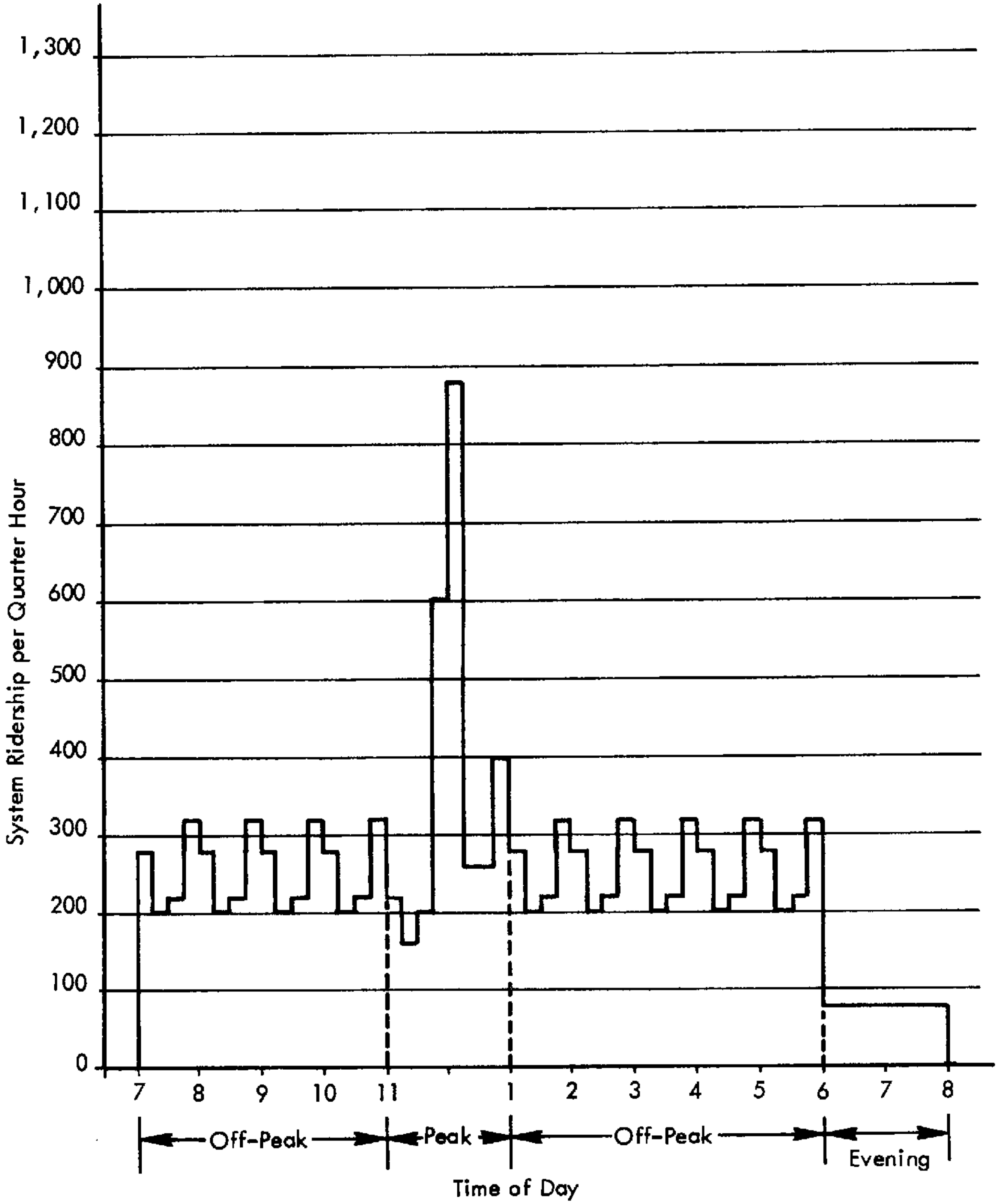


FIGURE 3-2. DEMAND PROFILE FOR ACTIVITY CENTER LINE-HAUL DEMAND MODEL

TABLE 3-5. STATION-TO-STATION DEMAND FOR EACH QUARTER-HOUR, ACTIVITY CENTER LINE-HAUL

	O-D Pairs						
	1-2	1-3	2-1	2-3	3-1	3-2	Total
Off-Peak Hour							
Q1	48	56	42	44	47	38	275
Q2	34	39	29	30	33	26	191
Q3	39	45	33	35	38	30	220
Q4	56	65	48	50	54	44	317
Total	177	205	152	159	172	138	1003
Peak Hours 11:00 - 12:00							
Q1	18	44	60	18	45	28	213
Q2	20	44	27	4	44	25	164
Q3	24	44	43	4	44	37	196
Q4	30	44	234	20	69	204	601
Total	92	176	364	46	202	294	1174
12:00 - 1:00							
Q1	215	92	249	230	64	22	872
Q2	56	64	45	33	54	10	262
Q3	59	66	40	12	60	21	258
Q4	99	66	49	75	55	58	402
Total	429	288	383	350	233	111	1794
Evening Hour							
Q1 - 4	17	16	17	5	24	7	86
Total	68	64	68	20	96	28	344

Total Daily Trips = 9(1003) + 1174 + 1794 + 2(344) = 12,683

3.5.2 Activity Center Circulation Demand

The activity center circulation demand model is based on data from a 1974 passenger flow study of the Airtrans system operating at the Dallas/Fort Worth Regional Airport. The data consist of turnstile counts at each of 14 passenger stations, taken over 15-minute intervals during 3 peak periods. Turnstile counts were taken over half-hour intervals during off-peak periods, but these data were not made available to GM TSD. Consequently, demand for off-peak intervals was estimated based on total trips made during each of the three eight-hour work shifts. Turnstile counts--actual counts or estimates--do not specify the station-to-station demands as needed for analysis purposes. Therefore, a second major task in the generation of the activity center circulation demand model was to approximate the station-to-station demand by assigning trips which enter at each station to exit at the other stations in proportion to the total number of exiting passengers at each station. The final step in generating the demand model for this application was to select the discrete matrices suitable for representing the demand.

The available turnstile counts do not include data for the off-peak periods (8:00 to 11:00 a.m., 2:00 to 4:00 p.m., and 8:00 p.m. to 7:00 a.m.). In order to produce the information necessary for generating the demand model, station entry and exit demand data were estimated for 15-minute intervals during the off-peak periods. Only the day-time off-peak periods (8:00 to 11:00 a.m., and 2:00 to 4:00 p.m.) were considered at this level of detail. The demand for the system during the evening hours is expected to be quite low, and therefore, it need not be represented in great detail.

The estimates of station entry and exit demand for the daytime off-peak periods are based on the total number of entering and exiting trips per station during each of the three work shifts and on the fact that the time intervals for which 15-minute turnstile counts are given in the Airtrans Passenger Flow Study[5] are peak periods. This, of course, implies that the remaining time periods have lower demands. For each shift the total numbers of entering and exiting trips are as follows*:

Shift		Entry	Exit
1st Shift	(7:30 a.m. to 3:30 p.m.)	4914	6126
2nd Shift	(3:30 p.m. to 11:30 p.m.)	4369	5904
3rd Shift	(11:30 p.m. to 7:30 a.m.)	683	1382

The average entry count per 15-minute interval for each shift is:

1st Shift 154
2nd Shift 137
3rd Shift 21.

*The variation between entering and exiting trips is attributed to people "jumping" the entry turnstiles to avoid paying the fare, exit turnstile counts due to baggage, and other sources of error.

Figure 3-3, the observed demand profile for the Airtrans system as reported in the Passenger Flow Study,[5] indicates that the recorded 15-minute trip levels are well in excess of the average number for each shift. As expected, the demand for the unrecorded 15-minute intervals must be significantly lower than the recorded levels to result in the given shift averages. In order to estimate the demand for 15-minute intervals during the off-peak periods, it was assumed that the demand level first decreases then gradually builds up to the next peak. It was further assumed that the slope of the off-peak demand fluctuations is approximately equal to the greatest hourly variation in demand during the adjacent peak period. This assumption, coupled with the constraint that the shift total be reproduced, led to the estimates of off-peak 15-minute interval demand as presented in Figure 3-4.

These estimates of the total number of trips entering the system during each 15-minute interval of the off-peak periods were then distributed among station pairs to estimate the number of trips entering and exiting each station during the off-peak periods. The following process was used to estimate off-peak trip production and attraction for each station:

A. Determine entering trips per station and time interval

1. Determine the percent of all unreported first-shift trips entering the station under consideration. The equation is: (number of trips entering the station during the 1st shift minus the number of reported trips entering the station during the 1st shift) divided by the total number of unreported trips for all stations during the 1st shift.

2. Determine the unreported station entry loads for each time interval by multiplying the estimated system entry loads per 15-minute interval by the percent of unreported trips entering the station under consideration (determined in Step "A-1" above).

B. Determine exiting trips per station and time interval

1. Compute the average unreported exit volume/entry volume ratio for each station during the first shift. The unreported exit volume for each station is equal to the total exit volume for a station during the first shift minus the recorded exit volumes for the same station during the first shift. The unreported entry volume per station for the first shift was determined in Step "A-2."

2. Determine the unrecorded quarter-hour exit loads per station by multiplying the average unreported exit volume/entry volume ratio for each station (determined in Step "B-1") by the entry load for that station.

Upon completion of these steps, the entry and exit loads for each station have been estimated for each of the unreported 15-minute intervals. It should be noted that one unreported time interval, 3:30 p.m. to 4:00 p.m., does not fall into the first shift; however, the ratios of the first shift have been applied to its distribution of trips.

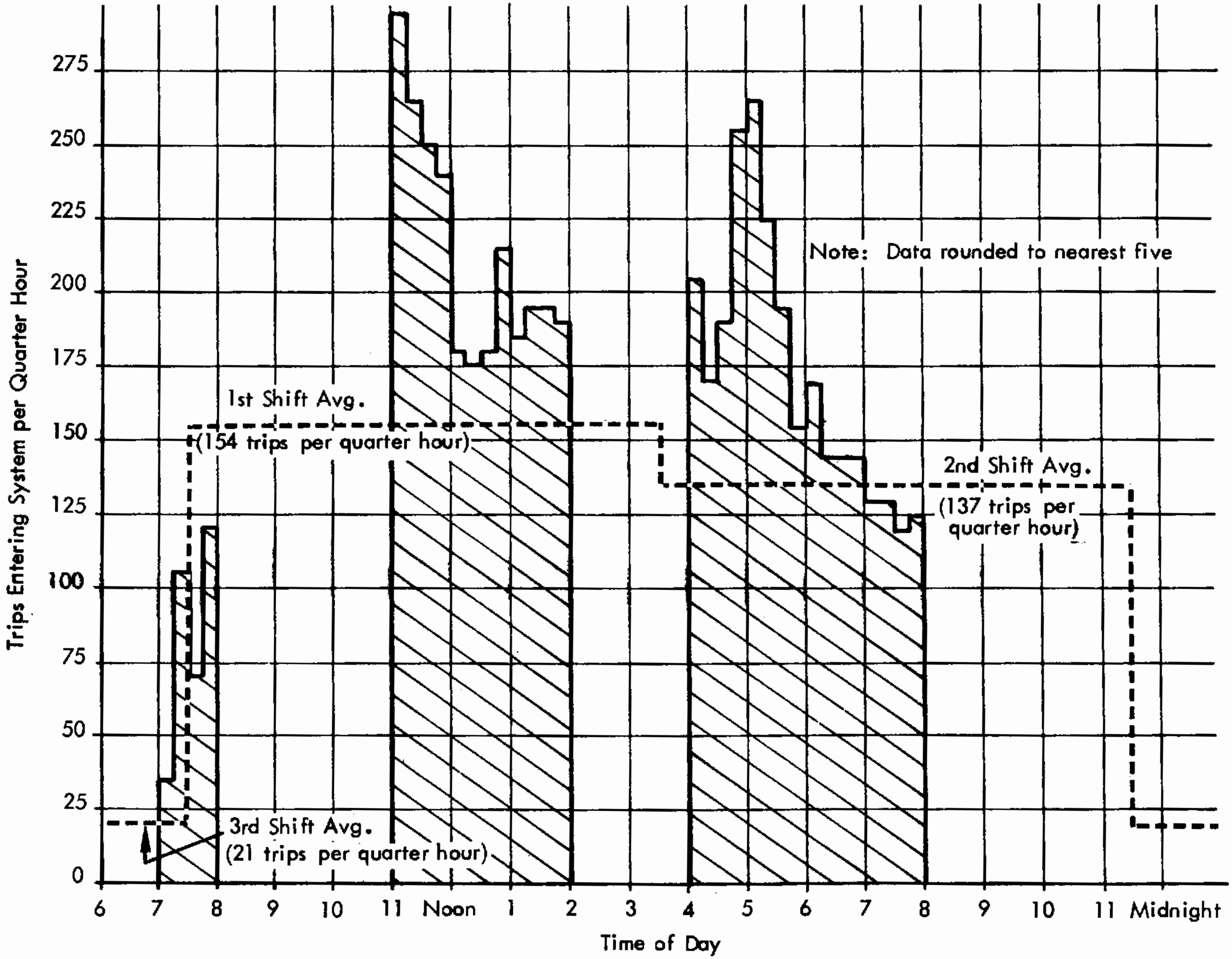


FIGURE 3-3. AIRTRANS DEMAND PROFILE (1974 Passenger Flow Study Data)

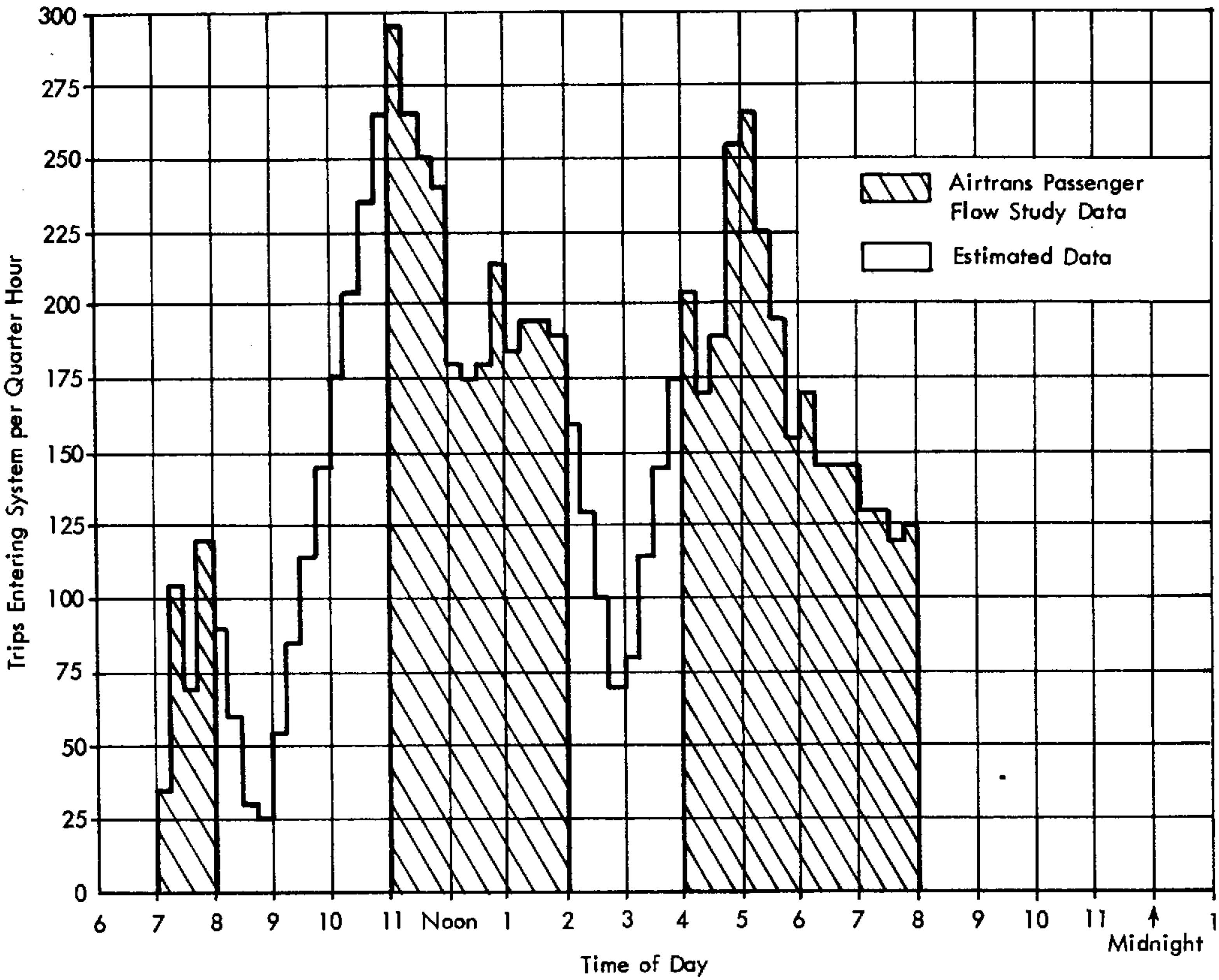


FIGURE 3-4. TOTAL DAILY DEMAND DISTRIBUTION, ACTIVITY CENTER CIRCULATION APPLICATION

The next step in the demand model generation process for this application is to translate the observed peak period ond estimated off-peak period trip production and attraction totals into station-to-station matrices. The first step is to eliminate certain unlikely origin-destination pairs. The relative station locations are illustrated in Figure 4-2. This figure shows the multiple loop network to be used in SLT analysis in the activity center line-haul application. The first combinations to be eliminated are those between a single station; for example, Station 5 to Station 5. Also each pair of adjacent stations within each terminal area is assumed to be separated by a walking distance. Therefore, the following trips were eliminated:

3 to 4	6 to 7	10 to 11
4 to 3	7 to 6	11 to 10
4 to 5	8 to 9	
5 to 4	9 to 8	

Trips between the parking stations (all combinations of 1, 2, 12, and 13) were also disallowed. Finally, it was assumed that each trip originating in a parking area would utilize the parking area serviced by the same route (of the existing Airtrans network) as the trip's destination; that is, it was assumed that departing passengers experience no transfers on the existing Airtrans network. This assumption eliminates the following trips:

Station 1 to Station 8, 9, 10, 11, and 14
Station 2 to Station 8, 9, 10, 11, and 14
Station 12 to Station 3, 4, 5, 6, and 7
Station 13 to Station 3, 4, 5, 6, and 7

However, the reverse of these O-D pairs could not be eliminated since passengers frequently return via an airline, and hence station, which is different than the one they used for departure.

Trips entering each station were distributed to other stations, except for the station pairs eliminated as described above, according to the relative attraction of each station by applying the following steps for each quarter-hour period:

A. Divide the number of exiting trips per station by the total number of exiting trips during that quarter-hour.

B. For each origin station:

   1. Apply an adjustment factor to each of the fractions calculated in A. This factor provides the capability of altering the weighting, or attractiveness, of each O-D pair. In this case a weight of either 0 or 1 was used. Zeros were used to eliminate the O-D pairs listed above.

2. Check to see if the sum of the fractions for all destinations totals 1.00. The sum may be less than 1.00 due to the application of the adjustment factors in B-1. If the sum is less than 1.0, distribute the difference (1.00 - actual total fraction) in proportion to the fractions computed in B-1.

3. Multiply the distribution fractions resulting from Step B-2 by the total numbers of trips entering the system at the origin station during the time interval under consideration. Then multiply the result by an overall magnitude scaling factor (which was assumed to be 1 for this case).

Figure 3-5 shows the demand magnitudes, aggregated over half-hour intervals, which result from the O-D distributions for the period between 7:00 a.m. and 8:00 p.m. Half-hour intervals proved to display similar characteristics to the quarter-hour intervals; consequently, the half-hour was selected as the basic time interval to be used for further analysis.

Variations between a half-hour total of Figure 3-5 (e.g., 11:00 to 11:30 a.m. which has 552 trips) and the sum of the two corresponding quarter-hour totals of Figure 3-3 (e.g., 11:00 to 11:15 a.m. + 11:15 to 11:30 a.m. for a total of 560 trips) result from round-offs made during the various calculations previously described.

For modeling purposes it is desirable to minimize the number of different O-D matrices to the extent possible to reduce the storage space and the number of calculations. Using the demand profile of Figure 3-5 as a base, certain modifications were made to reduce the number of unique half-hour intervals to be represented while retaining the unique peaking characteristics of the airport application. In general, the time intervals for which data were estimated, rather than observed, were aggregated since the demand during these intervals is relatively small and is not based upon direct observations. The resultant demand model is illustrated in Figure 3-6.

The estimated demand for a portion of the morning off-peak period (from 8:00 to 9:30 a.m.) was aggregated and is represented in the model by a single demand matrix. Similarly, the estimated demand for the afternoon off-peak period (from 2:00 to 4:00 p.m.) was aggregated and is represented by another demand matrix. The data in Figure 3-5 show that the demand profile for the period from 10:00 a.m. to 12:30 p.m. is approximately symmetrical. To minimize the number of discrete matrices to be stored, symmetry is assumed during this period. The demand matrix for the 10:00 to 10:30 a.m. interval is assumed to also apply to the 12:00 to 12:30 p.m. interval, and the matrix for the 10:30 to 11:00 a.m. interval is also applied during the 11:30 a.m. to 12:00 p.m. interval. Figure 3-5 shows that the magnitude of demand varies little during the period from 12:30 to 2:00 p.m. Therefore, the demand for this period was aggregated and represented in the model by a single matrix.

The demand for the last part of the second shift (8:00 to 11:30 p.m.) is assumed to be spatially distributed in the same way as the demand for the afternoon off-peak period (from 2:00 to 4:00 p.m.), and the magnitude of the demand (200 trips per half-hour) is that required to produce the second shift total. The spatial distribution of the very low

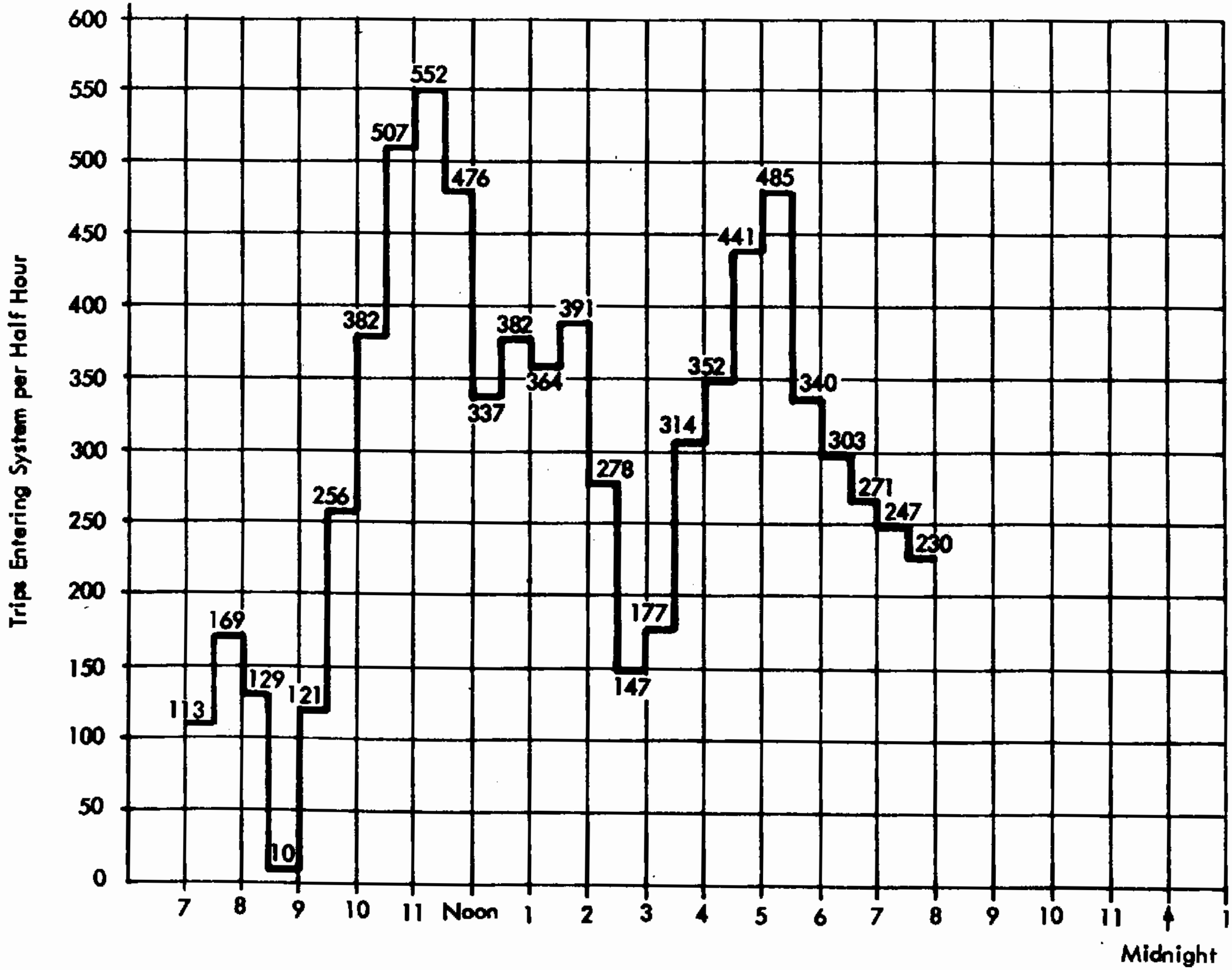


FIGURE 3-5. SLT 2 DEMAND PROFILE (trips per half hour)

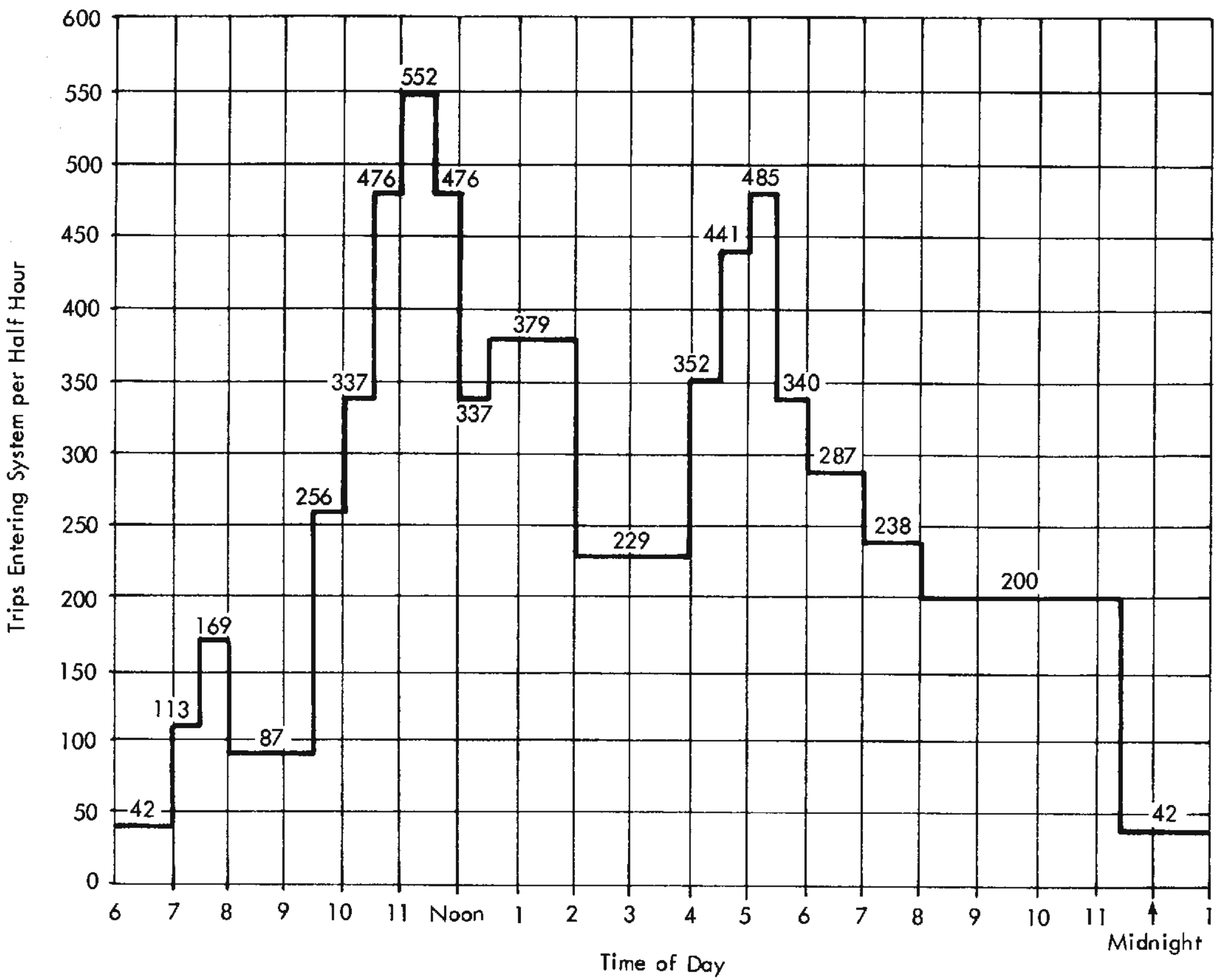


FIGURE 3-6. STATION-TO-STATION DEMAND MODEL FOR THE ACTIVITY CENTER CIRCULATION APPLICATION

evening demand is also assumed to be the same as that of the afternoon off-peak period (2:00 to 4:00 p.m.), and the magnitude corresponds to the third-shift average of 42 passengers per half-hour. The final demand model for the activity center circulation application consists of a set of 15 distinct spatial distributions and 17 different demand matrices. Three of these matrices share the same spatial distribution of demand but differ in the total magnitude of demand. The three similar matrices apply over the following periods: 2:00 to 4:00 p.m., 229 trips per half-hour; 8:00 to 11:30 p.m., 200 trips per half-hour; 11:30 p.m. to 7:00 a.m., 42 trips per half-hour.

Two matrices, representing peak half-hour intervals, are presented for illustrative purposes. Table 3-6 is the station-to-station demand matrix for the morning peak interval (11:00 to 11:30 a.m.), and Table 3-7 illustrates the station-to-station demand for the afternoon peak (5:00 to 5:30 p.m.). The numbers in parentheses in the left-hand column of the tables refer to origin stations identified in Figure 4-2. The numbers in parentheses in the first row refer to destination stations. Demand for the two transfer stations in the multiple loop network to be used in the analysis of an SLT system in the activity center circulation application (SLT 2) is not shown. The transfer stations do not serve as origins or final destinations. However, all of the demand which originates at a station on one loop and is destined for a station on another loop must pass through one of the transfer stations. The link load data presented in Section 4.3.1.2 indicates that the morning peak interval (11:00 to 11:30 a.m.) volume through each transfer station is 44 trips per half-hour and 59 trips per half-hour for Stations 15 and 16, respectively.

3.5.3 CBD Circulation Demand

Three CBD circulation demand models representing a low-, medium-, and high-demand CBD application were generated. The three demand models differ only in the magnitude of travel and are based on three sources of demand information for the Detroit CBD. A one-way, zone-to-zone, 12-hour trip matrix for secondary trips (trips having both origin and destination within the CBD) was developed during a study performed in 1972 for the Southeastern Michigan Transportation Authority (SEMTA)[6]. The trip matrix is based on projected 1990 demand data and does not include trips which are less than 457 metres (1500 feet), as it was assumed in the study that these short trips are not potential people mover trips. The second source of data is the Detroit Downtown People Mover (DPM) Proposal[7] which describes the estimated hourly variations in demand magnitude for the proposed DPM system. The demand profile presented in the DPM Proposal covers a 12-hour period in one-hour intervals. The projected demand includes primary trips (trips having either the origin or destination outside the CBD) as well as secondary trips, and it is based on projected 1978 demand data. The final source of reference material used to generate the CBD circulation demand models is a study performed for SEMTA[8] which identifies the temparal distribution of demand within the peak hour (noon to 1:00 p.m.).

The general process for generating the zone-to-zone demand for the CBD circulation application is to use the Feeder System Model (FSM) to map the reference zone-to-zone demand data onto the Detroit DPM network, to determine the resulting magnitude of station-to-station demand, and then to scale the zone-to-zone demand matrix so that the station-to-station demand magnitude produced by the FSM equals the Detroit DPM projection. Ex-

TABLE 3-6. MORNING PEAK INTERVAL STATION-TO-STATION DEMAND FOR THE ACTIVITY CENTER CIRCULATION APPLICATION

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	3	2	2	5	2	0	0	0	0	0	0	0	14
(2)	0	0	2	3	1	4	2	0	0	0	0	0	0	0	12
(3)	0	0	0	0	1	4	2	5	3	4	2	0	0	0	21
(4)	1	0	0	0	0	8	3	9	7	6	3	1	2	1	41
(5)	1	0	4	0	0	7	3	9	6	7	3	1	2	1	44
(6)	3	1	8	8	5	0	0	20	15	13	6	2	3	2	86
(7)	0	0	2	2	1	0	0	4	3	4	1	0	1	1	19
(8)	4	2	14	14	8	26	9	0	0	21	11	3	6	3	121
(9)	2	2	11	10	5	17	8	0	0	15	8	2	4	3	87
(10)	0	0	1	2	0	2	1	2	2	0	0	0	0	0	10
(11)	1	1	5	5	3	10	3	11	8	0	0	1	2	2	52
(12)	0	0	0	0	0	0	0	4	3	3	1	0	0	0	11
(13)	0	0	0	0	0	0	0	6	5	4	2	0	0	1	18
(14)	0	0	2	2	0	3	1	3	2	2	1	0	0	0	16
TOTAL TRIPS DURING INTERVAL (11:00 AM TO 11:30 AM)															552

TABLE 3-7. AFTERNOON PEAK INTERVAL STATION-TO-STATION DEMAND FOR THE ACTIVITY CENTER CIRCULATION APPLICATION

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	3	4	2	5	2	0	0	0	0	0	0	0	16
(2)	0	0	3	2	2	3	1	0	0	0	0	0	0	0	11
(3)	1	1	0	0	3	7	3	7	4	5	3	1	1	1	37
(4)	1	1	0	0	0	9	3	9	6	6	3	1	2	2	43
(5)	1	0	5	0	0	6	2	6	4	3	2	1	1	1	32
(6)	1	0	5	6	4	0	0	8	5	5	3	1	2	2	42
(7)	1	1	3	3	2	0	0	4	3	3	1	0	1	1	23
(8)	2	2	11	12	7	16	6	0	0	10	5	2	3	3	79
(9)	2	2	10	10	6	14	5	0	0	9	5	2	3	3	71
(10)	1	1	8	8	5	11	3	11	7	0	0	1	2	2	60
(11)	1	1	4	5	2	7	2	5	5	0	0	1	1	1	35
(12)	0	0	0	0	0	0	0	3	2	2	1	0	0	0	8
(13)	0	0	0	0	0	0	0	6	5	4	2	0	0	2	19
(14)	0	0	1	2	0	2	0	2	1	1	0	0	0	0	9
TOTAL TRIPS DURING INTERVAL (5:00 PM TO 5:30 PM)															485

cept for the fact that the zone-to-zone demand is projected 1990 secondary trip data while the desired station-to-station demand is 1978 secondary and primary trip estimates, this process is essentially equivalent to calibrating the FSM diversion curve with the Detroit DPM demand projections. Due to the lack of more consistent data, it is assumed that the projected distribution of 1990 secondary trips is representative of the distribution of total trips in 1978, and that the temporal distribution of total 1990 trips is representative of that of the total 1978 trips. The process and results of demand model generation for the CBD circulation application are presented in more detail in the following paragraphs.

The reference 12-hour, secondary trip matrix does not include return trips. It is assumed, however, that for each trip a return trip would be made. Therefore, the first step was to modify the daily secondary trip matrix so that all trip segments are included. This was accomplished by increasing the number of trips from one zone to another (from Zone i to Zone j) by the number of trips from Zone j to i. This process produces a symmetrical matrix.

The reference demand matrix represents the spatial distribution of secondary trips. According to the SEMTA-supported study which produced the matrix,[6] potential secondary transit trips have proved to be substantially greater than potential primary transit trips. Consequently, the effect of the primary trips on the overall spatial distribution of the demand is assumed to be negligible. Except for the overall magnitude, therefore, the daily secondary trip distribution is assumed to represent the total demand distribution including primary trips.

No information has been found which can be used to describe how the spatial distribution of demand in the Detroit CBD changes as a function of time. As a result, only one spatial distribution is used to describe demand during all demand intervals during the service day. However, an estimated profile of 1990 people mover demand is presented in SEMTA's DPM Proposal[7] and is reproduced in this report as Figure 3-7. It was assumed by SEMTA that this profile also represents the relative hourly variation in trip-making activity in 1978.

The average value of the demand estimate for each hour was used to produce Figure 3-8 which shows the percentage of all estimated people mover trips which occur in each hour of the 12-hour service day. At the right side of the figure, a profile of peak-hour trips is given by quarter-hour intervals. This breakdown, developed during a study of secondary trips for SEMTA[8], indicates that 30 percent of the trips occur during both the second and third quarter-hours. Since the great majority of trips during the peak hour are secondary trips, this profile has been applied to the combined trip total.

The range of people mover ridership estimated by SEMTA and shown in Figure 3-7 for 1990 was used to define the three CBD circulation demand models. The low demand CBD circulation demand corresponds in magnitude to the "pessimistic" ridership projection which totals 39,450 daily trips in 1978. The high demand CBD circulation model corresponds to the "optimistic" projection which totals 65,500 daily trips in 1978. The demand magnitude for the medium demand CBD circulation application is the average of the "pessimistic" and "optimistic" projections and totals 52,475 trips per day.

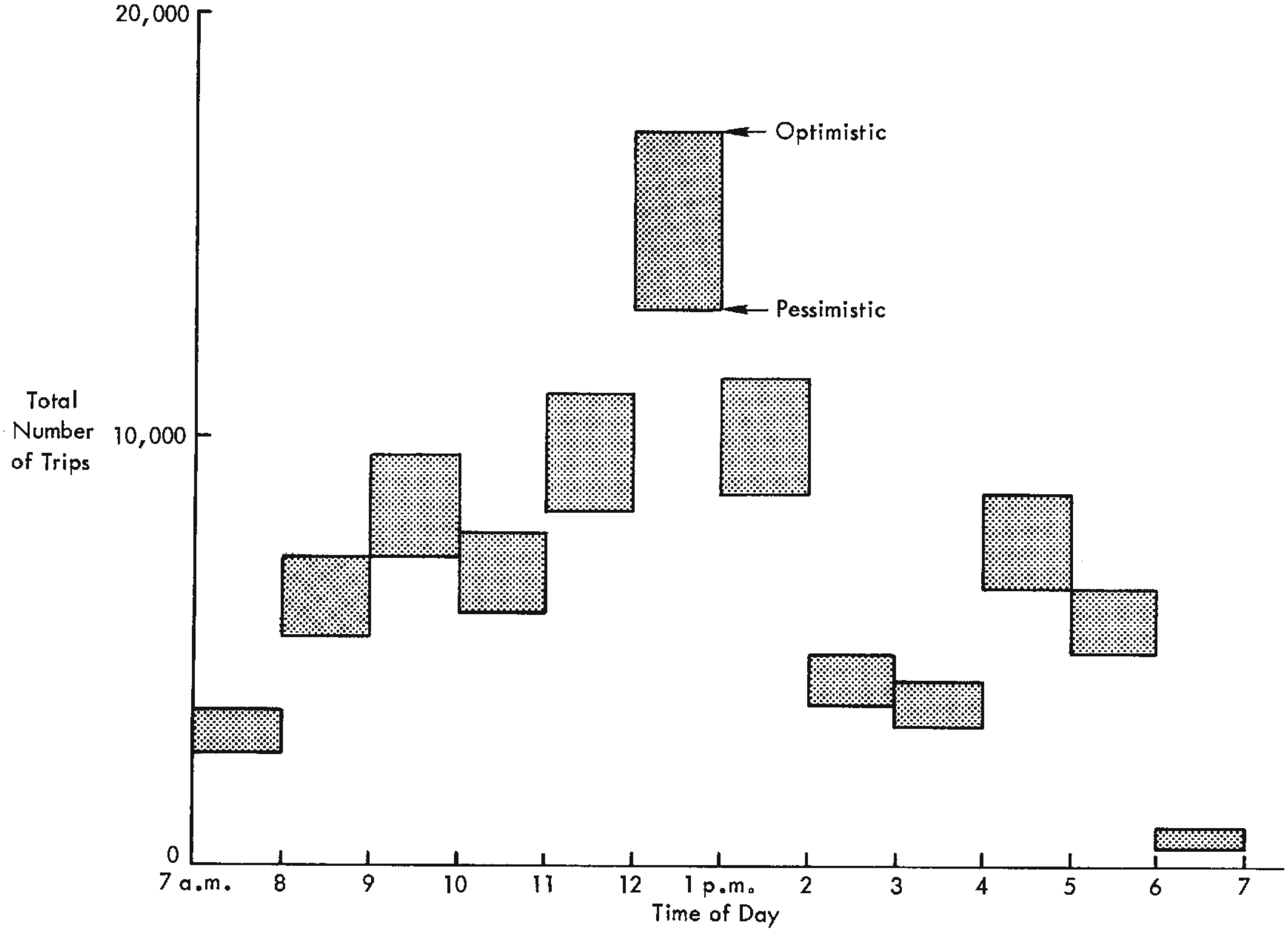


FIGURE 3-7. 1990 PEOPLE MOVER RIDERSHIP BY TIME OF DAY

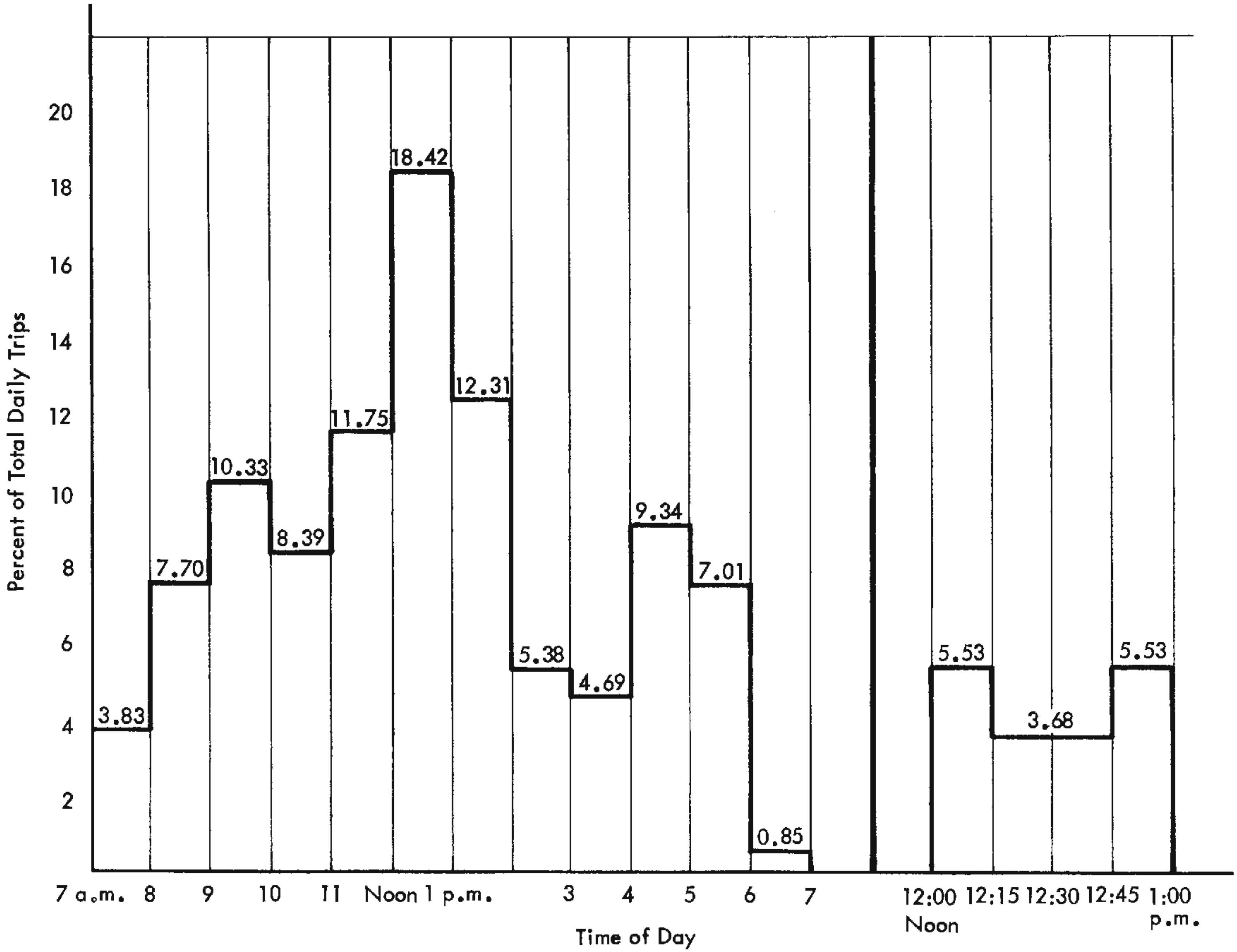


FIGURE 3-8. DAILY DEMAND PROFILE, CBD CIRCULATION DEMAND MODEL

The next step in the CBD circulation demand model generation process is to produce a station-to-station demand matrix using the reference zone-to-zone matrix and the Feeder System Model (FSM), and then to compare the resulting station-to-station demand magnitude with the SEMTA projections. The SEMTA DPM demand projection is based on the one-way, counter-clockwise loop network illustrated in Figure 4-3. Consequently, this network was used to generate the station-to-station demand for comparison with the projected DPM demand. The FSM requires several inputs to produce the station-to-station trip matrix:

- Zone-to-zone trip matrix
- Zone centroid locations
- Station locations
- Station-to-station performance matrix
- Performance scale factors for:
    - Zone-to-station performance
    - Zone-to-zone performance
    - AGT performance.

As indicated above, the reference zone-to-zone demand matrix was obtained from a SEMTA report. The zone centroid locations are defined in terms of the U.S. Geological coordinate system and were obtained from the Southeastern Michigan Council of Governments. Station locations for the single-lane loop network were defined in terms of the U.S. Geological coordinate system using the Network Build Module processor in conjunction with a Tektronix Graphics Tablet.

The station-to-station performance matrix is a trip time matrix for travel on the network and includes wait time, vehicle dwell time, and travel time. These trip times are based on the following assumptions:

Cruise velocity - 27 km/h
Acceleration/deceleration - 1.0 m/s^2
Station dwell time - 30s
Average woit time - 2.0 min (one-half of the assumed headway).

Table 3-8 shows the network travel times by link including the effect of station dwell time. The nodes which define the links coincide with stations as illustrated in Figure 4-3.

The performance scale factors are used to calculate station access/egress times and direct zone-to-zone travel times for use in the FSM diversion function which selectively assigns trips to the AGT network. The zone-to-station performance scale factor is used to convert the rectilinear distance between zone centroids and stations to travel time. Similarly, the zone-to-zone performance scale factor converts the rectilinear distance between O-D zone centroids into trip time. Since the areo under consideration is small (approximately one square mile), walking is considered to be both the station access mode and the alternate transportation mode. The scale factor, then, represents an average walk speed. A speed of 61 m/min (200 ft/min) has been assumed.

TABLE 3-8. LINK TRAVEL TIMES

LINK	TIME (SECONDS)
(1,2) , (2,1)	95
(2,3) , (3,2)	93
(3,4) , (4,3)	91
(4,5) , (5,4)	77
(5,6) , (6,5)	91
(6,7) , (7,6)	91
(7,8) , (8,7)	81
(8,9) , (9,8)	81
(9,10) , (10,9)	73
(10,11) , (11,10)	61
(11,1) , (1,11)	136

With these inputs the FSM was used to determine the station-to-station demand matrix for the single-lane loop network proposed for the Detroit DPM. The FSM assigned 179,827 trips to the AGT network compared to SEMTA'S "optimistic" estimate of 65,500 trips. The wide variation in the station-to-station demand magnitudes is due primarily to the fact that the reference zone-to-zone demand matrix is a 1990 projection while SEMTA'S DPM ridership projection is based on 1978 activity levels. Differences also exist in the approach used by SEMTA and GMTSD to assign trips to the network. Another discrepancy, which would tend to reduce the difference in the two ridership estimates, is the fact that the reference zone-to-zone demand accounts for only secondary trips while the SEMTA ridership estimates include primary as well as secondary trips. This discrepancy has only a minor effect, however, since primary trips account for a low percentage of DPM ridership as projected by SEMTA. In order to obtain the desired number of trips for each demand level--pessimistic, average, and optimistic projected ridership--scale factors were applied to the demand matrix. The scale factors are the ratios of desired demand magnitude (39,450 ; 52,475 ; and 65,500 trips per day) to the demand magnitude resulting from the FSM (179,827 trips per day) and equal to 0.2194, 0.2918, and 0.3642 for the low demand, medium demand, and high demand, respectively. These scale factors were applied to the zone-to-zone demand matrix to produce demand models for the three CBD circulation demand applications. These matrices are then used as input to the FSM to generate station-to-station demand matrices for different network configurations in the CBD circulation application area. The three zone-to-zone matrices for the 31-zone area are presented in Tables 3-9, 3-10, and 3-11 for the low demand, medium demand, and high demand CBD circulation application, respectively. The relative location of the zones within the Detroit CBD is illustrated in Figure 3-9.

Table 4-1 shows that there are five SLT deployments and one PRT deployment to be considered in the CBD circulation application during the System Operations Studies. Five station-to-station demand matrices were developed to support the SLT analyses using the FSM with the appropriate zone-to-zone demand matrix and station-to-station performance matrix. The network configurations on which the station-to-station demands are based include the single-lane loop illustrated in Figure 4-3, the dual-lane loop illustrated in Figure 4-4, and the multiple shuttle illustrated in Figure 4-5. Since the station locations for all of these networks are identical, the link travel times presented in Table 3-8 were used to estimate the station-to-station performance matrix for all of the SLT networks except for one of the shuttle alternatives. An average wait time of two minutes was assumed for the loop deployments. Two alternative modes of operation for the shuttle deployment were assumed for the purpose of generating station-to-station demand. In one case vehicle arrivals at transfer stations are synchronized to minimize transfer times. In order to accomplish this, travel times on the shorter shuttles are increased relative to the non-synchronized mode until they equal the travel time on the longest shuttle. This effect was accounted for in the station-to-station performance matrix by assuming longer station dwell times for the synchronous shuttles than for the non-synchronized case. In general, the station dwell times for the synchronized shuttle are 30 seconds except for three stations (Stations 1, 9, and 10) where an increase in dwell (either 55 or 60 seconds) is necessary to attain equivalent travel times on all shuttles. Table 3-11A shows the resultant link travel times for the synchronized shuttle alternative. Table 3-12 shows

TABLE 3-9. 12-HOUR ZONE-TO-ZONE DEMAND FOR THE LOW-DEMAND CBD CIRCULATION APPLICATION

	(10)	(11)	(12)	(13)	(14)	(20)	(21)	(22)	(23)	(30)	(31)	(32)	(40)	(41)	(42)	(43)
(10)	0	0	0	0	50	4	0	62	0	0	58	68	34	138	92	92
(11)	0	0	0	0	0	92	0	382	0	930	398	442	224	926	0	582
(12)	0	0	0	0	0	46	0	200	846	0	0	0	122	494	328	304
(13)	0	0	0	0	0	50	0	226	0	572	246	274	138	572	0	348
(14)	50	0	0	0	0	24	0	100	422	246	0	0	62	246	166	162
(20)	4	92	46	50	24	0	0	0	0	68	34	34	4	68	44	40
(21)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(22)	62	382	200	226	100	0	0	0	0	294	128	138	70	0	0	178
(23)	0	0	846	0	422	0	0	0	0	1162	508	572	290	0	0	744
(30)	0	930	0	572	246	68	0	294	1162	0	0	332	166	686	464	432
(31)	58	398	0	246	0	34	0	128	508	0	0	0	74	298	196	190
(32)	68	442	0	274	0	34	0	138	572	332	0	0	78	332	220	204
(40)	34	224	122	138	62	4	0	70	290	166	74	78	0	0	108	0
(41)	138	926	494	572	246	68	0	0	0	686	298	332	0	0	0	0
(42)	92	0	328	0	166	44	0	0	0	464	196	220	108	0	0	0
(43)	92	582	304	348	162	40	0	178	744	432	190	204	0	0	0	0
(44)	84	0	274	0	138	34	0	146	0	386	166	178	92	0	0	0
(50)	366	2078	1108	0	0	138	0	398	1732	1636	726	760	392	1606	0	976
(51)	44	246	132	0	0	2	0	70	324	196	92	92	46	192	124	112
(52)	30	166	92	98	46	0	0	46	212	128	62	62	34	124	84	78
(60)	30	196	100	122	58	4	0	62	240	138	62	70	0	0	94	0
(61)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(62)	74	482	258	258	132	34	0	152	618	366	162	168	92	366	240	0
(63)	92	610	324	366	162	40	0	182	772	452	196	220	104	0	0	0
(64)	100	612	328	0	166	38	0	178	794	474	204	220	108	466	0	0
(65)	62	382	202	230	100	20	0	108	482	290	124	138	70	290	192	0
(66)	24	166	92	100	44	2	0	50	202	124	58	62	34	124	84	78
(70)	0	4	0	2	0	0	0	0	2	2	0	0	0	2	0	0
(71)	16	122	68	74	34	0	0	34	162	92	40	44	20	92	62	62
(72)	0	4	0	0	0	0	0	0	4	2	0	0	0	2	0	0
(101)	20	152	78	92	38	2	0	46	186	104	46	58	0	104	74	70
(TOT)	1540	9196	5396	3808	2396	822	0	3250	10274	9742	4068	4766	2362	7128	2572	4652

TABLE 3-9. 12-HOUR ZONE-TO-ZONE DEMAND FOR THE LOW-DEMAND CBD CIRCULATION APPLICATION (Cont.)

	(44)	(50)	(51)	(52)	(60)	(61)	(62)	(63)	(64)	(65)	(66)	(70)	(71)	(72)	(101)	(TOT)
(10)	84	366	44	30	30	0	74	92	100	62	24	0	16	0	20	1540
(11)	0	2078	246	166	196	0	482	610	612	382	166	4	122	4	152	9196
(12)	274	1108	132	92	100	0	258	324	328	202	92	0	68	0	78	5396
(13)	0	0	0	98	122	0	298	366	0	230	100	2	74	0	92	3808
(14)	138	0	0	46	58	0	132	162	166	100	44	0	34	0	38	2396
(20)	34	138	2	0	4	0	34	40	38	20	2	0	0	0	2	822
(21)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(22)	146	398	70	46	62	0	152	182	178	108	50	0	34	0	46	3250
(23)	0	1732	324	212	240	0	618	772	794	482	202	2	162	4	186	10274
(30)	386	1636	196	128	138	0	366	452	474	290	124	2	92	2	104	9742
(31)	166	726	92	62	62	0	162	196	204	124	58	0	40	0	46	4068
(32)	178	760	92	62	70	0	168	220	220	138	62	0	44	0	58	4766
(40)	92	392	46	34	0	0	92	104	108	70	34	0	20	0	0	2362
(41)	0	1606	192	124	0	0	366	0	466	290	124	2	92	2	104	7128
(42)	0	0	124	84	94	0	240	0	0	192	84	0	62	0	74	2572
(43)	0	976	112	78	0	0	0	0	0	0	78	0	62	0	70	4652
(44)	0	0	92	64	84	0	196	0	0	152	68	0	46	0	62	2262
(50)	0	0	0	0	348	0	818	0	0	644	290	38	200	20	274	14548
(51)	92	0	0	0	44	0	98	122	0	74	34	0	0	0	34	2170
(52)	64	0	0	0	30	0	68	78	78	0	16	0	0	0	16	1612
(60)	84	348	44	30	0	0	0	0	100	62	28	0	16	0	20	1908
(61)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(62)	196	818	98	68	0	0	0	0	240	0	0	0	50	0	62	4974
(63)	0	0	122	78	0	0	0	0	0	0	0	0	62	0	74	3856
(64)	0	0	0	78	100	0	240	0	0	0	84	0	58	0	74	4322
(65)	152	644	74	0	62	0	0	0	0	0	0	0	0	0	46	3668
(66)	68	290	34	16	28	0	0	0	84	0	0	0	0	0	12	1776
(70)	0	38	0	0	0	0	0	0	0	0	0	0	0	0	0	50
(71)	46	200	0	0	16	0	50	62	58	0	0	0	0	0	4	1358
(72)	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	32
(101)	62	274	34	16	20	0	62	74	74	46	12	0	4	0	0	1748
(TOT)	2262	14548	2170	1612	1908	0	4974	3856	4322	3668	1776	50	1358	32	1748	116256

TABLE 3-10. 12-HOUR ZONE-TO-ZONE DEMAND FOR THE MEDIUM-DEMAND CBD CIRCULATION APPLICATION

	(10)	(11)	(12)	(13)	(14)	(20)	(21)	(22)	(23)	(30)	(31)	(32)	(40)	(41)	(42)	(43)
(10)	0	0	0	0	68	12	0	84	0	0	74	92	46	186	124	122
(11)	0	0	0	0	0	112	0	514	0	1238	532	586	304	1238	0	774
(12)	0	0	0	0	0	62	0	274	1118	0	0	0	162	652	432	420
(13)	0	0	0	0	0	68	0	304	0	756	328	362	182	750	0	466
(14)	68	0	0	0	0	34	0	138	572	332	0	0	84	332	224	204
(20)	12	112	62	68	34	0	0	0	0	92	40	40	16	92	62	58
(21)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(22)	84	514	274	304	138	0	0	0	0	386	166	182	92	0	0	240
(23)	0	0	1118	0	572	0	0	0	0	1554	674	750	382	0	0	986
(30)	0	1238	0	756	332	92	0	386	1554	0	0	436	226	918	612	582
(31)	74	532	0	328	0	40	0	166	674	0	0	0	94	396	274	246
(32)	92	586	0	362	0	40	0	182	750	436	0	0	104	436	298	278
(40)	46	304	162	182	84	16	0	92	382	226	94	104	0	0	146	0
(41)	186	1238	652	750	332	92	0	0	0	918	396	436	0	0	0	0
(42)	124	0	432	0	224	62	0	0	0	612	274	298	146	0	0	0
(43)	122	774	420	466	204	58	0	240	986	582	246	278	0	0	0	0
(44)	108	0	350	0	182	40	0	196	0	514	226	240	124	0	0	0
(50)	482	2758	1472	0	0	182	0	520	2304	2176	960	1014	516	2130	0	1296
(51)	62	328	174	0	0	12	0	92	432	268	114	122	62	250	166	162
(52)	34	224	122	132	62	2	0	62	284	168	78	78	40	166	108	100
(60)	34	268	138	162	70	16	0	84	324	190	78	92	0	0	124	0
(61)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(62)	100	648	348	392	172	46	0	200	824	486	204	232	114	482	324	0
(63)	122	812	428	490	220	58	0	246	1018	598	268	290	146	0	0	0
(64)	138	814	432	0	224	58	0	240	1046	620	278	298	152	614	0	0
(65)	78	514	274	304	138	34	0	152	638	382	166	182	92	382	250	0
(66)	34	224	122	132	62	2	0	68	274	162	74	78	38	162	104	100
(70)	0	12	2	2	0	0	0	0	4	2	0	0	0	2	0	2
(71)	28	162	92	94	44	0	0	46	202	124	58	58	34	124	84	74
(72)	0	12	2	2	0	0	0	0	16	4	0	0	0	4	2	0
(101)	34	196	100	122	58	4	0	62	246	142	62	70	0	146	98	92
(TOT)	2062	12270	7176	5048	3220	1142	0	4348	13648	12968	5390	6318	3156	9462	3432	6202

TABLE 3-10. 12-HOUR ZONE-TO-ZONE DEMAND FOR THE MEDIUM-DEMAND CBD CIRCULATION APPLICATION (Cont.)

	(44)	(50)	(51)	(52)	(60)	(61)	(62)	(63)	(64)	(65)	(66)	(70)	(71)	(72)	(101)	(TOT)
(10)	108	482	62	34	34	0	100	122	138	78	34	0	28	0	34	2062
(11)	0	2758	328	224	268	0	648	812	814	514	224	12	162	12	196	12270
(12)	350	1472	174	122	138	0	348	428	432	274	122	2	92	2	100	7176
(13)	0	0	0	132	162	0	392	490	0	304	132	2	94	2	122	5048
(14)	182	0	0	62	70	0	172	220	224	138	62	0	44	0	58	3220
(20)	40	182	12	2	16	0	46	58	58	34	2	0	0	0	4	1142
(21)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(22)	196	520	92	62	84	0	200	246	240	152	68	0	46	0	62	4348
(23)	0	2304	432	284	324	0	824	1018	1046	638	274	4	202	16	246	13648
(30)	514	2176	268	168	190	0	486	598	620	382	162	2	124	4	142	12968
(31)	226	960	114	78	78	0	204	268	278	166	74	0	58	0	62	5390
(32)	240	1014	122	78	92	0	232	290	298	182	78	0	58	0	70	6318
(40)	124	516	62	40	0	0	114	146	152	92	38	0	34	0	0	3156
(41)	0	2130	250	166	0	0	482	0	614	382	162	2	124	4	146	9462
(42)	0	0	166	108	124	0	324	0	0	250	104	0	84	2	98	3432
(43)	0	1296	162	100	0	0	0	0	0	0	100	2	74	0	92	6202
(44)	0	0	124	84	104	0	268	0	0	200	92	2	62	0	84	3000
(50)	0	0	0	0	466	2	1088	0	0	852	382	50	274	34	348	19306
(51)	124	0	0	0	58	0	132	162	0	94	40	0	0	0	40	2894
(52)	84	0	0	0	38	0	92	100	100	0	28	0	0	0	28	2130
(60)	104	466	58	38	0	0	0	0	132	84	34	0	30	0	34	2560
(61)	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
(62)	268	1088	132	92	0	0	0	0	320	0	0	0	68	0	78	6618
(63)	0	0	162	100	0	0	0	0	0	0	0	0	74	0	94	5126
(64)	0	0	0	100	132	0	320	0	0	0	104	2	74	0	100	5746
(65)	200	852	94	0	84	0	0	0	0	0	0	0	0	0	62	4878
(66)	92	382	40	28	34	0	0	0	104	0	0	0	0	0	24	2340
(70)	2	50	0	0	0	0	0	0	2	0	0	0	0	0	0	80
(71)	62	274	0	0	30	0	68	74	74	0	0	0	0	0	16	1822
(72)	0	34	0	0	0	0	0	0	0	0	0	0	0	0	0	76
(101)	84	348	40	28	34	0	78	94	100	62	24	0	16	0	0	2340
(TOT)	3000	19306	2894	2130	2560	2	6618	5126	5746	4878	2340	80	1822	76	2340	154760

TABLE 3-11. 12-HOUR ZONE-TO-ZONE DEMAND FOR THE HIGH-DEMAND CBD CIRCULATION APPLICATION

	(10)	(11)	(12)	(13)	(14)	(20)	(21)	(22)	(23)	(30)	(31)	(32)	(40)	(41)	(42)	(43)
(10)	0	0	0	C	84	20	0	100	0	0	92	108	58	232	162	152
(11)	0	0	0	C	0	142	0	624	0	1540	676	740	382	1540	0	960
(12)	C	0	0	0	0	78	0	342	1396	0	0	0	196	818	536	514
(13)	0	0	C	C	0	84	0	382	0	946	420	446	230	936	0	582
(14)	84	0	0	C	0	38	0	168	710	420	0	0	100	420	278	268
(20)	20	142	78	84	38	0	0	0	0	108	58	58	28	104	74	70
(21)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(22)	100	624	342	382	168	0	0	0	0	482	212	226	112	0	0	298
(23)	0	0	1396	0	710	0	0	0	0	1936	830	936	474	0	0	1238
(30)	0	1540	0	946	420	108	C	482	1936	0	0	548	284	1142	764	726
(31)	92	676	0	420	0	58	0	212	830	0	0	0	122	490	328	312
(32)	108	740	0	446	0	58	0	226	936	548	0	0	132	548	366	348
(40)	58	382	196	230	100	28	C	112	474	284	122	132	0	0	186	0
(41)	232	1540	818	936	420	104	0	0	0	1142	490	548	0	0	C	0
(42)	162	0	536	C	278	74	0	0	0	764	328	366	186	0	0	0
(43)	152	960	514	582	268	70	0	298	1238	726	312	348	0	0	0	0
(44)	138	0	440	0	230	58	0	246	0	644	284	304	162	0	0	0
(50)	610	3446	1852	C	0	230	C	652	2882	2728	1200	1256	652	2656	0	1620
(51)	74	420	224	0	0	20	0	112	536	328	146	146	74	320	204	196
(52)	46	282	152	162	74	2	0	74	350	220	98	100	58	208	138	132
(60)	44	328	166	200	92	24	0	100	398	236	98	112	0	0	162	0
(61)	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(62)	124	868	428	49C	220	62	0	246	1034	612	268	294	146	610	398	0
(63)	152	1010	532	612	274	70	0	304	1274	750	328	362	182	0	0	0
(64)	166	1014	536	C	282	68	0	304	1318	784	348	366	190	774	0	0
(65)	98	632	342	382	168	38	0	190	806	476	204	226	112	476	320	0
(66)	40	278	146	166	74	4	0	82	348	202	92	98	50	202	138	132
(70)	C	20	2	4	0	0	0	0	16	4	0	0	0	4	2	2
(71)	34	200	104	122	58	2	0	58	258	162	70	74	38	162	100	94
(72)	C	20	2	2	0	0	0	0	28	12	0	0	0	12	2	2
(101)	34	246	132	152	68	12	0	74	304	182	76	92	0	182	124	112
(TOT)	2568	15308	8938	6318	4026	1452	0	5388	17072	16236	6750	7886	3968	11836	4282	7758

TABLE 3-11. 12-HOUR ZONE-TO-ZONE DEMAND FOR THE HIGH-DEMAND CBD CIRCULATION APPLICATION (Cont.)

	(44)	(50)	(51)	(52)	(60)	(61)	(62)	(63)	(64)	(65)	(66)	(70)	(71)	(72)	(101)	(TOT)
(10)	138	610	74	46	44	0	124	152	166	98	40	0	34	0	34	2568
(11)	0	3446	420	282	328	0	808	1010	1014	632	278	20	200	20	246	15308
(12)	440	1852	224	152	166	0	428	532	536	342	146	2	104	2	132	8938
(13)	0	0	0	162	200	0	490	612	0	382	166	4	122	2	152	6318
(14)	230	0	0	74	92	0	220	274	282	168	74	0	58	0	68	4026
(20)	58	230	20	2	24	0	62	70	68	38	4	0	2	0	12	1452
(21)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(22)	246	652	112	74	100	0	246	304	304	190	82	0	58	0	74	5388
(23)	0	2882	536	350	398	0	1034	1274	1318	806	348	16	258	28	304	17072
(30)	644	2728	328	220	236	0	612	750	784	476	202	4	162	12	182	16236
(31)	284	1200	146	58	98	0	268	328	348	204	92	0	70	0	74	6750
(32)	304	1256	146	100	112	0	294	362	366	226	98	0	74	0	92	7886
(40)	162	652	74	58	0	0	146	182	190	112	50	0	38	0	0	3968
(41)	0	2656	320	208	0	0	610	0	774	476	202	4	162	12	182	11836
(42)	0	0	204	138	162	0	398	0	0	320	138	2	100	2	124	4282
(43)	0	1620	196	132	0	0	0	0	0	0	132	2	94	2	112	7758
(44)	0	0	152	100	138	0	328	0	0	246	108	2	74	0	100	3754
(50)	0	0	0	0	582	4	1358	0	0	1064	476	62	338	38	432	24138
(51)	152	0	0	0	74	0	162	200	0	122	58	0	0	0	58	3626
(52)	100	0	0	0	46	0	108	132	128	0	34	0	0	0	34	2678
(60)	138	582	74	46	0	0	0	0	166	100	44	0	34	0	38	3182
(61)	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	4
(62)	328	1358	162	108	0	0	0	0	398	0	0	2	84	2	98	8280
(63)	0	0	200	132	0	0	0	0	0	0	0	0	94	2	122	6400
(64)	0	0	0	128	166	0	398	0	0	0	138	4	94	2	124	7204
(65)	246	1064	122	0	100	0	0	0	0	0	0	0	0	0	74	6076
(66)	108	476	58	34	44	0	0	0	138	0	0	0	0	0	34	2944
(70)	2	62	0	0	0	0	2	0	4	0	0	0	0	0	0	124
(71)	74	338	0	0	34	0	84	94	94	0	0	0	0	0	24	2278
(72)	0	38	0	0	0	0	2	2	2	0	0	0	0	0	0	124
(101)	100	432	58	34	38	0	98	122	124	74	34	0	24	0	0	2926
(TOT)	3754	24138	3626	2678	3182	4	8280	6400	7204	6076	2944	124	2278	124	2926	193524

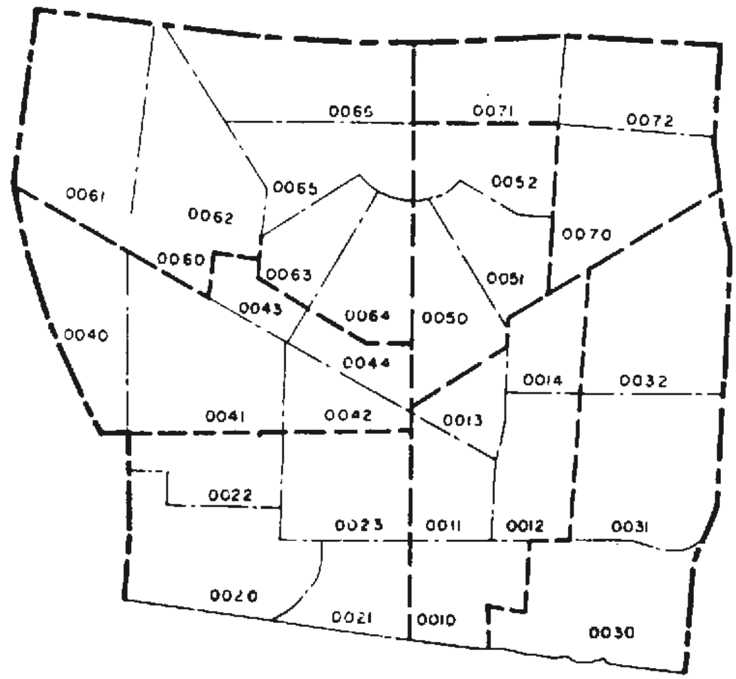


FIGURE 3-9. RELATIVE ZONE LOCATIONS IN DETROIT CBD

TABLE 3-11A. SYNCHRONIZED SHUTTLE NETWORK LINK TRAVEL TIMES

Link From	Link To	Synchronized* (min.)
1	2	2.08**
2	3	1.55
3	4	1.52
4	5	1.28
5	6	1.52
6	7	1.52
7	8	1.35
8	9	1.35
9	10	1.63***
10	11	1.43***
11	1	2.27
1	11	2.77**
11	10	1.02
10	9	1.63
9	8	1.77***
8	7	1.35
7	6	1.52
6	5	1.52
5	4	1.28
4	3	1.52
3	2	1.55
2	1	1.58

* Includes a 30-second dwell time, unless noted otherwise
** Includes a 60-second dwell time
*** Includes a 55-second dwell time

the assumed average wait times for the two shuttle alternatives. Transfer time is another element of wait time for the shuttle deployment. An average transfer time of 30 seconds was assumed for the synchronized shuttle alternative. The transfer times listed in Table 3-13, which are one-half the assumed headway on each shuttle, were assumed for the non-synchronized case; no transfer time penalty is assumed for the synchronized case.

The 12-hour, station-to-station demand matrices which were generated for the five SLT deployments using the FSM are presented in Tables 3-14 through 3-18. Two matrices for the shuttle deployment, non-synchronized and synchronized, are presented. Since the zone-to-zone demand is symmetrical, the direction of operation of the single-lane loops has no effect on the station-to-station demand which is generated using the FSM. Because the proposed DPM system for Detroit is intended to operate in the counter-clockwise direction, that direction is assumed in this study.

Each 12-hour station-to-station matrix can be converted to a matrix which represents one of the standard time intervals by multiplying the matrix by the appropriate factor in Figure 3-8. For example, to obtain a peak 15-minute matrix which is expressed as an hourly rate, the 12-hour matrix is multiplied by 4(.0553) or .2212. This result for each of the SLT deployments in the CBD circulation application is presented in Tables 3-19 through 3-23.

Station-to-station demand matrices for the PRT deployment in the high demand CBD circulation application was determined in a similar manner using the FSM and the appropriate zone-to-zone demand model. The assumptions used in generating the PRT 1 demand are:

- AGT Velocity - 36 km/h
- Feeder Velocity - 4.8 km/h
- Average Wait Time - 3 minutes
- Service Policy - Demand responsive.

These assumptions were used in conjunction with the network shown in Figure 4-19 to generate inter-station travel times and then to map zone-to-zone demands into station-to-station demands. The daily station-to-station demand for PRT 1 is shown in Table 3-23A.

TABLE 3-12. AVERAGE PASSENGER WAIT TIME FOR SHUTTLE ALTERNATIVES

Shuttle	Average Wait Time - Minutes	
	Synchronized	Non-Synchronized
2-3-4-5	4.40	4.35
5-6-7-8	4.40	4.39
8-9-10-11	4.40	4.59
11-1-2	4.40	3.85

TABLE 3-13. NON-SYNCHRONIZED STATION TRANSFER TIMES (SECONDS)

Station	Direction of Travel	
	Clockwise	Counter-Clockwise
2	4.35	3.85
5	4.39	4.35
8	4.59	4.39
11	3.85	3.59

Assumptions:

- Cruise Velocity is 27 km/h
- Station dwell applied to each link
- Acceleration/deceleration rate is 1 m/s^2
- Transfer time = 1/2 headway

TABLE 3-14. 12-HOUR STATION-TO-STATION DEMAND FOR THE MEDIUM DEMAND CBD CIRCULATION APPLICATION, COUNTER-CLOCKWISE LOOP NETWORK

from \ to	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(2)	127	0	0	0	0	114	78	304	111	177	107	0	0	0	1018
(3)	0	0	0	0	0	72	63	660	324	267	334	0	0	0	1720
(4)	0	335	144	0	0	0	103	703	864	659	1137	0	0	0	3945
(5)	0	104	67	1007	0	0	0	346	456	853	894	0	0	0	3727
(6)	0	179	119	3084	405	0	0	0	657	2438	1633	0	0	0	8515
(7)	0	249	117	2238	2785	1483	0	0	0	0	1458	0	0	0	8330
(8)	0	78	47	900	888	758	618	0	0	0	2	0	0	0	3291
(9)	0	162	98	1007	1860	1900	747	1368	0	0	0	0	0	0	7142
(10)	0	0	0	0	584	1311	700	1521	0	0	0	0	0	0	4116
(11)	0	95	51	742	1170	2644	1280	3917	410	0	0	0	0	0	10309
TOTAL TRIPS DURING INTERVAL (7:00 AM TO 7:00 PM)															52113

TABLE 3-15. 12-HOUR STATION-TO-STATION DEMAND FOR THE HIGH DEMAND CBD CIRCULATION APPLICATION, COUNTER-CLOCKWISE LOOP NETWORK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(2)	157	0	0	0	0	144	97	383	136	226	133	0	0	0	1276
(3)	0	0	0	0	0	91	75	828	414	336	414	0	0	0	2158
(4)	0	419	178	0	0	0	133	887	1076	821	1424	0	0	0	4938
(5)	0	125	89	1259	0	0	0	442	570	1050	1119	0	0	0	4654
(6)	0	227	147	3873	511	0	0	0	824	3027	2048	0	0	0	10657
(7)	0	318	152	2800	3487	1853	0	0	0	0	1833	0	0	0	10443
(8)	0	97	61	1124	1134	949	776	0	0	0	6	0	0	0	4147
(9)	0	205	128	1255	2315	2368	924	1725	0	0	0	0	0	0	8920
(10)	0	0	0	0	722	1629	872	1911	0	0	0	0	0	0	5134
(11)	0	118	60	930	1459	3315	1616	4913	514	0	0	0	0	0	12925
TOTAL TRIPS DURING INTERVAL															65252

TABLE 3-16. 12-HOUR STATION-TO-STATION DEMAND FOR THE MEDIUM-DEMAND CBD CIRCULATION APPLICATION, TWO-WAY LOOP NETWORK

from \ to	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	127	0	0	0	0	0	0	0	0	0	0	0	0	127
(2)	127	0	0	111	104	179	226	103	111	177	107	0	0	0	1245
(3)	0	0	0	88	67	119	117	47	63	267	334	0	0	0	1102
(4)	0	111	88	0	1007	3084	2238	604	845	0	1137	0	0	0	9114
(5)	0	104	67	1007	0	405	2785	888	1860	584	576	0	0	0	8276
(6)	0	179	119	3084	405	0	1483	758	1900	1311	1253	0	0	0	10492
(7)	0	226	117	2238	2785	1483	0	618	747	700	1045	0	0	0	9959
(8)	0	103	47	604	888	758	618	0	1368	1521	2925	0	0	0	8832
(9)	0	111	63	845	1860	1900	747	1368	0	0	410	0	0	0	7304
(10)	0	177	267	0	584	1311	700	1521	0	0	0	0	0	0	4560
(11)	0	107	334	1137	576	1253	1045	2925	410	0	0	0	0	0	7787
TOTAL TRIPS DURING INTERVAL (7:00 AM TO 7:00 PM)															68798

TABLE 3-17. 12-HOUR STATION-TO-STATION DEMAND FOR THE LOW DEMAND CBD CIRCULATION APPLICATION, NON-SYNCHRONOUS SHUTTLE NETWORK

from \ to	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	0	0	0	0	0	1	26	0	152	0	0	0	179
(2)	0	0	0	0	163	39	18	182	50	0	777	0	0	0	1229
(3)	0	0	0	0	111	20	86	14	0	0	318	0	0	0	549
(4)	0	0	0	0	2395	0	349	237	0	0	245	0	0	0	3226
(5)	0	163	111	2395	0	292	2179	1610	519	0	386	0	0	0	7655
(6)	0	39	20	0	292	0	1	1342	483	867	864	0	0	0	3908
(7)	0	18	86	348	2179	1	0	0	125	0	0	0	0	0	2757
(8)	1	182	14	237	1610	1342	0	0	335	1542	2874	0	0	0	8137
(9)	26	50	0	0	519	483	125	335	0	0	541	0	0	0	2079
(10)	0	0	0	0	0	867	0	1542	0	0	0	0	0	0	2409
(11)	152	777	318	245	386	864	0	2874	541	0	0	0	0	0	6157
TOTAL TRIPS DURING INTERVAL															38285

TABLE 3-18. 12-HOUR STATION-TO-STATION DEMAND FOR THE HIGH DEMAND CBD CIRCULATION APPLICATION, SYNCHRONOUS SHUTTLE NETWORK

from \ to	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2
(2)	0	0	0	0	75	132	185	57	79	131	78	0	0	0	737
(3)	0	0	0	0	50	86	94	34	45	188	237	0	0	0	734
(4)	0	0	0	0	658	1944	1465	860	604	0	607	0	0	0	6138
(5)	0	75	50	658	0	235	1919	659	1312	403	407	0	0	0	5718
(6)	0	132	86	1942	235	0	1	555	1354	1078	747	0	0	0	6130
(7)	0	185	94	1464	1919	1	0	0	528	578	616	0	0	0	5385
(8)	1	57	34	860	659	555	0	0	76	183	1154	0	0	0	3579
(9)	0	91	27	558	1297	1341	523	76	0	0	0	0	0	0	3913
(10)	0	130	186	0	398	916	483	0	0	0	0	0	0	0	2113
(11)	1	105	255	807	407	901	508	1405	198	0	0	0	0	0	4587
TOTAL TRIPS DURING INTERVAL															39036

TABLE 3-19. PEAK 15-MINUTE STATION-TO-STATION DEMAND EXPRESSED AS AN HOURLY RATE FOR THE MEDIUM-DEMAND CBD CIRCULATION APPLICATION, COUNTER-CLOCKWISE LOOP NETWORK

from \ to	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(2)	28	0	0	0	0	25	17	67	24	39	23	0	0	0	223
(3)	0	0	0	0	0	15	13	145	71	59	73	0	0	0	376
(4)	0	74	31	0	0	0	22	155	191	145	251	0	0	0	869
(5)	0	23	14	222	0	0	0	76	100	188	197	0	0	0	820
(6)	0	39	26	682	89	0	0	0	145	539	361	0	0	0	1881
(7)	0	55	25	495	616	328	0	0	0	0	322	0	0	0	1841
(8)	0	17	10	199	196	167	136	0	0	0	0	0	0	0	725
(9)	0	35	21	222	411	420	165	302	0	0	0	0	0	0	1576
(10)	0	0	0	0	129	289	154	336	0	0	0	0	0	0	908
(11)	0	21	11	164	258	584	283	866	90	0	0	0	0	0	2277
TOTAL TRIPS DURING INTERVAL															11496

TABLE 3-20. PEAK 15-MINUTE STATION-TO-STATION DEMAND EXPRESSED AS AN HOURLY RATE FOR THE HIGH DEMAND CBD CIRCULATION APPLICATION, COUNTER-CLOCKWISE LOOP NETWORK

from \ to	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(2)	34	0	0	0	0	31	21	84	30	49	29	0	0	0	278
(3)	0	0	0	0	0	20	16	183	91	74	91	0	0	0	475
(4)	0	92	39	0	0	0	29	196	238	181	314	0	0	0	1089
(5)	0	27	19	278	0	0	0	97	126	232	247	0	0	0	1026
(6)	0	50	32	856	113	0	0	0	182	669	453	0	0	0	2355
(7)	0	70	33	619	771	409	0	0	0	0	405	0	0	0	2307
(8)	0	21	13	248	250	209	171	0	0	0	1	0	0	0	913
(9)	0	45	28	277	512	523	204	381	0	0	0	0	0	0	1970
(10)	0	0	0	0	159	360	192	422	0	0	0	0	0	0	1133
(11)	0	26	13	205	322	733	357	1086	113	0	0	0	0	0	2855
TOTAL TRIPS DURING INTERVAL															14401

TABLE 3-21. PEAK 15-MINUTE STATION-TO-STATION DEMAND EXPRESSED AS AN HOURLY RATE FOR THE MEDIUM DEMAND CBD CIRCULATION APPLICATION, TWO-WAY LOOP NETWORK

from \ to	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	28	0	0	0	0	0	0	0	0	0	0	0	0	28
(2)	28	0	0	24	23	39	49	22	24	39	23	0	0	0	271
(3)	0	0	0	19	14	26	25	10	13	59	73	0	0	0	239
(4)	0	24	19	0	222	682	495	133	186	0	251	0	0	0	2012
(5)	0	23	14	222	0	89	616	196	411	129	127	0	0	0	1827
(6)	0	39	26	682	89	0	328	167	420	289	277	0	0	0	2317
(7)	0	49	25	495	616	328	0	136	165	154	231	0	0	0	2199
(8)	0	22	10	133	196	167	136	0	302	336	647	0	0	0	1949
(9)	0	24	13	186	411	420	165	302	0	0	90	0	0	0	1611
(10)	0	39	59	0	129	289	154	336	0	0	0	0	0	0	1006
(11)	0	23	73	251	127	277	231	647	90	0	0	0	0	0	1719
TOTAL TRIPS DURING INTERVAL															15178

TABLE 3-22. PEAK 15-MINUTE STATION-TO-STATION DEMAND EXPRESSED AS AN HOURLY RATE FOR THE LOW DEMAND CBD CIRCULATION APPLICATION, NON-SYNCHRONIZED SHUTTLE NETWORK

from \ to	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	0	0	0	0	0	0	5	0	33	0	0	0	38
(2)	0	0	0	0	36	8	3	40	11	0	171	0	0	0	269
(3)	0	0	0	0	24	4	19	3	0	0	70	0	0	0	120
(4)	0	0	0	0	529	0	77	52	0	0	54	0	0	0	712
(5)	0	36	24	529	0	64	481	356	114	0	85	0	0	0	1689
(6)	0	8	4	0	64	0	0	296	106	191	191	0	0	0	860
(7)	0	3	19	76	481	0	0	0	27	0	0	0	0	0	606
(8)	0	40	3	52	356	296	0	0	74	341	635	0	0	0	1797
(9)	5	11	0	0	114	106	27	74	0	0	119	0	0	0	456
(10)	0	0	0	0	0	191	0	341	0	0	0	0	0	0	532
(11)	33	171	70	54	85	191	0	635	119	0	0	0	0	0	1358
TOTAL TRIPS DURING INTERVAL															8437

TABLE 3-23. PEAK 15-MINUTE STATION-TO-STATION DEMAND EXPRESSED AS AN HOURLY RATE FOR THE LOW DEMAND CBD CIRCULATION APPLICATION, SYNCHRONIZED SHUTTLE NETWORK

from \ to	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(2)	0	0	0	0	16	29	40	12	17	28	17	0	0	0	159
(3)	0	0	0	0	11	19	20	7	9	41	52	0	0	0	159
(4)	0	0	0	0	145	430	324	145	133	0	178	0	0	0	1355
(5)	0	16	11	145	0	51	424	145	290	89	90	0	0	0	1261
(6)	0	29	19	429	51	0	0	122	299	238	165	0	0	0	1352
(7)	0	40	20	323	424	0	0	0	116	127	136	0	0	0	1186
(8)	0	12	7	145	145	122	0	0	16	84	255	0	0	0	786
(9)	0	11	5	132	286	296	115	16	0	0	0	0	0	0	861
(10)	0	28	41	0	88	202	106	0	0	0	0	0	0	0	465
(11)	0	23	56	178	90	199	112	310	43	0	0	0	0	0	1011
TOTAL TRIPS DURING INTERVAL															8595

TABLE 3-23A. DAILY STATION DEMAND DISTRIBUTION - PRT 1

ORIGIN	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	0	0	0	43	143	20	60	85	78	69	99	26	13	184
2	7	0	0	57	225	49	99	128	133	106	123	52	19	485
3	0	37	0	0	0	0	0	0	0	0	0	0	44	0
4	0	122	98	0	1434	107	405	831	483	431	243	950	28	0
5	0	150	106	2974	0	177	964	2310	1875	1377	491	1760	0	0
6	0	381	199	2646	1622	0	433	2455	2991	2557	3379	157	2	0
7	0	99	60	1678	928	1104	0	227	460	552	1095	321	0	0
8	0	125	81	960	1321	3538	711	0	335	524	1312	366	0	1066
9	0	0	0	0	0	0	0	0	0	719	0	0	0	0
10	0	105	68	850	1919	323	545	0	0	0	1262	372	1	2949
11	0	62	48	770	1230	306	1093	2176	1598	1275	0	2627	1	0
12	0	55	28	196	326	70	314	384	75	408	53	0	0	0
13	0	18	12	145	373	0	0	0	0	1	233	70	0	303
14	0	372	127	1045	5264	535	1334	1639	66	1325	3041	0	0	0

3.5.4 CBD Line-Haul Demand

Two CBD line-haul demand models representing a low-demand and a high-demand CBD application were generated. The two demand models differ only in the magnitude of demand. The models are based on two sources of demand information for the Houston CBD: "Downtown Houston Transit Needs Analysis"[10] and "Houston Downtown People Mover" proposal.[11] The "Transit Needs Analysis" presents zone-to-zone demand matrices for two types of trips within the CBD: parking and circulation. Parking trips (pedestrian trips to and from parking lots within the CBD) occur during the hours of 6:00 to 9:00 a.m. and 4:00 to 7:00 p.m. while circulation (secondary) trips occur during the interval from 9:00 a.m. to 4:00 p.m. Identical spatial distributions are reported for the two parking trip intervals, and a different spatial distribution is reported for the circulation trips. The three-hour parking trip matrix is presented as Table 3-24, and the seven-hour circulation trip matrix is presented as Table 3-25 for reference. Figure 3-10 is a map of the Houston CBD in which the zones are identified.

According to the Houston DPM proposal, a large percentage of the projected people mover ridership in the peak period consists of metropolitan area bus patrons who would use the automated system for a portion of their trip. The DPM proposal contains station-to-station matrices which indicate the magnitude and distribution of projected bus transfer trips. Two bus transfer trip matrices are presented in the proposal -- one for the morning peak period from 6:00 to 9:00 a.m. and one for the afternoon peak from 4:00 to 7:00 p.m. The trip matrices are based on the 8-station single lane loop network proposed for the Houston DPM and are presented as Table 3-26. Figure 4-8 illustrates the network and identifies the stations by number. It is also estimated in the DPM proposal that a total of 1413 trips would be made during the evening hours from 7:00 p.m. to midnight. Since no further information is given concerning these trips, it is assumed that the evening trips are evenly distributed over the five-hour period and are distributed spatially in a pattern identical to that of the circulation trips. DPM demand estimates presented in the Houston proposal are listed by trip purpose for each hour of the 13-hour service day in Table 3-27. The table also shows the percentage of total daily trips on the automated system which occurs during each hour of the service day. Figure 3-11 displays the resulting demand profile. This profile illustrates the general form of the CBD line-haul demand model. As indicated above, the daily demand is represented by three different demand matrices: morning peak period parking and bus transfer trips (6:00 to 9:00 a.m.), midday period circulation trips (9:00a.m. to 4:00 p.m.), and afternoon peak period parking and bus transfer trips (4:00 to 7:00 p.m.). The spatial distribution during the evening period (7:00 p.m. to midnight) is represented by the midday period demand matrix. Except for the evening period when the magnitude of demand is assumed to be constant, the demand magnitude is changed each hour by multiplying the appropriate matrix by an hourly demand factor. The hourly factors are listed in Table 3-28.

The general process for generating the demand model for the CBD line-haul application is similar to the process described in the previous section. The FSM is used to generate station-to-station demand matrices using the zone-to-zone parking and circulation trip matrices. The bus transfer trip motrices which are available only in station-to-station format, are then added to the FSM output to complete the station-to-station representation

TABLE 3-24. 1980 PARKING TRIPS IN HOUSTON CBD

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
5.											5			10				14	349						116	161	
6.																											
7.																											
8.																											
9.											6			4				15	94						125	62	1
10.											23			6				34	170						227	100	1
11.					5				6	23		10	3			1	5			3	1			1			
12.											10			10				14	639						94	166	1
13.											3			59				9	228						76	105	3
14.					10				4	6		10	59			1	3			24	70			1			
15.																											
16.											1			1				8	40						53	23	
17.											5			3				112	315						419	146	1
18.					14				15	34		14	9			8	112			33	11		2	17			
19.					349				94	170		639	228			40	315			1484	270		11	87			
20.											3			24				33	1484						219	386	20
21.											1			70				11	270						90	125	4
22.																											
23.																		2	11						57	20	
24.											1			1				17	87						1047	205	1
25.					116				125	227		94	76			53	419			219	90		57	1047			
26.					161				62	100		166	105			23	146			386	125		20	205			
27.					1				1	1		1	3				1			20	4			1			
28.											1			29				10	196						261	458	24
29.											1			1				6	46						136	68	1
30.														1				4	31						113	50	
31.					44				106	192		29	29			45	355			67	34		49	888			
32.					146				157	250		104	95			58	365			242	113		50	513			
33.					178				85	125		145	116			29	161			337	138		22	179			
34.											1			4				5	103						138	242	13
35.											1			23				11	196						260	362	11
36.																											
37.																		2	14						42	21	
38.					25				52	84		16	16			20	123			36	19		17	173			
39.					91				97	143		60	59			33	184			139	70		25	204			
40.														1				2	41						54	95	1
41.														3				2	38						51	70	1
42.											1			7				4	69						91	112	2
43.																		2	13						31	18	3
44.																											
45.																		1	9						27	13	
46.					1				1	2		1	1				2			2	1			2			
47.											1			2				5	88						117	163	1
48.														3				2	56						75	91	2
49.														1				1	14						19	21	
50.																											
51.																											
52.					7				13	18		4	5			4	21			10	6		3	21			
53.											1			1				4	33						99	50	
54.														1				2	41						54	66	1
55.					1				1	1		1	1				1			3	2			1			
56.														4				3	49						65	69	1

	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
5.				44	146	178					25	91							1						7			1	
6.																													
7.																													
8.																													
9.				106	157	85					53	97							1						13			1	
10.				192	250	125					84	143							2						18			1	
11.	1	1					1	1							1					1						1			
12.				29	104	145					16	60							1						4			1	
13.				29	95	116					16	59							1						5			1	
14.	29	1	1				4	23					1	2	7					2	2	1				1	1		4
15.																													
16.				45	58	29					20	33													4				
17.				355	365	161					123	184							2						21			1	
18.	10	6	4				5	11		2			1	2	4	2		1		5	3	1				4	2		3
19.	196	46	31				103	196		14			41	38	69	13		9		88	56	14				33	41		49
20.				67	242	337					36	139							2						10			3	
21.				34	113	138					19	70							1						6			2	
22.																													
23.				49	50	22					17	25													3				
24.				888	513	179					173	204		51					2						21			1	
25.	261	136	113				138	260		42			54	70	91	31		27		117	75	19				99	54		65
26.	458	68	50				242	362		21			95	2	112	18		13		163	91	21				50	66		69
27.	24	1					13	11					1		3					1	2						1		1
28.				80	288	400					43	165							2						12			4	
29.				463	476	210					161	240							2						28			1	
30.				866	500	174					169	199							2						20			1	
31.	80	463	866				117	221		142			46	43	78	60		91		99	64	16				84	46		55
32.	288	476	500				608	908		146			238	176	280	89		94		409	229	53				346	166		172
33.	400	210	174				1903	1600		64			746	311	390	48		41		720	319	65				152	231		194
34.				117	608	1903					51	242							2						11			6	
35.				221	908	1600					110	457							5						27			11	
36.																													
37.				142	146	64					444	295							2						24			1	
38.	43	168	169				51	110		444			80	60	94	83		285		138	77	18				117	56		58
39.	165	240	199				242	457		295			853	356	446	124		189		823	365	74				697	264		222
40.				46	238	746					80	853							4						10			2	
41.				43	176	311					60	356							3						10				
42.				78	280	390					94	446							4						20				
43.				60	89	48					83	124							4						40				
44.																													
45.				91	94	41					285	189							13						138				
46.	2	3	2				2	5		2			4	3	4	4		13		55	14	2							
47.				99	409	720					138	823							55						67				
48.				64	239	319					77	365							14						37				
49.				16	53	65					18	74							2						9				
50.																													
51.																													
52.	12	28	20				11	27		24			10	10	20	40		138		67	37	9							
53.				84	346	152					117	697							46						508				
54.				46	166	231					56	264							10						108				
55.	4	1	1				6	11		1			2	9	11	1		1		20	81	7							
56.				55	172	194					58	222							6						63				

TABLE 3-25. 1980 CIRCULATION TRIPS IN HOUSTON CBD

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
5.										1	9	4	2	1			1	10	18	3	1				4	9	1
6.																											
7.																											
8.																											
9.																											
10.					1						71	5	1	4			6	13	12	1	1			64	21	7	3
11.					9					73		199	42	57			48	1626	442	56	21			203	521	215	51
12.					4					5	190		40	22			5	101	381	29	8			16	43	105	16
13.					2					1	42	40		108			2	23	71	72	14			18	25	34	41
14.					1					4	57	22	108				5	67	111	78	179			16	39	69	39
15.																											
16.																											
17.					1					6	48	5	2	5				211	78	9	4			545	117	37	12
18.					10					13	1626	101	23	67			311		2683	163	60			1146	3940	710	183
19.					18					12	442	381	71	111			78	2653		655	149			419	977	3368	391
20.					3					1	56	29	72	78			9	163	855		169			79	131	230	483
21.					1					1	21	8	14	179			4	60	149	169				26	45	72	71
22.																											
23.																											
24.										64	203	16	18	16			545	1146	419	79	26				3056	1055	113
25.					4					21	521	43	25	39			117	3940	977	111	45			3056		4296	394
26.					9					7	215	105	34	69			37	710	3368	230	72			1055	4296		1725
27.					1					3	51	16	41	39			12	183	391	483	71			113	394	1725	
28.					1					1	14	5	7	48			3	35	78	44	120			44	85	172	303
29.				1																							
30.										3	18	2	2	3			13	60	35	8	3			110	91	60	12
31.					1					28	137	14	13	18			142	530	269	55	21			2165	1017	531	91
32.					4					15	322	35	21	40			68	1285	581	98	40			1202	5965	1458	255
33.					5					9	168	58	31	53			38	533	1237	162	58			492	1382	5425	531
34.					1						17	7	5	19			2	25	76	40	16			32	120	181	458
35.											4	2	1	12			1	8	17	7	13			18	34	32	40
36.																											
37.																											
38.										17	85	9	10	12			65	309	170	38	15			370	414	296	52
39.					5					7	335	34	15	44			37	559	401	68	35			1010	2162	769	220
40.					2					1	36	13	5	16			5	68	186	24	12			149	237	402	98
41.					1						15	6	4	15			2	32	55	23	11			64	85	104	144
42.					1						9	3	2	18			1	13	39	11	14			35	43	48	50
43.																											
44.																											
45.										12	63	7	8	9			40	217	127	31	12			145	242	204	37
46.					1					3	50	6	5	9			13	152	95	20	9			110	277	164	37
47.					1						14	5	2	8			2	19	82	8	5			65	82	97	35
48.					1						10	4	2	10			1	11	31	11	6			46	51	51	41
49.											5	1	1	8			1	6	13	5	6			17	20	20	19
50.																											
51.																											
52.										11	50	6	8	9			33	193	119	30	13			98	196	181	34
53.					1						17	3	1	5			2	30	20	5	3			67	83	45	17
54.					1					1	15	5	2	7			2	26	50	9	5			53	70	85	29
55.					1					1	20	6	4	15			4	40	63	25	12			55	78	99	70
56.											3	1	1	3				4	7	1	3			8	10	11	8

	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
5.	1			1	4	5	1					5	2	1	1				1	1	1					1	1	1	
6.																													
7.																													
8.																													
9.																													
10.	1		1	28	15	9					17	7	1					12	1						11		1	1	
11.	14		18	137	322	168	17	4			85	235	36	15	9			63	50	14	10	5			59	17	15	20	3
12.	5		2	14	35	58	7	2			9	34	13	6	3			7	6	5	4	1			6	3	5	6	1
13.	7		2	13	21	31	5	1			10	15	5	4	2			8	5	2	2	1			8	1	2	6	1
14.	48		3	18	40	53	19	12			12	46	16	15	18			9	9	8	10	8			9	5	7	15	3
15.																													
16.																													
17.	3		13	142	68	34	2	1			65	37	5	2	1			40	12	2	1	1			33	2	2	4	
18.	38		60	530	1285	533	25	8			309	559	68	22	13			217	152	19	11	6			193	30	26	40	4
19.	70		35	269	581	1237	76	17			170	401	166	55	29			127	95	51	21	13			119	29	50	63	7
20.	44		8	55	98	162	40	7			39	68	24	23	11			31	20	8	11	5			30	5	9	25	3
21.	120		3	21	40	58	16	13			15	35	12	11	16			12	9	5	6	6			13	3	5	12	3
22.																													
23.																													
24.	44		110	2165	1202	492	83	18			370	1010	149	66	35			145	110	65	46	17			98	67	53	55	8
25.	85		91	1017	5965	1382	120	24			414	2162	237	85	43			242	277	82	51	20			196	93	70	78	10
26.	172		60	531	1458	5425	181	32			296	769	402	104	48			204	164	97	51	20			181	45	85	99	11
27.	303		12	91	255	531	458	40			52	220	98	144	50			37	37	35	61	19			34	17	29	70	8
28.			5	33	66	109	37	56			32	53	20	21	38			18	13	7	11	11			17	4	7	18	5
29.																													
30.	5			710	304	125	17	4			149	221	32	13	7			66	30	13	9	4			47	14	11	13	2
31.	33		710		6058	1400	150	29			2945	2487	281	105	52			736	266	103	66	24			409	110	82	86	11
32.	66		304	6058		7797	346	56			1423	11558	703	196	87			667	896	186	102	37			476	218	145	154	18
33.	108		125	1400	7797		1293	119			583	3692	2621	411	145			346	369	392	169	53			281	114	240	224	24
34.	37		17	150	346	1293		44			88	130	64	120	27			62	42	11	19	9			56	7	14	57	4
35.	56		4	29	56	115	44				19	32	12	15	50			14	10	3	5	8			14	2	4	12	3
36.																													
37.																													
38.	22		149	2945	1423	583	88	19				10031	647	198	85			2174	541	182	109	36			670	201	130	121	15
39.	53		221	2487	11558	3692	138	32			10031		2912	408	190			2721	5301	371	151	55			1549	504	276	296	29
40.	20		12	281	703	2621	64	12			647	2912		344	73			314	328	305	68	21			226	49	139	123	10
41.	21		13	105	196	411	120	15			195	408	346		146			121	94	35	114	23			99	15	34	165	10
42.	38		7	82	87	145	27	50			85	190	73	146				59	41	14	37	81			53	8	16	59	19
43.																													
44.																													
45.	18		66	736	667	346	62	14			2174	2721	314	121	59				2243	476	214	61			2478	494	252	203	24
46.	13		30	266	896	369	42	10			541	5301	328	94	41			2243		814	201	49			709	917	269	191	18
47.	7		13	103	186	392	11	3			192	371	305	35	14			476	814		88	20			372	52	273	154	9
48.	11		9	66	102	169	19	5			109	151	68	114	27			214	201	88		67			155	21	61	582	19
49.	11		4	24	37	53	8	8			36	55	21	23	31			61	49	20	67				50	8	18	87	49
50.																													
51.																													
52.	17		47	409	476	281	56	14			670	1549	226	99	53			2478	709	272	155	50				2536	725	461	47
53.	4		14	110	218	114	7	3			201	504	49	15	8			494	917	52	21	8			2536		384	193	13
54.	7		11	82	145	240	14	4			130	276	139	34	16			252	269	273	61	18			725	384		932	35
55.	18		13	86	154	224	97	12			121	296	123	165	99			203	191	154	582	97			461	193	932		261
56.	5		2	11	18	24	4	3			15	39	10	10	19			24	18	9	19	49			47	13	35	261	

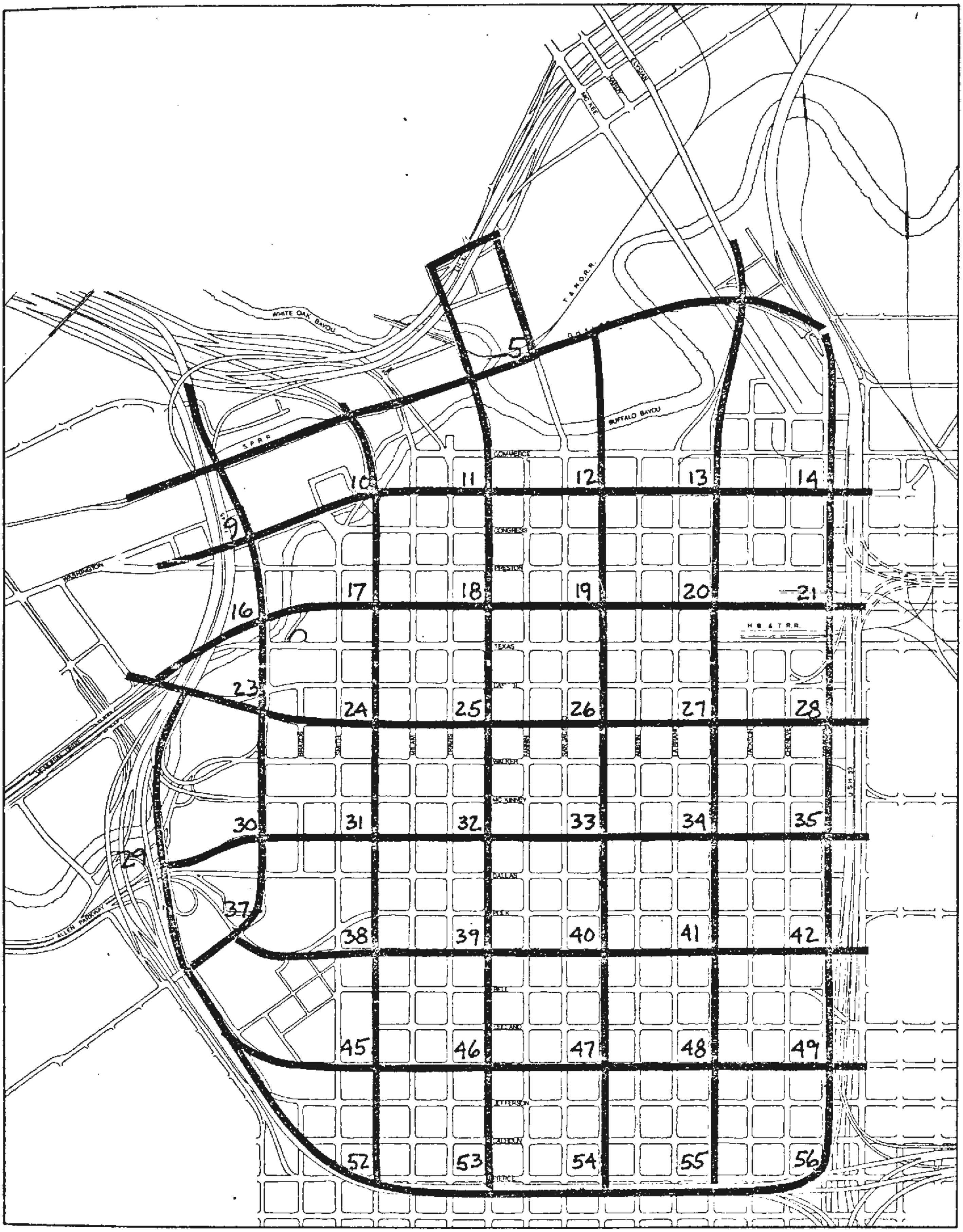


FIGURE 3-10. RELATIVE ZONE LOCATIONS IN HOUSTON CBD

HOUSTON CBD
RICE CENTER FOR COMMUNITY DESIGN & RESEARCH
500' 0 500' 1000' 1500' 2000'

TABLE 3-26. STATION-TO-STATION BUS TRANSFER DEMAND FOR THE PROPOSED HOUSTON DOWNTOWN PEOPLE MOVER

Morning Peak Period			Afternoon Peak Period		
Origin Station	Destination Station	Demand	Origin Station	Destination Station	Demand
1	2	752	1	6	133
1	3	1523	3	6	967
1	4	1076	4	6	1957
1	5	291	5	6	1383
1	6	475	8	1	400
1	7	320	5	1	291
6	1	133	6	1	475
6	7	416	7	1	320
6	4	1383	4	1	1076
6	3	1957	3	1	1523
6	2	967	2	1	752
6	8	400			
TOTAL		9693	TOTAL		9277

TABLE 3-27. HOUSTON CBD DEMAND DATA

Hour	Parking		Circulation		Bus Transfer		Evening		Total	
	# Trips	% of Total	# Trips	% of Total	# Trips	% of Total	# Trips	% of Total	# Trips	% of Total
12-1 a.m.										
1-2										
2-3										
3-4										
4-5										
5-6										
6-7	81	0.32			1260	4.92			1341	5.24
7-8	416	1.62			6494	25.37			6910	26.99
8-9	124	0.48			1939	7.57			2063	8.06
9-10			129	0.50					129	0.50
10-11			217	0.85					217	0.85
11-12			625	2.44					625	2.44
12-1 p.m.			961	3.75					961	3.75
1-2			836	3.27					836	3.27
2-3			663	2.59					663	2.59
3-4			544	2.13					544	2.13
4-5	404	1.58			6030	23.55			6434	25.13
5-6	205	0.80			3061	11.96			3266	12.76
6-7	12	0.05			186	0.73			198	0.77
7-8							283	1.11	283	1.11
8-9							283	1.11	283	1.11
9-10							283	1.11	283	1.11
10-11							283	1.11	283	1.11
11-12							281	1.08	281	1.08
Total	1242	4.85	3975	15.53	18970	74.10	1413	5.52	25600	100.00

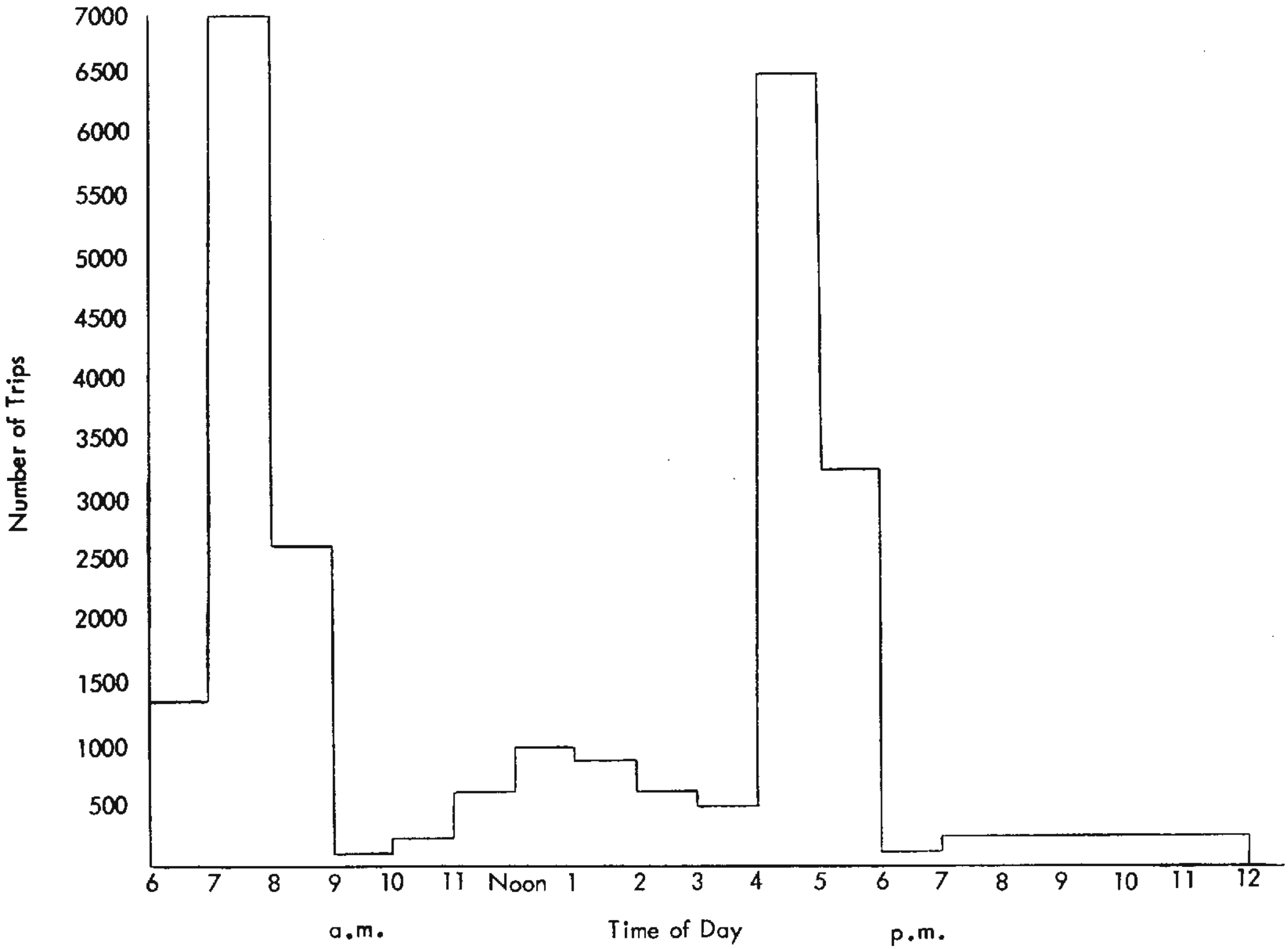


FIGURE 3-11. DEMAND PROFILE

TABLE 3-28. HOURLY DEMAND FACTORS FOR CBD LINE-HAUL DEMAND

Hour	Reference Demand Magnitude	Hourly Demand Factor
Morning Peak		
6 - 7 a.m.	1341	.13
7 - 8	6910	.67
8 - 9	2063	.20
Total	10314	1.00
Off-Peak		
9 - 10 a.m.	129	.03
10 - 11	217	.04
11 - 12	625	.12
12 - 1 p.m.	961	.18
1 - 2	836	.16
2 - 3	663	.12
3 - 4	544	.10
7 - 8	283	.05
8 - 9	283	.05
9 - 10	283	.05
10 - 11	283	.05
11 - 12	281	.05
Total	5388	1.00
Afternoon Peak		
4 - 5 p.m.	6434	.65
5 - 6	3266	.33
6 - 7	198	.02
Total	9898	1.00

of demand. The details of the demand model generation process for the CBD line-haul application are presented in the following paragraphs.

The first step in the demand model generation process was one of calibration. The FSM was used to generate station-to-station demand using the reference zone-to-zone demand matrices and the network configuration proposed for the Houston DPM. The resulting station-to-station demand magnitude was compared to the estimate reported in the Houston DPM proposal. The zone-to-zone matrices were then scaled so that the FSM output would be the desired demand magnitude. Applying scale factors to the input demand matrices is equivalent to applying the same scale factors to the FSM diversion curve. The scaled zone-to-zone demand matrices can then be input to the FSM to estimate the station-to-station demand for alternative networks in the CBD line-haul application.

The FSM requires several inputs to produce the station-to-station trip matrix:

- Zone-to-zone trip matrix
- Zone centroid locations
- Station locations
- Station-to-station performance matrix
- Performance scale factors
  - Zone-to-station performance
  - Zone-to-zone performance
  - AGT performance.

The two zone-to-zone matrices, which apply during different periods of the day, were obtained from the Downtown Houston Transit Needs Analysis and are included as Tables 3-24 and 3-25. Both the zone centroid and station locations were defined in terms of X,Y coordinates in a common coordinate system using the Network Build Module Processor in conjunction with a Tektronix Graphics Tablet. The station-to-station performance matrix is a trip time matrix for travel between stations on the network and is based on the following assumptions:

- Cruise velocity - 48 km/h
- Acceleration/deceleration - 1.0 m/s^2
- Station dwell time - 30 s
- Average wait time - 36 s (one-half the assumed headway).

Table 3-29 shows the network travel times by link which were used for the calibration process. The nodes which define the links coincide with stations as illustrated in Figure 4-8. The performance scale factors are used to calculate station access/egress times and direct zone-to-zone travel times for use in the FSM diversion function. Since the area under consideration is relatively small, walking is considered to be both the station access/egress mode and the alternative transportation mode. The scale factors, then, represent an average walk speed which is used to convert distance into travel time. A speed of 61 m/minute. (200 ft/min) has been assumed.

TABLE 3-29. LINK TRAVEL TIMES

Single-Lane Loop in CBD Line-Haul Application	
Links	Travel Time (seconds)
(1, 2)	74
(2, 3)	72
(3, 4)	63
(4, 5)	88
(5, 6)	59
(6, 7)	80
(7, 4)	79
(4, 3)	63
(3, 2)	72
(2, 8)	82
(8, 1)	68
	Total: 800

Using these inputs, the FSM was used to determine the station-to-station demand matrix for the single-lane loop network proposed for the Houston DPM. Comparison of these results with demand estimates presented in the Houston DPM proposal indicated that the parking trip matrix should be scaled by a factor of .0605 and the circulation trip matrix should be scaled by a factor of .0414 to make the FSM output consistent with the DPM estimates. These scaled zone-to-zone matrices, in conjunction with the reference station-to-station bus transfer matrices presented in Table 3-26 form the basis for the CBD line-haul demand model.

Table 4-1 shows that there are four SLT deployments to be considered in the CBD line-haul application during the System Operations Studies. Three of the system deployments utilize the one-way open-loop network illustrated in Figure 4-8. This network is identical to the one proposed for the Houston DPM project. Therefore it was possible to use the station-to-station bus transfer data reported in the DPM proposal directly. The parking and circulation trip portion of the demand was generated using the FSM with the scaled zone-to-zone demand matrices and the link travel times shown in Table 3-29. For the LGRT system (SLT 9 as defined in Table 4-2) the average wait time was assumed to be 36s while for the SGRT systems (SLT 10 and SLT 11) the average wait time was assumed to be 15s. The difference is due to the assumption that the smaller vehicle system would be operated on shorter headways resulting in shorter average wait times. The difference in assumed wait time results in slight differences in the number of trips assigned to the network. The station-to-station demand for the LGRT system, open-loop network deployment, in the low-demand CBD line-haul application(SLT 9) is presented in Tables 3-30, 3-31, and 3-32 which are the morning peak period matrix, off-peak period matrix, and afternoon peak period matrix, respectively. The corresponding matrices for the SGRT system (SLT 10) are presented as Tables 3-33, 3-34, and 3-35. The peak period matrices for the SGRT deployment are almost identical to those for the LGRT deployment and the off-peak demands differ in total magnitude by less than 10 percent. Therefore in order to minimize the number of matrices to be stored and manipulated the demand matrices generated for SLT 9 (Tables 3-30, 3-31, and 3-32) will be used for the SLT 10 deployment as well.

To permit comparisons among systems designed for similar applications having different demand magnitudes, another CBD line-haul demand model was developed to represent a high demand application. A SGRT system (SLT 11 as defined in Table 4-2) is to be analyzed in this high demand CBD line-haul application. The demand for this application was generated by scaling the low demand CBD line-haul matrices generated for the SLT 10 deployment by a factor of two. The resulting daily demand of 51,200 trips is reasonably representative of a high demand application since the average estimated demand for the seven cities which received favorable responses to their DPM proposals is 41,000 trips. Any of the station-to-station matrices for the total peak or off-peak period can be converted to a matrix which represents one hour in the period by multiplying the matrix by the appropriate factor in Table 3-28. The morning and evening peak hour demand matrices for the SLT 9 and SLT 10 deployments are presented in Tables 3-36 and 3-37 for reference. As indicated above the peak hour matrices for the SLT 11 deployment (high demand application) can be obtained by doubling all the elements in these matrices.

One of the SLT systems to be anayzed in the CBD line-haul application (SLT 8 as defined in Table 4-2) is deployed on the multiple-loop network illustrated in Figure 4-7.

TABLE 3-30. MORNING PEAK PERIOD STATION-TO-STATION DEMAND FOR THE LOW DEMAND CBD LINE-HAUL APPLICATION, OPEN-LOOP - LGRT DEPLOYMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	768	1550	1082	295	475	320	8	0	0	0	0	0	0	4498
(2)	11	0	45	10	2	3	10	10	0	0	0	0	0	0	91
(3)	25	45	0	35	10	20	41	22	0	0	0	0	0	0	198
(4)	9	12	42	0	3	5	0	7	0	0	0	0	0	0	78
(5)	0	0	0	0	0	3	7	0	0	0	0	0	0	0	10
(6)	133	970	1980	1391	0	0	417	400	0	0	0	0	0	0	5291
(7)	0	10	44	33	7	1	0	2	0	0	0	0	0	0	97
(8)	12	9	22	7	0	0	2	0	0	0	0	0	0	0	52
TOTAL TRIPS DURING INTERVAL (6:00 a.m. to 9:00 a.m.)															10315

TABLE 3-31. OFF-PEAK PERIOD STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, OPEN-LOOP - LGRT DEPLOYMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	227	109	32	27	11	8	2	0	0	0	0	0	0	416
(2)	173	0	539	171	54	17	44	57	0	0	0	0	0	0	1055
(3)	104	539	0	573	176	43	105	81	0	0	0	0	0	0	1625
(4)	44	203	684	0	104	64	0	32	0	0	0	0	0	0	1131
(5)	0	0	0	0	0	19	36	0	0	0	0	0	0	0	55
(6)	21	38	99	160	0	0	115	12	0	0	0	0	0	0	445
(7)	8	48	118	204	35	31	0	9	0	0	0	0	0	0	453
(8)	3	54	77	25	12	6	9	0	0	0	0	0	0	0	186
TOTAL TRIPS DURING INTERVAL (9:00 a.m. to 4:00 p.m. & 7:00 p.m. to Midnight)															5366

TABLE 3-32. AFTERNOON PEAK PERIOD STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, OPEN-LOOP - LGRT DEPLOYMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	16	27	6	4	133	0	8	0	0	0	0	0	0	194
(2)	763	0	45	10	2	3	10	10	0	0	0	0	0	0	843
(3)	1548	45	0	35	10	987	41	22	0	0	0	0	0	0	2688
(4)	1085	12	42	0	3	1962	0	7	0	0	0	0	0	0	3111
(5)	291	0	0	0	0	1386	7	0	0	0	0	0	0	0	1684
(6)	475	3	23	8	0	0	1	0	0	0	0	0	0	0	510
(7)	320	10	44	33	7	1	0	2	0	0	0	0	0	0	417
(8)	412	9	22	7	0	0	2	0	0	0	0	0	0	0	452
TOTAL TRIPS DURING INTERVAL (4:00 p.m. to 7:00 p.m.)															9899

TABLE 3-33. MORNING PEAK PERIOD STATION-TO-STATION DEMAND FOR THE LOW DEMAND CBD LINE-HAUL APPLICATION, OPEN-LOOP - SGRT DEPLOYMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	769	1551	1082	295	475	320	8	0	0	0	0	0	0	4500
(2)	12	0	46	10	2	3	10	10	0	0	0	0	0	0	93
(3)	25	46	0	35	10	20	41	22	0	0	0	0	0	0	199
(4)	10	12	42	0	4	5	0	7	0	0	0	0	0	0	80
(5)	0	0	0	0	0	3	7	0	0	0	0	0	0	0	10
(6)	133	970	1980	1391	0	0	422	400	0	0	0	0	0	0	5296
(7)	0	10	45	33	7	1	0	2	0	0	0	0	0	0	98
(8)	12	10	22	7	0	0	2	0	0	0	0	0	0	0	53
TOTAL TRIPS DURING INTERVAL (6:00 a.m. to 9:00 a.m.)															10329

TABLE 3-34. OFF-PEAK PERIOD STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, OPEN-LOOP - SGRT DEPLOYMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	234	112	33	28	11	8	2	0	0	0	0	0	0	429
(2)	179	0	550	173	54	17	44	58	0	0	0	0	0	0	1075
(3)	106	550	0	588	177	44	110	81	0	0	0	0	0	0	1656
(4)	45	206	701	0	349	65	0	33	0	0	0	0	0	0	1399
(5)	0	0	0	0	0	19	36	0	0	0	0	0	0	0	55
(6)	21	38	101	163	0	0	215	12	0	0	0	0	0	0	550
(7)	8	48	121	211	36	32	0	9	0	0	0	0	0	0	465
(8)	25	56	78	25	12	6	9	0	0	0	0	0	0	0	211
TOTAL TRIPS DURING INTERVAL (9:00 a.m. to 4:00 p.m. & 7:00 p.m. to Midnight)															5840

TABLE 3-35. AFTERNOON PEAK PERIOD STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, OPEN-LOOP - SGRT DEPLOYMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	17	28	6	4	133	0	8	0	0	0	0	0	0	196
(2)	764	C	46	10	2	3	10	10	0	0	0	0	0	0	845
(3)	1548	46	0	35	10	987	41	22	0	C	0	0	0	0	2689
(4)	1086	12	42	0	4	1962	0	7	0	0	0	0	0	0	3113
(5)	291	C	C	0	0	1386	7	C	0	0	0	0	0	0	1684
(6)	475	3	23	8	0	0	6	0	0	0	0	0	0	0	515
(7)	320	10	45	33	7	1	0	2	0	0	0	0	0	0	418
(8)	412	10	22	7	0	0	2	C	0	C	0	0	0	0	453
TOTAL TRIPS DURING INTERVAL (4:00 p.m. to 7:00 p.m.)															9913

TABLE 3-36. MORNING PEAK-HOUR STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, OPEN-LOOP NETWORK-LGRT DEPLOYMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	TOT
(1)	0	514	1038	724	197	318	214	5	3010
(2)	7	0	30	6	1	2	6	6	58
(3)	16	30	0	23	6	13	27	14	129
(4)	6	8	28	0	2	3	0	4	51
(5)	0	0	0	0	0	2	4	0	6
(6)	89	649	1326	931	0	0	279	267	3541
(7)	0	6	29	22	4	0	0	1	62
(8)	8	6	14	4	0	0	1	0	33
TOTAL TRIPS DURING INTERVAL (7:00 a.m. to 8:00 a.m.)									6890

TABLE 3-37. AFTERNOON PEAK-HOUR STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, OPEN-LOOP NETWORK-LGRT DEPLOYMENT

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	TOT
(1)	0	10	17	3	2	86	0	5	123
(2)	495	0	29	6	1	1	6	6	544
(3)	1006	29	0	22	6	641	26	14	1744
(4)	705	7	27	0	1	1275	0	4	2019
(5)	189	0	0	0	0	900	4	0	1093
(6)	308	1	14	5	0	0	0	0	328
(7)	207	6	28	21	4	0	0	1	267
(8)	267	5	14	4	0	0	1	0	291
TOTAL TRIPS DURING INTERVAL (4:00 p.m. to 5:00 p.m.)									6409

The multiple-loop and one-way open-loop networks have several common stations, but in some cases multiple-loop stations are located up to a block away from the corresponding open-loop station. The multiple-loop network also has two additional stations which are not included in the open-loop network. Since the reference bus transfer demand data are in station-to-station format based on the open-loop network, the bus transfer matrices were modified to make them applicable to the multiple loop network. It was assumed that the number of bus transfer trips remains constant but that the alternate network causes some changes in the distribution of the trips. In general, the bus transfer matrices were modified in two ways. The first way attempts to account for the fact that the multiple-loop network has two more stations than the open-loop network. It is assumed that one-third of the trips which use the open-loop station closest to the added station are diverted to the added station in the multiple-loop network. Table 3-38 illustrates the relationships among stations which were used to assign open-loop bus transfer demand to the multiple-loop network. The multiple-loop and open-loop networks are illustrated in Figures 4-7 and 4-8, respectively. The table shows, for example, that morning peak period bus transfer demand destined to open-loop Station 2 is split among multiple-loop stations 4 and 1. Since Station 1 is a new station which does not appear in the open-loop network, one-third of the demand is assigned to it while the remaining two-thirds of the demand is assigned to Station 4. The second modification to the reference bus transfer demand is based on the assumption that bus patrons who choose to use the AGT system will attempt to access the system so as to minimize their travel time. This means that bus transfer patrons will access the AGT system at the transfer station nearest their destination. Since some transfers are inevitable with the multiple-loop network, it was assumed that fifty percent of the bus transfer trips (defined in terms of the open-loop network) which would have to transfer in the multiple-loop network would be able to access the system at the other bus transfer station thus eliminating the need to transfer. This reassignment of passengers to the other bus transfer station was not applied to trips from one bus transfer station to the other. The station-to-station bus transfer demand defined in terms of the multiple-loop network is presented as Table 3-39.

The remaining portion of the station-to-station demand for the multiple-loop network was generated by the FSM using the scaled zone-to-zone demand matrices generated as described previously. The station-to-station performance matrix is based on the following assumption:

- Cruise velocity - 48 km/h
- Acceleration/deceleration - 1.0 m/s^2
- Station dwell time - 30 s
- Average wait time - 38 s north loop
- Average wait time - 36 s south loop.

Table 3-40 shows the network travel times by link which were used to construct the station-to-station performance matrix for the multiple-loop network deployment. As before, an average walk speed of 61 m/min (200 ft/min) was assumed for the purpose of estimating access time and direct zone-to-zone trip time.

TABLE 3-38. MULTIPLE LOOP BUS TRANSFER STATION ASSIGNMENTS

Open Loop Station	Corresponding Multiple Loop Station	
	Station	Location With Respect to Open Loop Station
1	3	Same
2	4 1	Same New
3	5	1/2 Block Lower
4	6 10	1 Block Lower New
5	9	Same
6	8	Same
7	7	Same
8	2	Same

TABLE 3-39. STATION-TO-STATION BUS TRANSFER DEMAND FOR THE MULTIPLE-LOOP NETWORK

Multiple Loop					
Morning Peak Period			Afternoon Peak Period		
Origin Station	Dest. Station	Demand	Origin Station	Dest. Station	Demand
3	1	412	1	3	251
3	2	200	2	3	200
3	4	823	4	3	501
3	5	1523	5	3	1523
3	6	359	6	3	359
3	7	160	7	3	160
3	8	475	8	3	475
3	9	146	9	3	146
3	10	180	10	3	180
8	1	161	1	8	0
8	2	200	2	8	200
8	3	133	3	8	133
8	4	323	4	8	0
8	5	1957	5	8	967
8	6	1280	6	8	1663
8	7	576	7	8	160
8	9	145	9	8	1528
8	10	640	10	8	831
Total		9693			9277

TABLE 3-40. LINK TRAVEL TIMES, MULTIPLE LOOP IN CBD LINE-HAUL APPLICATION

Links	Travel Time (seconds)
North Loop	
(1, 2), (2, 1)	88
(2, 3), (3, 2)	72
(3, 4), (4, 3)	80
(4, 5), (5, 4)	66
(5, 1), (1, 5)	78
	Total: 384
South Loop	
(5, 6), (6, 5)	65
(6, 7), (7, 6)	73
(7, 8), (8, 7)	84
(8, 9), (9, 8)	61
(9, 10), (10, 9)	71
(10, 5), (5, 10)	76
	Total: 430

Vehicles on each of the loops of the multiple-loop network can be operated in either a clockwise or counter-clockwise direction. To investigate the effects of directionality on demand, station-to-station demand was generated for two cases:

- North loop-clockwise, south loop-counter-clockwise
- North loop-counter-clockwise, south loop-clockwise.

The station-to-station demand for the multiple-loop network in the low-demand CBD line-haul application (SLT 8) is presented in Tables 3-41, 3-42, and 3-43, which are the morning peak period matrix, off-peak period matrix, and afternoon peak period matrix, respectively. These matrices represent demand for the case in which the north loop is operated in a clockwise direction. The other case, in which the north loop is operated in a counter-clockwise direction, results in essentially the same magnitude of demand being assigned to the network.

The morning and evening peak hour demand matrices for the case in which the north loop is operated in a clockwise direction are presented in Tables 3-44 and 3-45. The corresponding matrices for the other case (north loop operated in a counter-clockwise direction) are presented in Tables 3-46 and 3-47.

TABLE 3-41. MORNING PEAK PERIOD STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, MULTIPLE-LOOP NETWORK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	12	6	8	42	0	4	1	0	0	0	0	0	0	73
(2)	20	0	0	9	16	0	2	0	0	0	0	0	0	0	47
(3)	422	208	0	823	1548	359	160	475	146	184	0	0	0	0	4325
(4)	2	9	16	0	3	0	0	0	0	0	0	0	0	0	30
(5)	0	10	20	27	0	0	41	14	2	5	0	0	0	0	119
(6)	0	7	10	8	31	0	0	5	3	0	0	0	0	0	64
(7)	0	2	0	10	41	37	0	0	145	7	0	0	0	0	242
(8)	161	200	133	326	1978	1288	577	0	0	640	0	0	0	0	5303
(9)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(10)	0	0	0	0	0	0	11	11	4	0	0	0	0	0	26
TOTAL TRIPS DURING INTERVAL (6:00 a.m. to 9:00 a.m.)															10229

Note: North loop - clockwise, south loop - counter-clockwise.

TABLE 3-42. OFF-PEAK PERIOD STATION-TO-STATION DEMAND MATRIX FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, MULTIPLE-LOOP NETWORK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	0	38	23	60	389	0	16	7	8	11	0	0	0	0	552
(2)	54	0	0	51	58	0	9	6	6	7	0	0	0	0	191
(3)	41	2	0	0	104	0	7	9	11	16	0	0	0	0	190
(4)	22	53	223	0	83	0	0	0	0	0	0	0	0	0	381
(5)	0	38	83	359	0	0	101	35	45	86	0	0	0	0	747
(6)	0	31	49	184	630	0	0	63	102	0	0	0	0	0	1059
(7)	0	9	8	47	114	237	0	0	0	39	0	0	0	0	454
(8)	0	10	21	35	78	173	115	0	0	0	0	0	0	0	432
(9)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
(10)	0	0	0	0	0	0	70	37	80	0	0	0	0	0	187
TOTAL TRIPS DURING INTERVAL (9:00 a.m. to 4:00 p.m. to Midnight)															4193

Note: North loop - clockwise, south loop - counter-clockwise.

TABLE 3-43. AFTERNOON PEAK PERIOD STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, MULTIPLE-LOOP NETWORK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	TOT
(1)	C	12	257	8	42	C	4	1	0	C	0	C	0	0	324
(2)	20	0	200	9	16	C	2	20C	0	0	0	C	C	0	447
(3)	1C	8	C	C	25	C	0	133	0	4	0	0	C	0	180
(4)	2	5	517	C	3	C	0	C	0	0	0	0	0	0	531
(5)	C	10	1543	27	0	C	41	581	2	5	0	C	C	C	2609
(6)	C	7	369	8	31	C	C	1668	3	0	0	0	0	0	2C86
(7)	C	2	16C	10	41	37	C	16C	C	7	0	C	C	0	417
(8)	C	C	475	3	21	8	1	C	0	0	0	C	C	C	508
(9)	C	C	146	C	C	C	C	1528	0	0	0	0	0	0	1674
(10)	C	C	180	0	0	0	11	842	4	C	0	0	C	C	1C37
TOTAL TRIPS DURING INTERVAL (4:00 p.m. to 7:00 p.m.)															9813

Note: North loop – clockwise, south loop – counter-clockwise.

TABLE 3-44. MORNING PEAK HOUR STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, MULTIPLE-LOOP NETWORK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	TOT
(1)	0	8	4	5	28	0	2	0	0	0	47
(2)	13	0	0	6	10	0	1	0	0	0	30
(3)	282	139	0	551	1037	240	107	318	97	123	2894
(4)	1	6	10	0	2	0	0	0	0	0	19
(5)	0	6	13	18	0	0	27	9	1	3	77
(6)	0	4	6	5	20	0	0	3	2	0	40
(7)	0	1	0	6	27	24	0	0	97	4	159
(8)	107	133	89	218	1325	862	386	0	0	428	3548
(9)	0	0	0	0	0	0	0	0	0	0	0
(10)	0	0	0	0	0	0	7	7	2	0	16
TOTAL TRIPS DURING INTERVAL (7:00 a.m. to 8:00 a.m.)											6830

Note: North loop - clockwise, south loop - counter clockwise.

TABLE 3-45. AFTERNOON PEAK HOUR STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, MULTIPLE-LOOP NETWORK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	TOT
(1)	0	7	167	5	27	0	2	0	0	0	208
(2)	12	0	129	5	10	0	1	129	0	0	286
(3)	6	5	0	0	16	0	0	86	0	2	115
(4)	1	5	336	0	1	0	0	0	0	0	343
(5)	0	6	1002	17	0	0	26	637	1	3	1692
(6)	0	4	239	5	20	0	0	1084	1	0	1353
(7)	0	1	103	6	26	24	0	103	0	4	267
(8)	0	0	308	1	13	5	0	0	0	0	327
(9)	0	0	94	0	0	0	0	993	0	0	1087
(10)	0	0	116	0	0	0	7	547	2	0	672
TOTAL TRIPS DURING INTERVAL (4:00 p.m. to 5:00 p.m.)											6350

Note: North loop - clockwise, south loop - counter-clockwise.

TABLE 3-46. MORNING PEAK HOUR STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, MULTIPLE-LOOP NETWORK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	TOT
(1)	0	13	6	1	0	0	0	0	0	0	20
(2)	8	0	5	6	6	4	1	0	0	0	30
(3)	280	133	0	562	1033	247	107	318	97	120	2897
(4)	5	6	0	0	18	5	6	2	0	0	42
(5)	28	10	16	2	0	20	27	14	0	0	117
(6)	0	0	0	0	0	0	24	5	0	0	29
(7)	2	1	0	0	27	0	0	0	0	7	37
(8)	108	133	89	216	1220	960	385	0	97	436	3644
(9)	0	0	0	0	1	2	0	0	0	2	5
(10)	0	0	2	0	3	0	4	0	0	0	9
TOTAL TRIPS DURING INTERVAL (7:00 a.m. to 8:00 a.m.)											6830

Note: North loop - counter-clockwise, south loop - clockwise.

TABLE 3-47. AFTERNOON PEAK HOUR STATION-TO-STATION DEMAND FOR THE LOW-DEMAND CBD LINE-HAUL APPLICATION, MULTIPLE-LOOP NETWORK

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	TOT
(1)	0	12	169	1	0	0	0	0	0	0	182
(2)	7	0	135	5	6	4	1	129	0	0	287
(3)	3	0	0	10	12	6	0	86	0	0	117
(4)	5	5	325	0	17	5	6	1	0	0	364
(5)	27	10	1006	1	0	20	26	642	0	0	1732
(6)	0	0	233	0	0	0	24	1086	0	0	1343
(7)	2	1	103	0	26	0	0	104	0	7	243
(8)	0	0	308	0	9	3	0	0	0	7	327
(9)	0	0	94	0	1	1	0	993	0	2	1091
(10)	0	0	119	0	3	0	4	540	0	0	666
TOTAL TRIPS DURING INTERVAL (4:00 p.m. to 5:00 p.m.)											6352

Note: North loop - counter-clockwise, south loop - clockwise.

3.5.5 High CBD Orientation, High Reverse Commutation Metropolitan Area Demand

The demand model for this application area is based on a 1965 home-interview survey of travel behavior in the Cincinnati Metropolitan Areas. The survey tape was obtained from the Ohio-Kentucky-Indiana Regional Council of Governments and contains 261,226 records which define travel among the region's 460 traffic analysis zones.

Generation of the metropolitan area demand models is essentially a four-step process. As a first step the trip records on the survey tape are screened to remove intra-zone trips and invalid records. At the same time the start time of each trip record is replaced with a code denoting the quarter-hour (1 through 96 for a 24-hour day) in which the trip is initiated. In other words, trips are aggregated to quarter-hour intervals. After completing this process and converting each trip record to binary format, the demand build module generates three files. Trip records which are accepted are reformatted and the following information is stored in one file:

- Origin zone
- Destination zone
- Quarter-hour number
- Mode
- Number of trips represented by the record (X100) .

A second file is created in which the trip records which were rejected for any reason are recorded in the same format as the entire survey record. The third file is a survey summary, and it is generally printed out. The summary records the number of trips and trip records by quarter-hour for all trips, for trips whose destination is the CBD, and for trips whose origin is the CBD.

As a second step in the demand model generation process, a set of demand profile histograms is generated using the survey summary data. Figure 3-12 shows the demand profile generated for total travel in the Cincinnati region. The data indicate that preferred times for trip initiation tend to be on the hour and half-hour. This may indicate an actual trend in travel behavior, but the preference is probably exaggerated to some extent by the quantization of time by survey respondents. Interviewees may tend to report that trips were initiated on the hour when in fact, the trips began 5 or 10 minutes past the hour. This uncertainty suggests that the time interval over which demand is aggregated for analysis purposes should not be shorter than one-half hour. Alternatively, survey data can be modified to produce a smoothed version of the demand profile so that temporal variations in demand can be observed more easily. The following smoothing formula was applied to each 15-minute interval:

$$Y(N) = .25\,D(N-1) + .50\,D(N) + .25\,D(N+1),$$

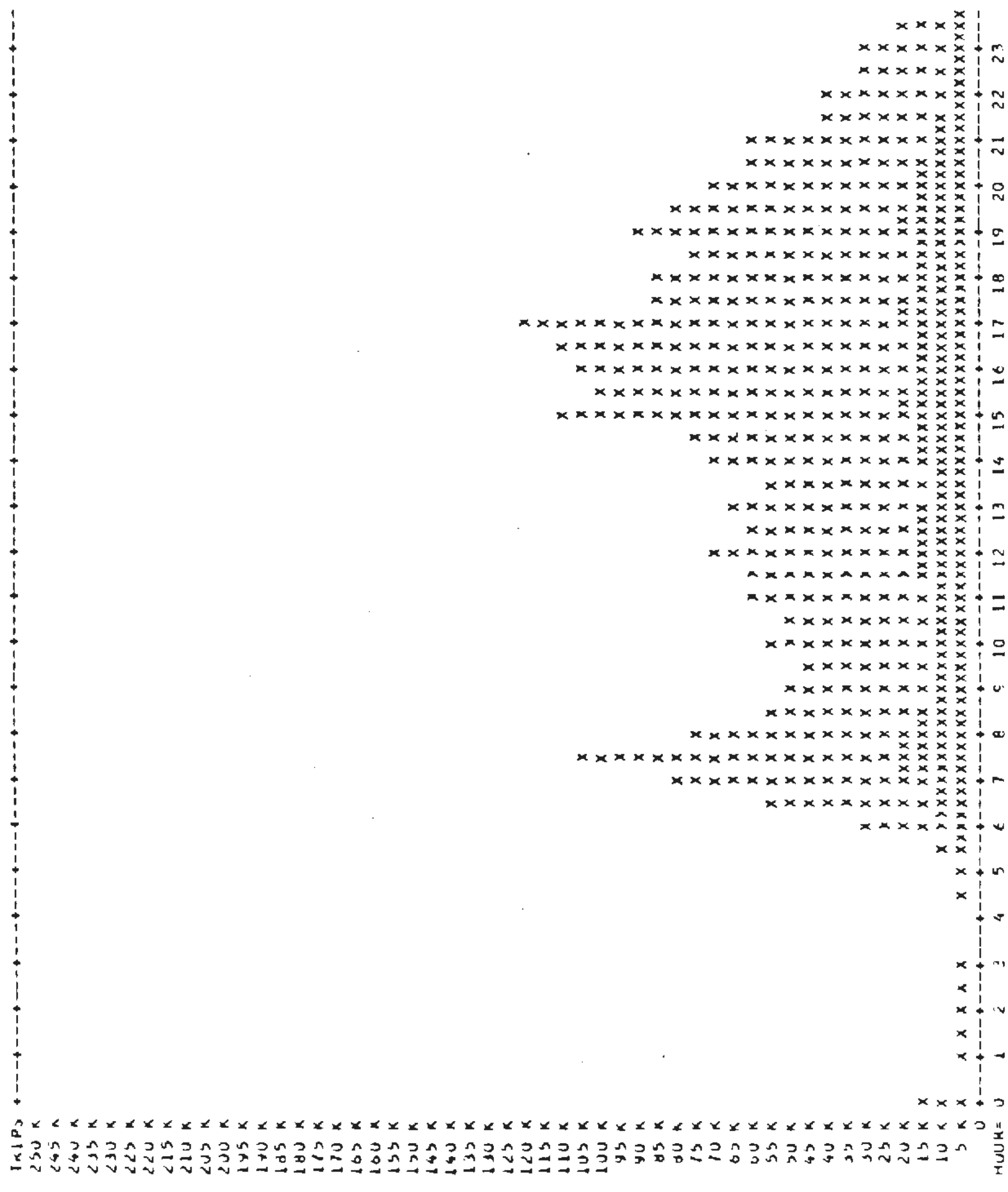


FIGURE 3-12. METROPOLITAN CINCINNATI 1965 SURVEY TRAVEL DEMAND PROFILE (TOTAL METRO AREA)

where

Y(N)	= smoothed demand magnitude for the Nth interval
D(N-1)	= actual demand magnitude for the previous interval as reported in the survey summary file
D(N)	= actual demand magnitude for the Nth interval
D(N+1)	= actual demand magnitude for the following interval.

The smoothed profile for total travel in the Cincinnati metropolitan area is shown in Figure 3-13. Demand profiles, which have been smoothed in the same way, showing CBD attraction and CBD production are presented in Figures 3-14 and 3-15, respectively. The CBD production profile does not show a large number of trips leaving the CBD in the morning peak period even though Cincinnati is classified as a high-reverse commutation application. This is not inconsistent as the classification is based on the percentage of total travel rather than on absolute magnitude and on trips originating in the entire central city rather than just in the CBD.

These profiles are used to complete the third step in the four-step demand model generation process. This third step consists of selecting the demand intervals to be used in modeling the temporal and spatial variations in demand. Travel demand in a metropolitan area can be described in terms of four basic intervals which exhibit fundamental differences in the spatial distribution of trip origins and destinations, in trip purpose, and in demand magnitude. The morning peak period is typically characterized by a relatively large proportion of inbound work trips. The afternoon peak period is generally directed outbound from the CBD and consists of shopping and personal business trips in addition to work trips. The afternoon peak period usually consists of more total travel and frequently has a higher peak demand than the morning peak period. The midday period between the peaks typically displays a more diffuse travel pattern than the peak periods and has a lower but quite significant magnitude. Finally, the evening period also typically exhibits a very diffuse spatial distribution and consists of shopping and entertainment trips with some home-based work trip activity which is generally not CBD oriented. The magnitude of demand during the evening period may be quite large during the early evening but is generally very low after midnight. The demand magnitudes associated with these four basic demand periods for the Cincinnati region are illustrated by the demand profile histograms. Figures 3-13 and 3-14 show that the morning peak period extends from about 6:00 a.m. to 9:00 a.m. and that the demand changes quite rapidly during this period. Figures 3-13 and 3-15 show that the afternoon peak period extends from about 3:00 p.m. to 6:00 p.m. (hours 15 to 18) and that the magnitude remains relatively high during most of the three-hour interval. Figure 3-13 indicates that the demand for the midday period is relatively constant with some increase in travel activity around noon. The demand magnitude during the evening period initially increases then gradually decreases until midnight. After midnight the demand is quite low and relatively constant until the morning peak period begins.

To represent the basic differences in spatial distribution the demand model for each metropolitan area application consists of four origin-destination (O-D) matrices which describe the demand distribution during the morning peak, midday, afternoon peak, and evening periods. Spatial variations could be represented by a larger number of matrices at the expense of increased data storage and computer run time requirements. However,

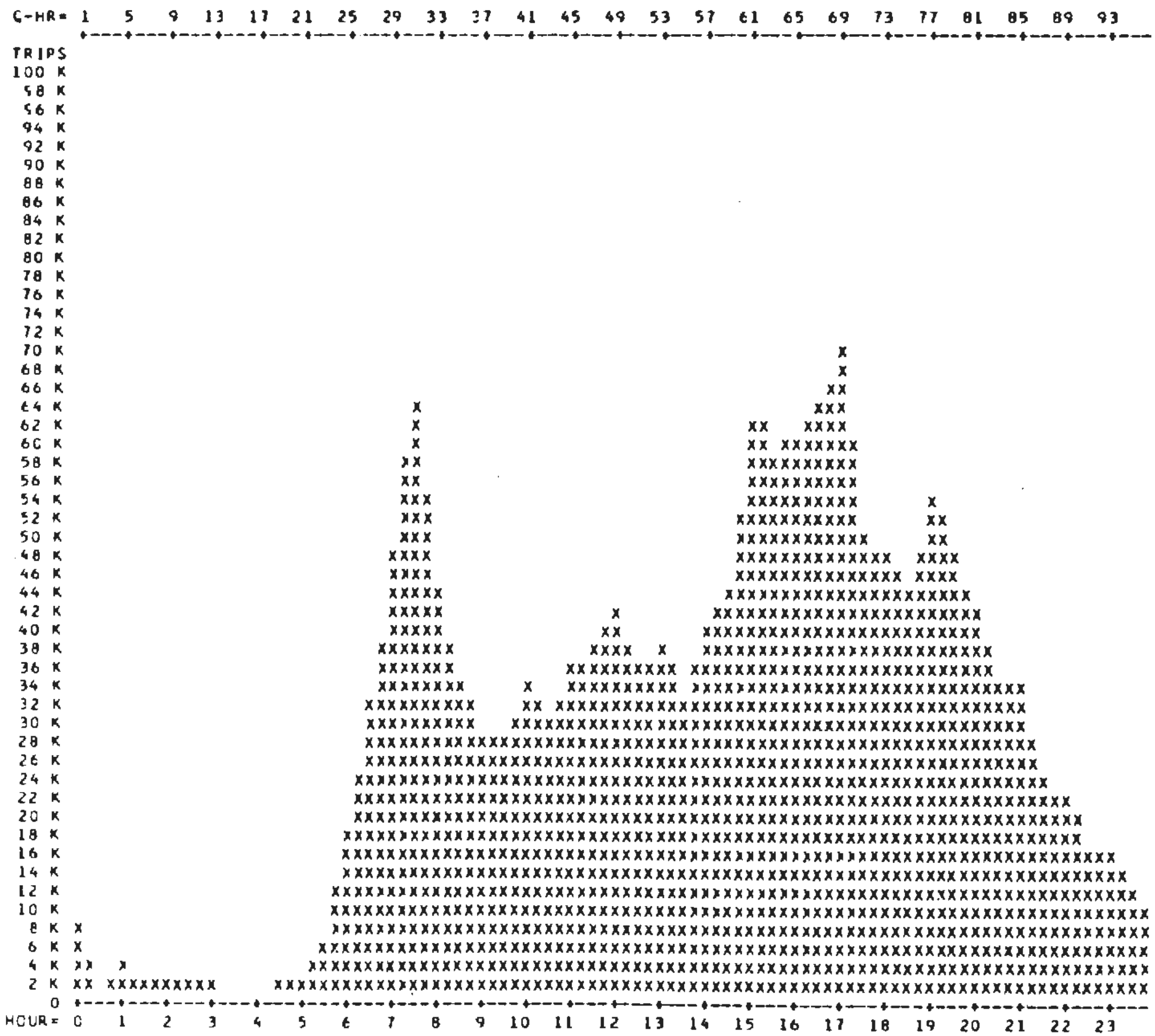


FIGURE 3-13. METROPOLITAN CINCINNATI 1965 SURVEY TRAVEL DEMAND PROFILE, SMOOTHED (TOTAL METRO AREA)

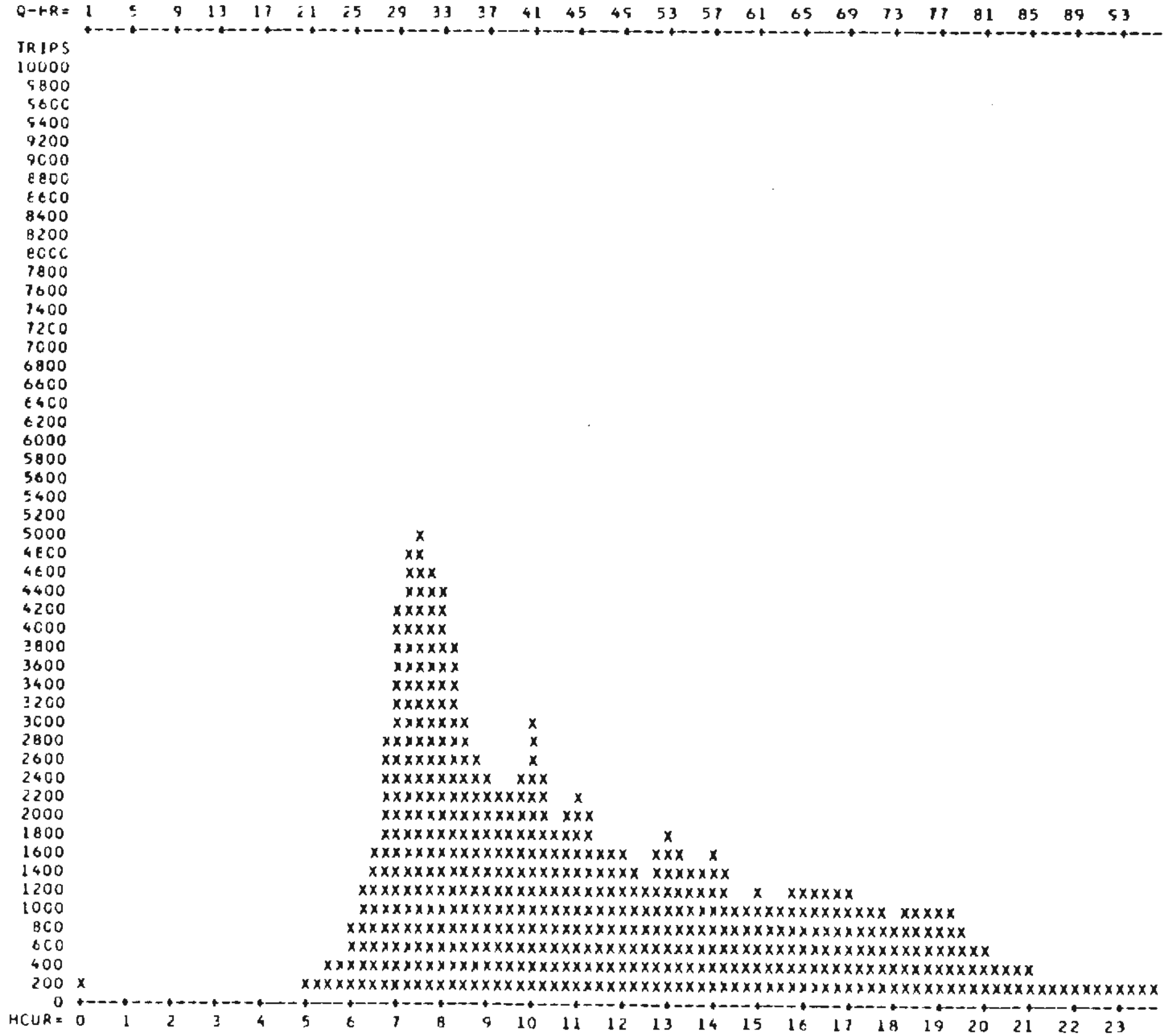


FIGURE 3-14. METROPOLITAN CINCINNATI 1965 SURVEY TRAVEL DEMAND PROFILE, SMOOTHED (CBD ATTRACTION)

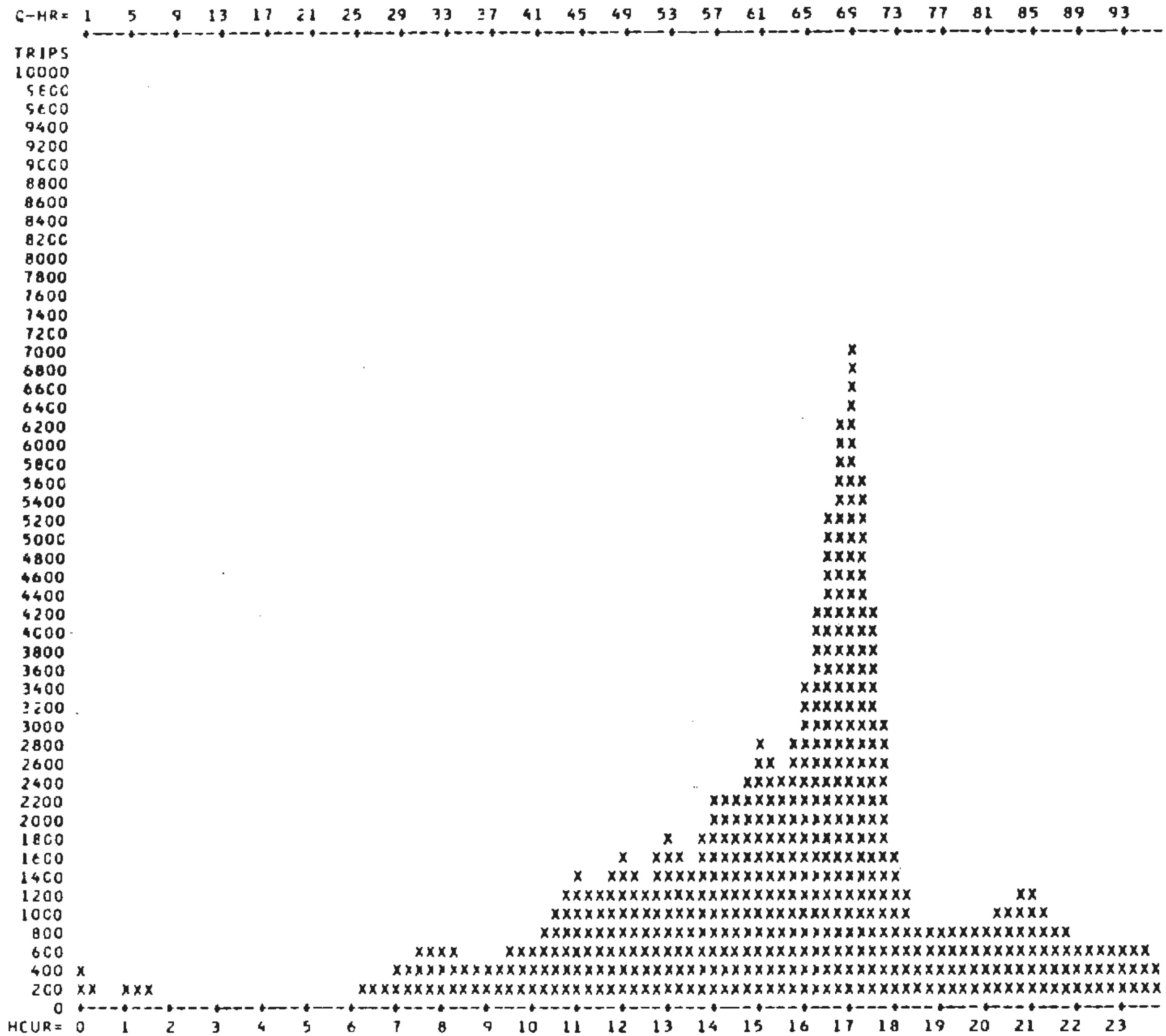


FIGURE 3-15. METROPOLITAN CINCINNATI 1965 SURVEY TRAVEL DEMAND PROFILE, SMOOTHED (CBD PRODUCTION)

as the interval over which the data is aggregated becomes small, the matrices become very sparse. The Cincinnati survey data itself is sparse in that the average number of records per possible O-D interchange is only 1.23 for the entire 24-hour period (261,226 records and 211,600 (460 x 460) zone-zone interchanges). The use of four spatiol demand matrices tends to balance the requirements of adequate detail and data storage.

Figure 3-16 illustrates the form of the temporal demond for the high CBD orientation high reverse commutation metropolitan area application. In order to smooth the data somewhat without arbitrarily modifying it by the smoothing technique described earlier, demand has been aggregated over one-hour intervals. The intervals over which the peak period matrices apply were extended so that the change from one matrix to another occurs during a period when the demand magnitude is not changing significantly. The four spatial demand matrices apply to the following periods:

- Morning peak period 5:00 a.m. to 10:00 a.m.
- Midday period 10:00 a.m. to 2:00 p.m.
- Afternoon peak period 2:00 p.m. to 7:00 p.m.
- Evening period 7:00 p.m. to 5:00 a.m.

The magnitude of demand is changed each hour by scaling the appropriate spatial demand matrix. The scaling factors are shown as percentage figures over each hour in Figure 3-16. These factors are derived relative to each other only within a given time period as listed above.

Another part of this step of the demand model generation process is the definition of the service area for which zone-to-zone demand is represented. Some zones for which demand data is available are eliminoted so that the service area corresponds more closely to the area of coverage of the automated guideway. In general, the service area is limited to an area extending about two miles beyond the outermost stations of the AGT network. The networks to be considered in this application are illustrated in Figure 4-10, 4-15, and 4-16. Table 3-48 defines the service area in terms of traffic analysis zones in the Cincinnati metropolitan area. The service area is bounded on the east by the Licking River and Madison Pike in Kentucky and by the Columbia Parkway, Stewart Road, and Plainfield Pike in Ohio. Galbraith Road approximates the northern boundary. The western boundary of the service area is approximated by North Bend Road, Colerain Avenue, Montana Avenue, Westwood, Northern Boulevard, and Neeb Road in Ohio and by the Kenton County line in Kentucky. The service area is bounded on the south by the towns of Edgewood and Elsmere and by the Kenton County line.

The final step in the demand generation process for metropolitan areas is to generate the four trip matrices in UTPS compressed format using as input the file of accepted trips which was created in step one. Trips which are outside the service area as defined in the previous step are then eliminated. While this provides an adequate temporal and spatial distribution for use in the program, the overall magnitude of the demand in this area was reduced to one-third in order to approximate anticipoted AGT travel volumes.

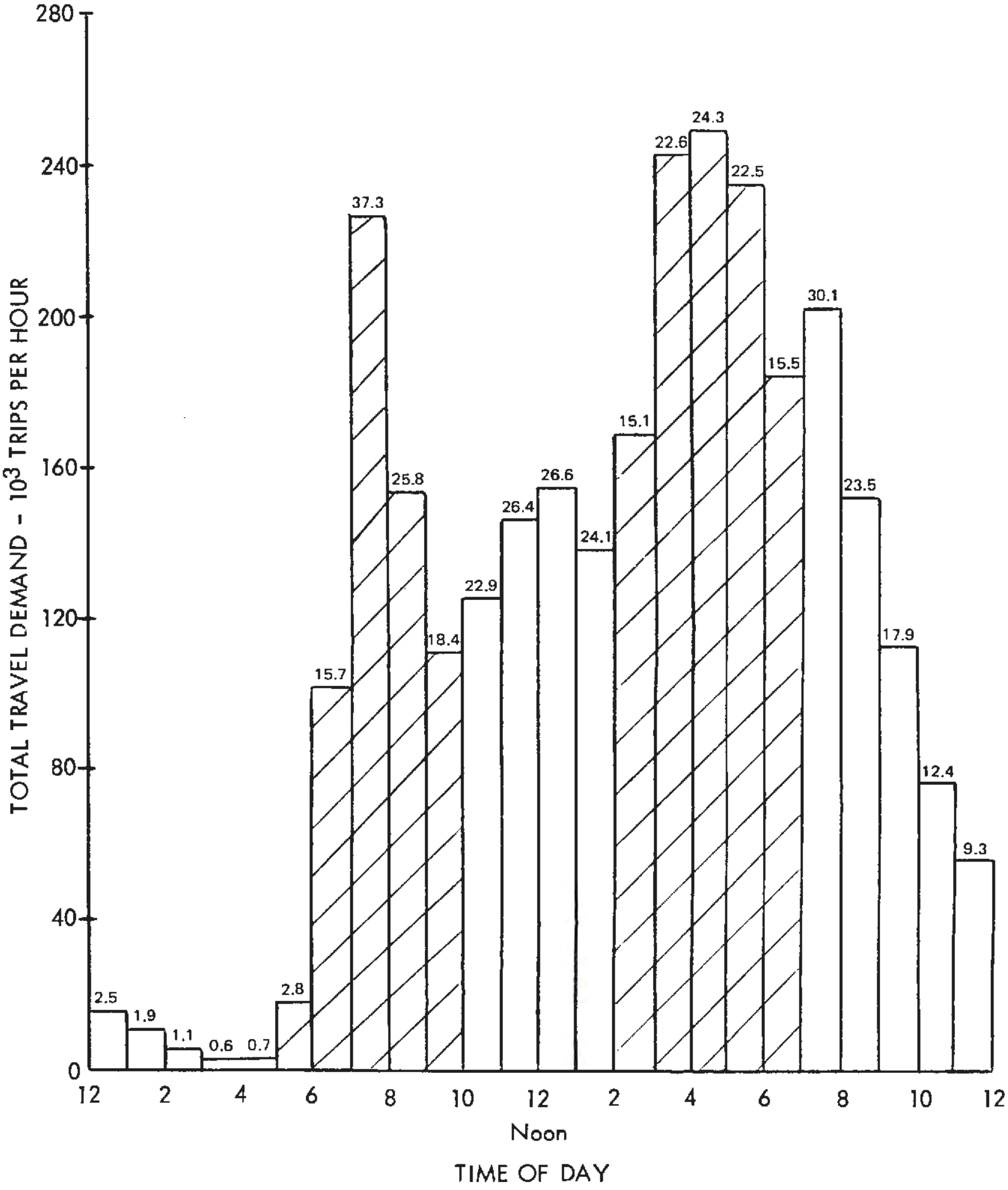


FIGURE 3-16. TRAVEL DEMAND IN THE CINCINNATI METROPOLITAN AREA

TABLE 3-48. ZONES COMPRISING THE SERVICE AREA FOR THE HIGH CBD ORIENTATION, HIGH REVERSE COMMUTATION APPLICATION AREA

Ohio
065-099
100-119
121-129
133-137
149-157
192-199
200-267
298-299
300-337
350-351
380-391
396
401-403
413-430
432-433
435-441
454-455
495
491-492
485
488-489
Kentucky
757-776
785-794
797-799
800-810

Note: The service area is defined in terms of traffic analysis zones in the Cincinnati, Ohio metropolitan area.

In this application area, the following assumptions were used to generate the inter-station travel times using the DESM, and then to map the zonal demand for each time period onto each of the three networks pictured in Figures 4-10 (ART 1), 4-15 (GRT 1), and 4-16 (GRT 2):

	ART 1	GRT 1	GRT 2
• Feeder Velocity			
To Stations (km/h)	10.8	10.8	10.8
Direct (km/h)	13.8	13.8	13.8
• AGT Velocity (km/h)	64.8	79.2	79.2
• Initial Wait Time (min.)	3	3	3
• AGT Service Routes			
(round trip between	11-25	1-4	20-16
stations as numbered	4-25	1-11	1-27
in Figures 4-10, 4-15	19-28	1-26	17-27
and 4-16; stopping at		1-28	
all intermediates)		7-23	

Of the total daily travel demand assumed in this application area, 35 percent (124,671) was found serviceable by the ART 1 network, while the GRT 1 and GRT 2 networks could service only 31 percent (110,172) and 32 percent (112,869), respectively. The station-to-station demand matrices are stored in the following members of the AGT.IANDD.DEMAND file:

	ART 1 Network	GRT 1 Network	GRT 2 Network
A.M. Peak Period	EARTIA	EGRTIA	EGRT2A
Mid-Day Period	EARTIM	EGRTIM	EGRT2M
P.M. Peak Period	EARTIP	EGRTIP	EGRT2P
Evening Period	EARTIE	EGRTIE	EGRT2E

For inspection, the total demand accessing and egressing each station is presented in Tables 3-48A, 3-48B, and 3-48C for these three networks. Four values are shown for each station, representing the demand during each of the four time periods of the day. Station numbers refer to the numbering on the networks pictured in Figures 4-10, 4-15, and 4-16, respectively.

3.5.6 Low CBD Orientation, High Reverse Commutation Metropolitan Area Demand

The demand model for this application area is based on a 1965 home-interview survey of travel behavior in the seven county Detroit metropolitan area. The survey tape was obtained from the Southeastern Michigan Council of Governments and contains 307,148 records which define travel among the region's 1446 traffic analysis zones.

TABLE 3-48A. DAILY STATION PATRONAGE - ART 1

STA. NO.	STATION DEMAND	
	ACCESS	EGRESS
1	1427.	1758.
	969.	918.
	2173.	2122.
	1136.	921.
2	998.	1289.
	906.	810.
	1739.	1459.
	661.	630.
3	1077.	1119.
	809.	752.
	1532.	1421.
	636.	692.
4	1428.	692.
	755.	723.
	1220.	1897.
	738.	962.
5	822.	1107.
	940.	789.
	1585.	1405.
	739.	709.
6	578.	1006.
	762.	812.
	1522.	1004.
	502.	521.
7	1324.	1351.
	1168.	1203.
	2129.	2107.
	933.	858.
8	1905.	1282.
	1350.	1182.
	2058.	2761.
	988.	1162.
9	1142.	879.
	809.	721.
	1316.	1544.
	686.	810.
10	1861.	1731.
	1557.	1537.
	2927.	3261.
	1695.	1657.
11	1796.	1247.
	1248.	1089.
	2155.	2551.
	1239.	1386.
12	1260.	1339.
	1074.	925.
	1766.	1716.
	710.	775.
13	828.	3848.
	1989.	2717.
	5196.	2023.
	1503.	828.
14	452.	3556.
	1126.	1565.
	4318.	1326.
	1173.	526.
15	123.	61.
	37.	55.
	116.	155.
	35.	59.
16	489.	601.
	542.	534.
	1045.	991.
	475.	445.
17	524.	557.
	490.	512.
	1028.	1033.
	620.	565.
18	505.	219.
	332.	327.
	599.	809.
	372.	468.
19	531.	305.
	273.	262.
	558.	785.
	319.	432.
20	406.	331.
	308.	254.
	646.	721.
	363.	430.
21	188.	111.
	72.	66.
	178.	237.
	104.	168.
22	411.	135.
	211.	182.
	362.	642.
	329.	394.
23	145.	84.
	80.	73.
	188.	261.
	114.	100.
24	658.	172.
	311.	351.
	566.	992.
	491.	532.
25	790.	384.
	410.	386.
	859.	1171.
	514.	556.
26	1898.	772.
	1226.	961.
	1714.	2756.
	1164.	1491.
27	2319.	650.
	1022.	971.
	1517.	2961.
	1182.	1574.
28	1135.	432.
	865.	965.
	1086.	1987.
	1178.	950.

TABLE 3-48B. DAILY STATION PATRONAGE - GRT I

STA. NO.	STATION DEMAND ACCESS	STATION DEMAND EGRESS
1	1508.	1861.
	1034.	983.
	2319.	2253.
	1181.	978.
2	924.	1204.
	845.	740.
	1607.	1355.
	625.	571.
3	1065.	1117.
	803.	749.
	1530.	1407.
	636.	690.
4	1430.	693.
	755.	721.
	1223.	1901.
	749.	965.
5	817.	1114.
	938.	795.
	1592.	1394.
	739.	702.
6	618.	1014.
	757.	812.
	1549.	1067.
	524.	565.
7	1318.	1362.
	1168.	1208.
	2135.	2096.
	940.	859.
8	2042.	1413.
	1442.	1297.
	2251.	2913.
	1054.	1234.
9	1251.	1016.
	919.	809.
	1475.	1707.
	753.	872.
10	1853.	1738.
	1555.	1538.
	2939.	3253.
	1704.	1662.
11	1789.	1246.
	1246.	1089.
	2155.	2544.
	1243.	1386.
12	1133.	1235.
	1014.	862.
	1630.	1552.
	642.	684.
13	805.	3717.
	1925.	2620.
	5030.	1949.
	1450.	800.
14	442.	3429.
	1096.	1516.
	4207.	1286.
	1146.	507.
15	121.	49.
	37.	54.
	114.	153.
	35.	59.
16	429.	404.
	456.	428.
	812.	824.
	350.	344.
17	367.	568.
	424.	555.
	855.	1171.
	545.	587.
18	593.	171.
	357.	258.
	767.	878.
	446.	484.
19	85.	260.
	58.	132.
	157.	299.
	80.	215.
20	314.	98.
	203.	146.
	351.	506.
	318.	324.
21	140.	88.
	85.	79.
	194.	276.
	131.	109.
22	636.	169.
	303.	344.
	560.	968.
	468.	519.
23	761.	383.
	406.	384.
	848.	1160.
	511.	553.
24	1859.	757.
	1209.	957.
	1707.	2705.
	1163.	1487.
25	2308.	651.
	1021.	972.
	1520.	2951.
	1185.	1569.
26	1130.	433.
	865.	966.
	1089.	1982.
	1180.	951.
27	590.	357.
	359.	262.
	651.	502.
	367.	362.
28	513.	293.
	248.	250.
	513.	733.
	290.	417.

TABLE 3-48C. DAILY STATION PATRONAGE - GRT 2

STA. NO.	STATION DEMAND ACCESS	STATION DEMAND EGRESS
1	1456.	718.
	769.	734.
	1249.	1934.
	759.	979.
2	1083.	1127.
	817.	759.
	1543.	1430.
	641.	697.
3	1012.	1284.
	902.	811.
	1729.	1471.
	657.	626.
4	1429.	1774.
	977.	916.
	2195.	2129.
	1146.	928.
5	1267.	1346.
	1081.	931.
	1776.	1726.
	714.	779.
6	867.	3907.
	2013.	2755.
	5277.	2094.
	1545.	869.
7	454.	3582.
	1133.	1575.
	4348.	1335.
	1181.	529.
8	123.	61.
	37.	55.
	116.	156.
	35.	59.
9	486.	601.
	538.	532.
	1036.	977.
	473.	439.
10	484.	552.
	477.	515.
	1040.	1006.
	616.	565.
11	397.	332.
	305.	255.
	620.	721.
	338.	431.
12	193.	113.
	76.	69.
	192.	252.
	106.	175.
13	411.	146.
	211.	188.
	360.	650.
	326.	409.
14	146.	88.
	85.	80.
	194.	279.
	134.	110.
15	662.	170.
	308.	347.
	567.	980.
	474.	525.
16	795.	387.
	413.	389.
	866.	1177.
	517.	560.
17	1166.	481.
	918.	1011.
	1178.	2084.
	1264.	1022.
18	2387.	672.
	1066.	1022.
	1602.	3070.
	1254.	1660.
19	1905.	777.
	1234.	970.
	1729.	2771.
	1175.	1506.
20	1806.	1253.
	1255.	1094.
	2166.	2565.
	1245.	1393.
21	1870.	1731.
	1564.	1543.
	2934.	3274.
	1705.	1666.
22	1257.	1015.
	923.	813.
	1478.	1718.
	755.	876.
23	2045.	1401.
	1442.	1296.
	2237.	2924.
	1049.	1233.
24	1301.	1333.
	1163.	1189.
	2100.	2067.
	908.	823.
25	583.	1011.
	768.	823.
	1532.	1012.
	503.	528.
26	826.	1117.
	949.	794.
	1596.	1413.
	743.	715.
27	535.	291.
	273.	243.
	558.	747.
	320.	380.
28	553.	228.
	346.	334.
	592.	849.
	379.	480.

The process for generating the demand model for this application is essentially the same four-step process described in the previous section. The survey tape is first screened and summary files are created. Then demand profile histograms are generated and used to select demand intervals. Finally, the demand matrices are generated and hourly factors are calculated.

A demand profile showing the temporal variation in demand magnitude for total travel in the Detroit region is presented in Figure 3-17. The figure shows actual survey data in terms of the number of trips per quarter-hour for each quarter-hour during a 24-hour day. The 15-minute intervals beginning on the hour and the half-hour are again shown to be preferred trip initiation intervals. Figure 3-18 shows the demand profile for total travel after the survey data has been smoothed using the formula presented in Section 3.5.5. Figures 3-19 and 3-20 are smoothed demand profiles for CBD attraction and CBD production, respectively. The figures show that the morning peak period extends from 6:00 a.m. to 9:00 a.m., and the afternoon peak period extends from about 3:00 p.m. to about 6:30 p.m. The figures also show the importance of the CBD as a trip attraction in terms of demand magnitude even though the Detroit area is classified as a low CBD orientation application.

The temporal demand distribution for the Low CBD Orientation, High Reverse Commutation Metropolitan Area Application is illustrated in Figure 3-21. As in the previous case, the intervals over which the peak period matrices apply were extended so that the change from one matrix to another accurs during a period when the demand magnitude is not changing significantly. The four spatial demand matrices apply to the following periods:

- Morning peak period 5:00 a.m. to 10:00 a.m.
- Midday period 10:00 a.m. to 2:00 p.m.
- Afternoon peak period 2:00 p.m. to 7:00 p.m.
- Evening period 7:00 p.m. to 5:00 a.m.

The magnitude of demand is changed each hour by scaling the appropriate spatial demand matrix. The scaling factors are shown as percentage figures for each hour of any one time interval. These values are listed above each hour in Figure 3-21.

The service area for the Low CBD Orientation, High Reverse Commutation Application is, in general, limited to an area extending about two miles beyond the outermost stations of the AGT networks. The networks to be considered in this application are illustrated in Figures 4-17 and 4-20. Table 3-49 defines the service area explicitly in terms of districts in the Detroit metropolitan area. Districts are aggregations of traffic analysis zones defined by the Southeastern Michigan Council of Governments. The service area, bounded by the Detroit River and Lake St. Clair and the city of Dearborn, includes the cities of Highland Park and Hamtramck, and borders on Conner Road.

The four spatial demand matrices representing trips within the service area were generated based on survey data. While this provided an adequate temporal and spatial distribution for use through the program, the overall magnitude of the demand in this area was reduced to three-quarters in order to approximate realistic volumes which can be accommodated using the Discrete Event Simulation Model.

In this application area, the following assumptions were used to generate the inter-station travel times using the DESM, and then to map the zonal demand for each time period onto each of the two networks pictured in Figures 4-17 (GRT 3) and 4-20 (PRT 2):

	GRT 3	PRT 2
• Feeder Velocity		
To Station (km/h)	10.8	10.8
Direct (km/h)	13.8	13.8
• AGT Velocity (km/h)	54.0	54.0
• Initial Wait Time (min.)	3	3
• AGT Service Routes	Demand responsive	Demand responsive

Of the total daily travel demand assumed in this application area, 28 percent (205,827) was found to be serviceable by the GRT 3 network, while the PRT 2 network could service 31 percent (222,470). The station-to-station demand matrices are stored in the following members of the AGT.IANDD.DEMAND file:

	GRT 3 Network	PRT 2 Network
A.M. Peak Period	EGRT3A	EPRT2A
Mid-Day Period	EGRT3M	EPRT2M
P.M. Peak Period	EGRT3P	EPRT2P
Evening Period	EGRT3E	EPRT2E

The total demand accessing and egressing each station for these two networks is presented in Tables 3-49A and 3-49B. Four values are shown for each station, representing the demand during each of the four time periods of the day. Station numbers refer to the numbering on the networks pictured in Figures 4-17 and 4-20.

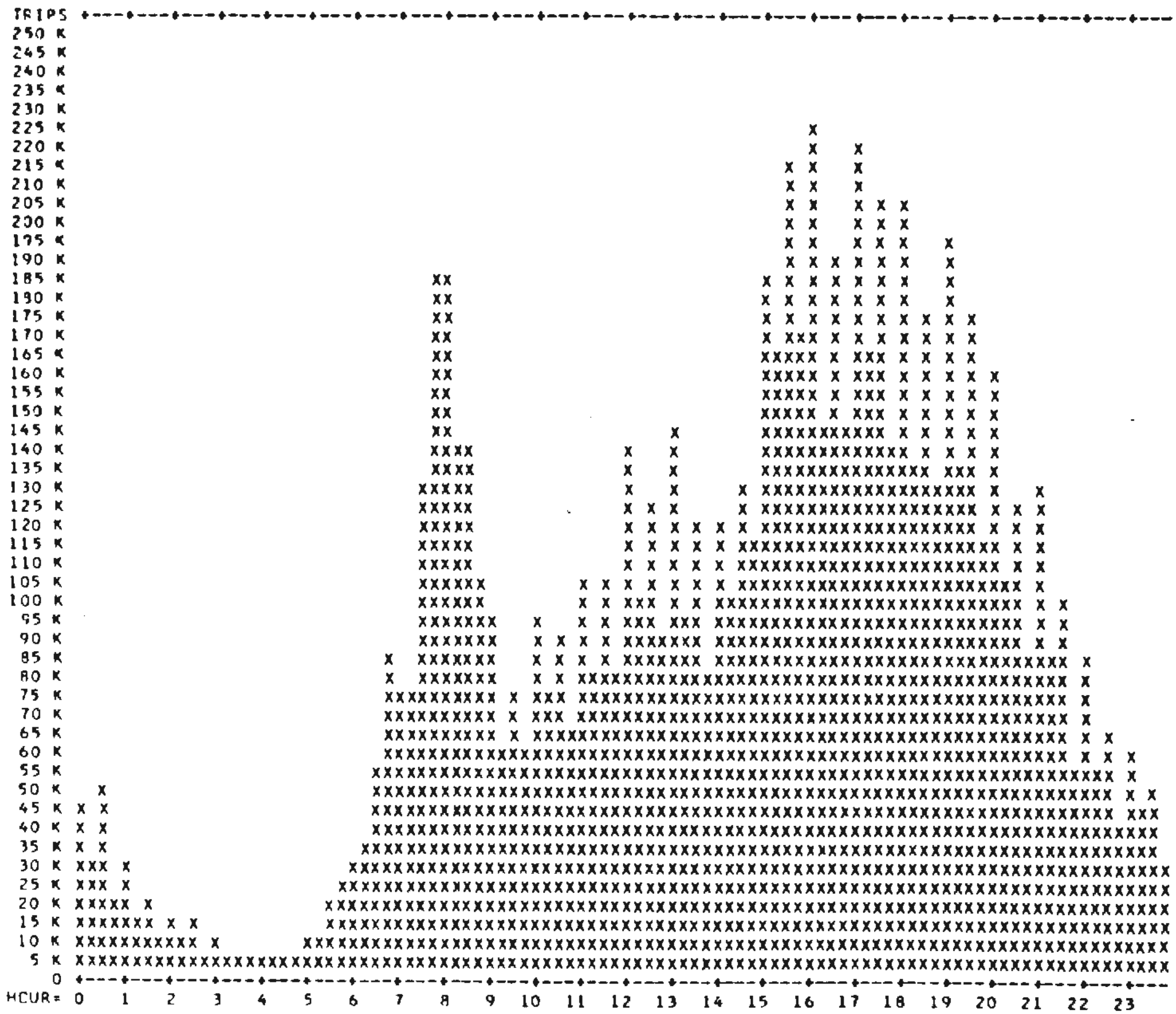


FIGURE 3-17. METROPOLITAN DETROIT 1965 TALUS SURVEY DEMAND PROFILE (TOTAL METRO AREA TRIPS)

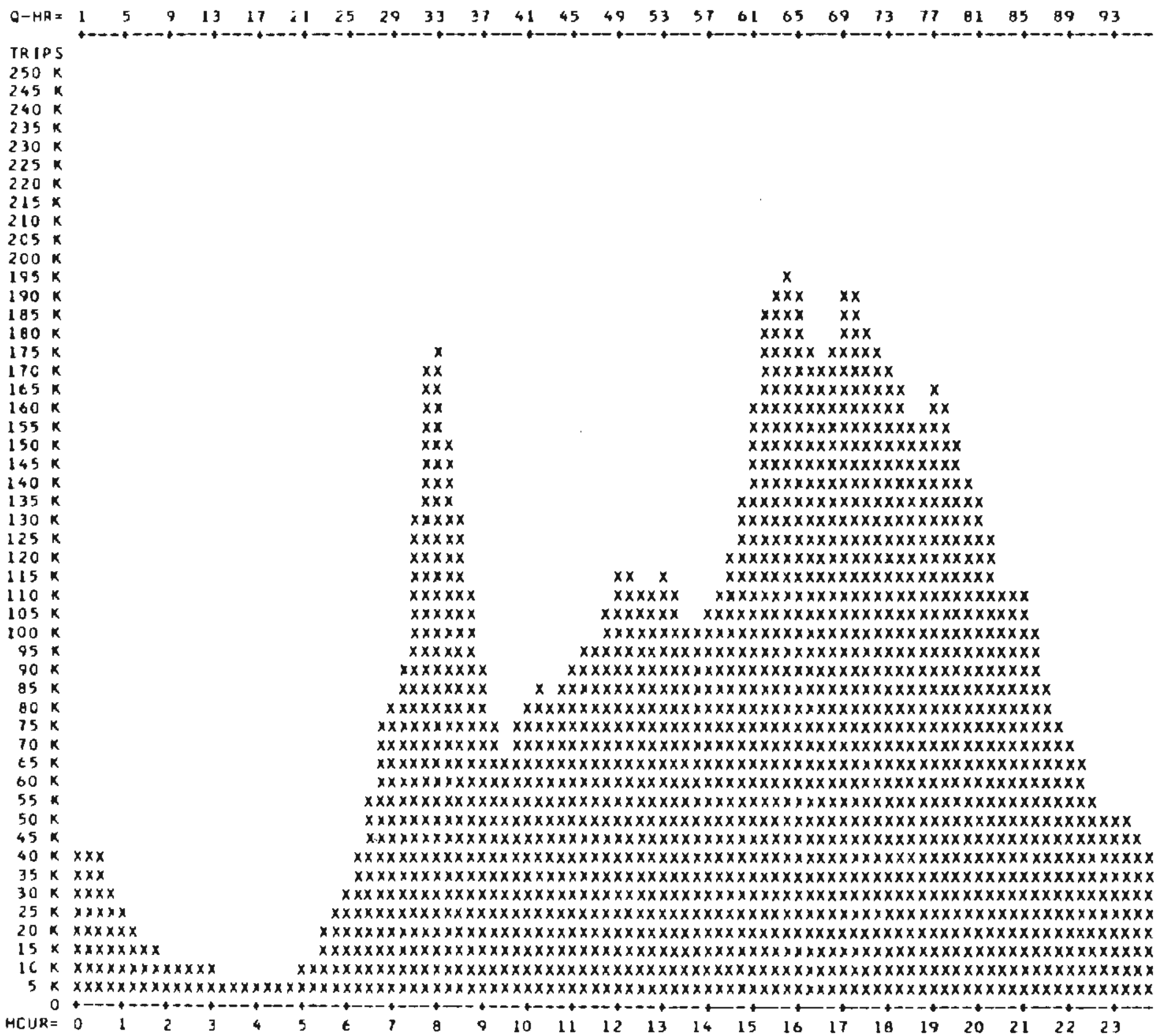


FIGURE 3-18. METROPOLITAN DETROIT 1965 SURVEY TRAVEL DEMAND PROFILE, SMOOTHED (TOTAL METRO AREA)

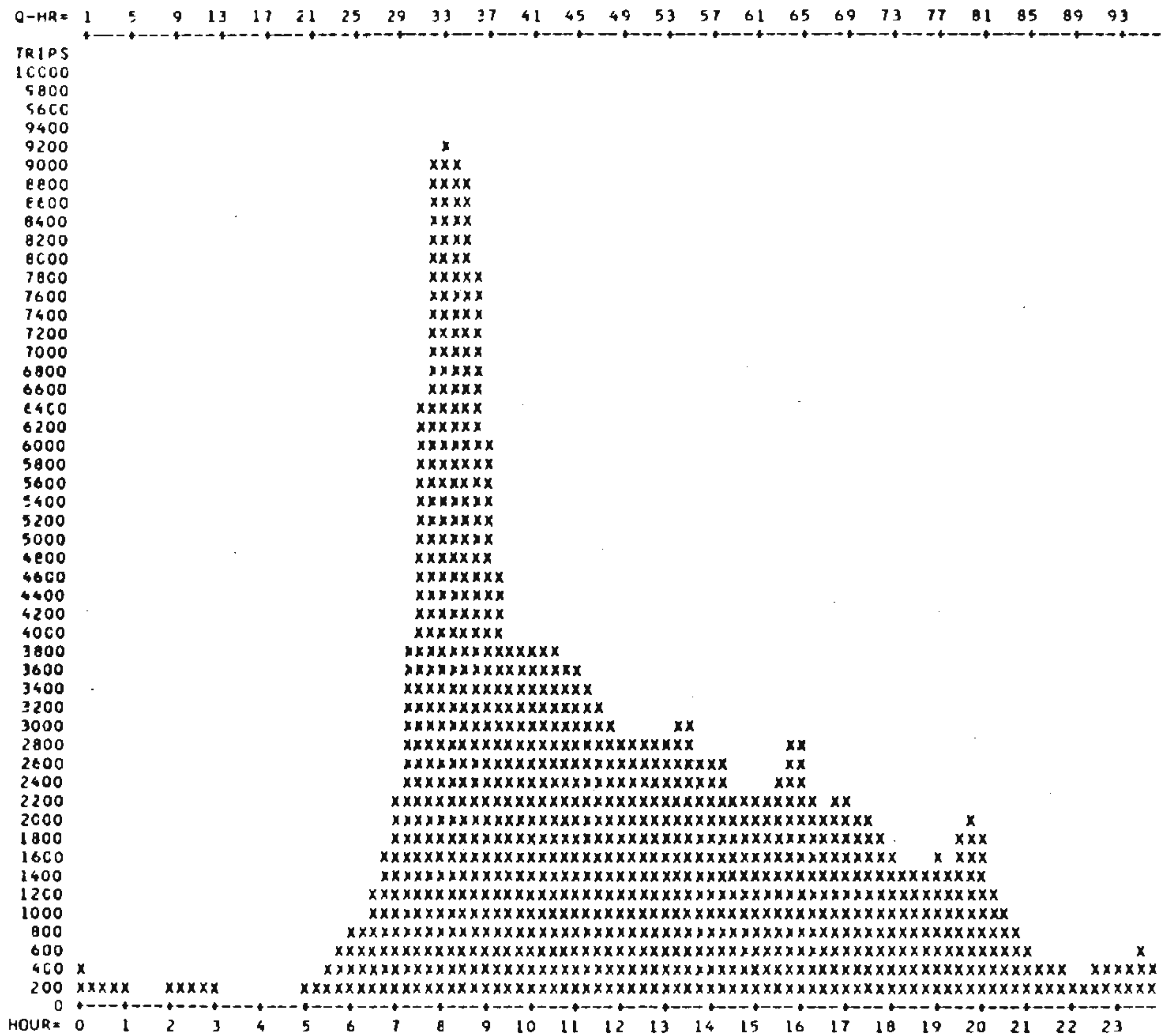


FIGURE 3-19. METROPOLITAN DETROIT 1965 SURVEY TRAVEL DEMAND PROFILE, SMOOTHED (CBD ATTRACTION)

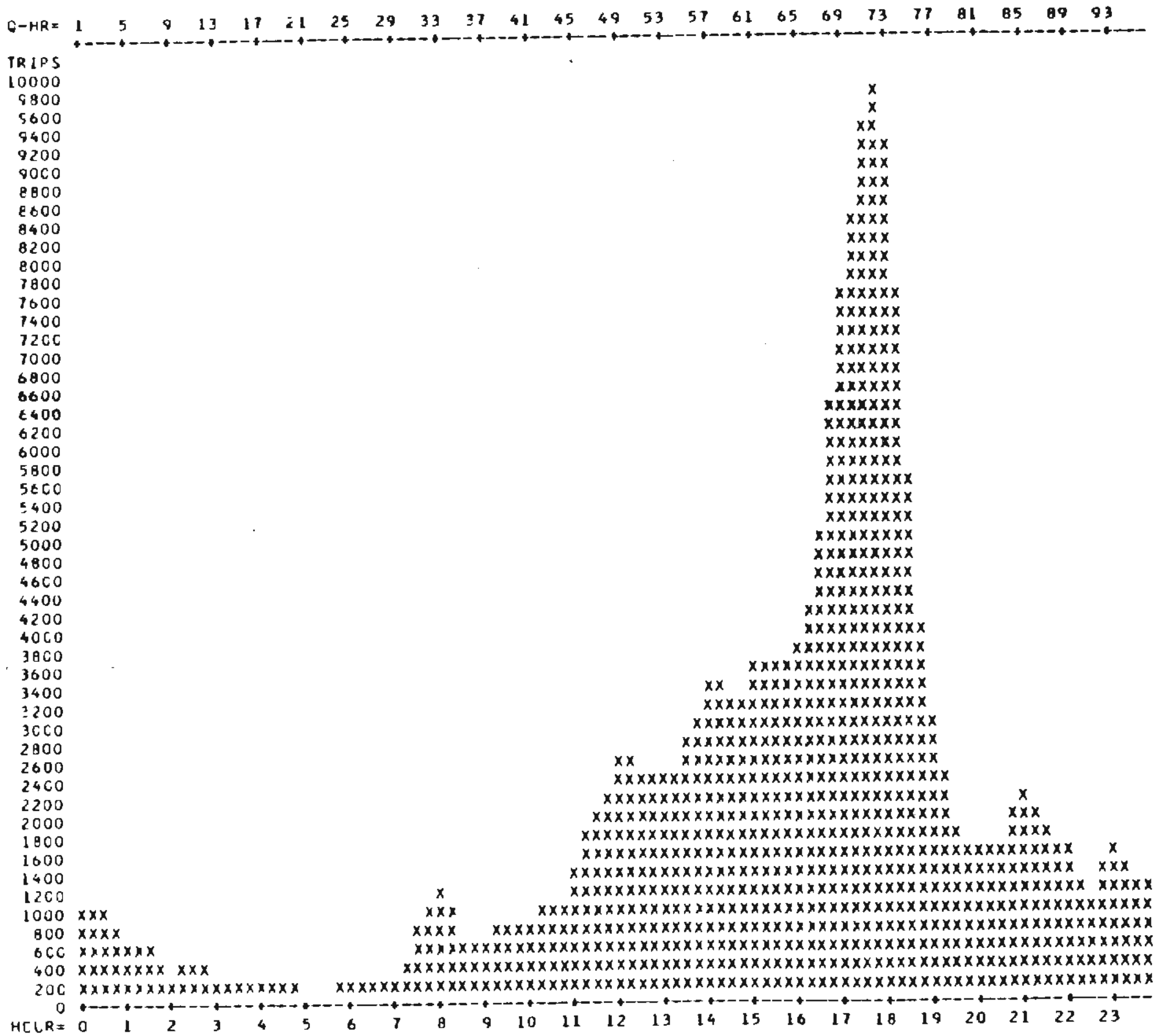


FIGURE 3-20. METROPOLITAN DETROIT 1965 SURVEY TRAVEL DEMAND PROFILE, SMOOTHED (CBD PRODUCTION)

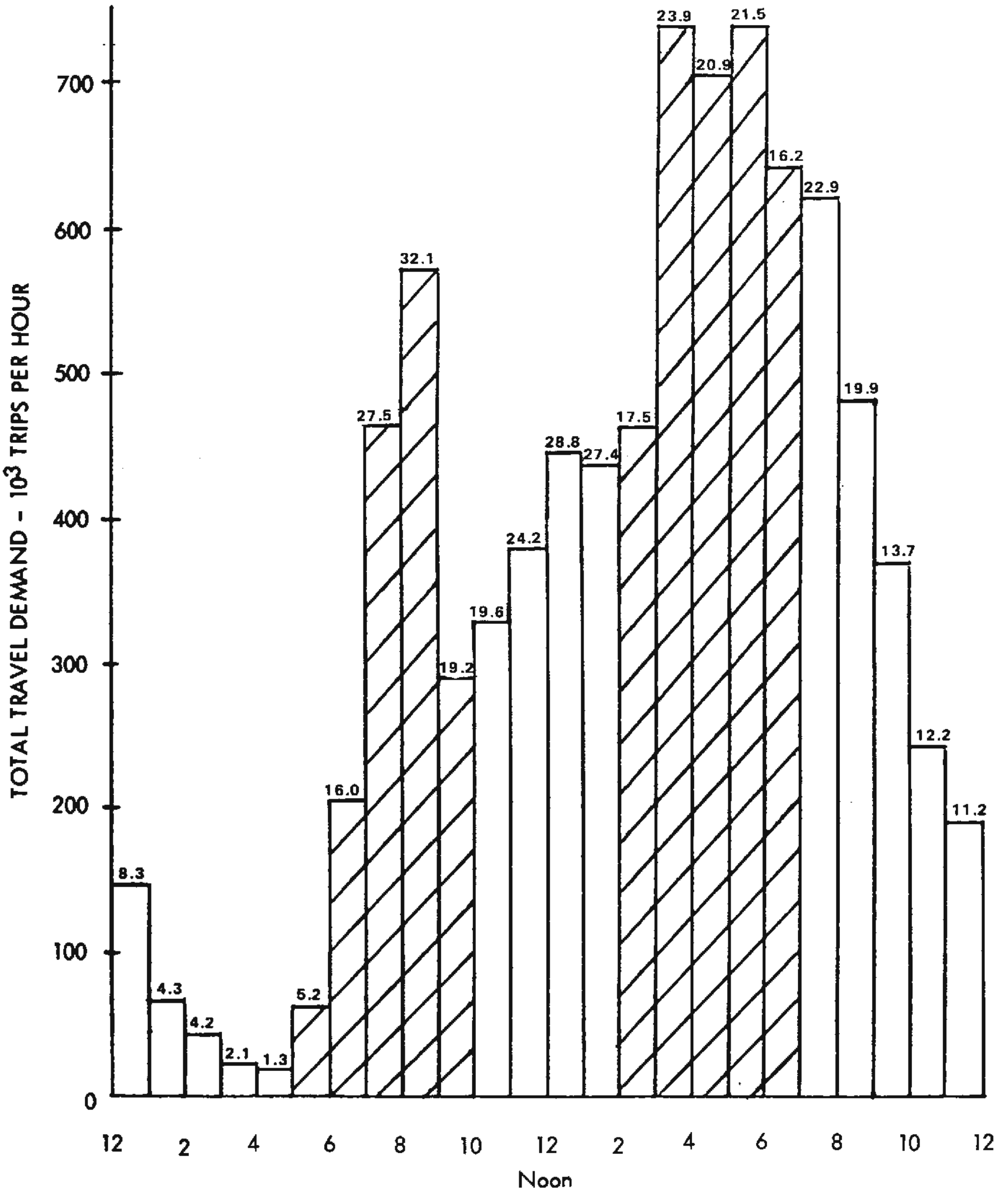


FIGURE 3-21. TRAVEL DEMAND IN THE DETROIT METROPOLITAN AREA

TABLE 3-49. DISTRICTS COMPRISING THE SERVICE AREA FOR THE LOW CBD ORIENTATION HIGH REVERSE COMMUTATION APPLICATION AREA

Districts:
001-019
021-026
029-032
034-035
062-064

TABLE 3-49A. DAILY STATION PATRONAGE - GRT 3

STA. NO.	STATION DEMAND ACCESS	STATION DEMAND EGRESS
1	5441.	2433.
	4578.	3249.
	6450.	8808.
	3764.	4873.
2	1093.	954.
	1255.	953.
	2139.	1923.
	973.	1076.
3	527.	638.
	1069.	1117.
	1775.	1571.
	864.	587.
4	378.	662.
	897.	682.
	1221.	1000.
	674.	540.
5	659.	742.
	858.	649.
	1574.	1023.
	960.	840.
6	730.	1583.
	1461.	1392.
	3265.	1586.
	1494.	469.
7	177.	169.
	277.	114.
	529.	235.
	277.	67.
8	224.	779.
	393.	327.
	1133.	735.
	465.	262.
9	101.	12.
	52.	24.
	76.	14.
	0.	0.
10	86.	222.
	180.	331.
	251.	319.
	90.	97.
11	231.	1383.
	546.	1257.
	1787.	1101.
	871.	760.
12	66.	240.
	263.	416.
	660.	363.
	115.	38.
13	0.	108.
	258.	98.
	399.	140.
	26.	29.
14	599.	1139.
	742.	930.
	1250.	1262.
	488.	561.
15	2832.	1198.
	1444.	1415.
	2447.	4476.
	1304.	2523.
16	1418.	748.
	833.	900.
	1888.	1929.
	1100.	1124.
17	326.	521.
	242.	417.
	901.	634.
	363.	411.
18	184.	261.
	206.	345.
	399.	628.
	361.	291.
19	502.	1127.
	583.	644.
	1725.	1610.
	908.	618.
20	1097.	1683.
	1007.	882.
	2195.	2278.
	1280.	888.
21	5158.	2128.
	3135.	2497.
	5146.	7724.
	2875.	3904.
22	818.	561.
	703.	565.
	1219.	1637.
	689.	1004.
23	1131.	729.
	928.	699.
	1417.	1858.
	823.	842.
24	2163.	1680.
	1407.	1008.
	3339.	2244.
	1438.	1301.
25	144.	389.
	159.	526.
	161.	1261.
	81.	480.
26	37.	183.
	77.	128.
	109.	89.
	19.	60.
27	1246.	794.
	971.	621.
	1706.	2023.
	866.	1239.
28	976.	1006.
	597.	684.
	1674.	1698.
	975.	671.
29	689.	798.
	637.	715.
	1579.	2062.
	1030.	767.
30	115.	481.
	258.	322.
	720.	453.
	150.	135.
31	215.	272.
	184.	323.
	206.	446.
	71.	115.
32	494.	225.
	682.	690.
	647.	948.
	556.	760.
33	560.	389.
	574.	651.
	766.	795.
	364.	309.
34	414.	2949.
	2167.	3680.
	6565.	3315.
	1947.	634.
35	346.	1354.
	657.	1033.
	1241.	1006.
	322.	311.
36	322.	245.
	235.	309.
	531.	478.
	236.	287.
37	161.	151.
	241.	225.
	379.	345.
	237.	294.
38	87.	358.
	190.	222.
	358.	347.
	164.	184.
39	187.	226.
	177.	137.
	359.	315.
	214.	147.
40	212.	626.
	352.	295.
	1030.	544.
	266.	205.

TABLE 3-49B. DAILY STATION PATRONAGE - PRT 2

STA. NO.	STATION DEMAND ACCESS	STATION DEMAND EGRESS
1	402.	524.
	637.	598.
	983.	940.
	684.	632.
2	271.	430.
	791.	606.
	927.	757.
	562.	391.
3	302.	0.
	515.	0.
	1110.	0.
	335.	0.
4	176.	786.
	418.	1062.
	883.	1614.
	517.	660.
5	418.	278.
	422.	275.
	803.	542.
	445.	162.
6	987.	897.
	1009.	1347.
	1477.	2752.
	781.	1718.
7	1320.	1398.
	1049.	886.
	2444.	2349.
	1582.	743.
8	29.	24.
	64.	14.
	100.	36.
	22.	22.
9	90.	237.
	305.	73.
	744.	177.
	286.	62.
10	0.	164.
	0.	96.
	0.	195.
	0.	167.
11	128.	40.
	218.	21.
	376.	93.
	325.	75.
12	69.	242.
	45.	166.
	251.	432.
	23.	183.
13	247.	248.
	196.	267.
	244.	415.
	96.	116.
14	531.	252.
	313.	102.
	786.	224.
	457.	74.
15	511.	1485.
	1408.	2224.
	4007.	2428.
	1105.	245.
16	174.	129.
	145.	209.
	385.	138.
	60.	53.
17	39.	166.
	113.	47.
	374.	146.
	52.	104.
18	73.	188.
	140.	216.
	131.	297.
	252.	145.
19	1186.	1178.
	851.	788.
	1697.	2595.
	1043.	1275.
20	218.	213.
	318.	232.
	798.	186.
	264.	94.
21	75.	336.
	136.	153.
	287.	276.
	142.	283.
22	105.	711.
	236.	331.
	231.	815.
	180.	237.
23	151.	691.
	194.	330.
	330.	423.
	151.	242.
24	1322.	555.
	899.	478.
	1517.	1925.
	796.	801.
25	4266.	1450.
	2574.	2057.
	4071.	6210.
	2336.	3330.
26	0.	9.
	0.	17.
	0.	0.
	0.	0.
27	263.	68.
	344.	310.
	411.	419.
	180.	190.
28	924.	251.
	701.	482.
	1289.	671.
	635.	280.
29	239.	175.
	298.	266.
	372.	646.
	189.	271.
30	730.	192.
	434.	275.
	799.	800.
	323.	303.
31	137.	1197.
	446.	978.
	873.	756.
	315.	465.
32	119.	407.
	238.	444.
	342.	610.
	139.	181.
33	58.	118.
	42.	176.
	65.	159.
	0.	53.
34	87.	28.
	134.	11.
	210.	11.
	75.	0.
35	113.	0.
	287.	0.
	695.	0.
	215.	0.
36	123.	833.
	266.	642.
	899.	1652.
	787.	811.
37	183.	404.
	205.	182.
	381.	402.
	177.	74.
38	54.	1024.
	473.	510.
	890.	582.
	313.	459.
39	542.	1003.
	1500.	1052.
	4165.	900.
	1777.	389.

TABLE 3-49B. DAILY STATION PATRONAGE - PRT 2 (cont.)

STA. NO.	STATION DEMAND ACCESS	STATION DEMAND EGRESS
40	112.	42.
	120.	13.
	376.	0.
	156.	0.
41	38.	0.
	74.	0.
	116.	0.
	20.	0.
42	2436.	1061.
	1429.	883.
	3235.	2070.
	1339.	890.
43	658.	462.
	697.	476.
	960.	797.
	471.	438.
44	880.	407.
	514.	397.
	933.	1505.
	545.	713.
45	671.	1031.
	377.	937.
	591.	2962.
	565.	1671.
46	408.	634.
	213.	820.
	575.	2011.
	192.	961.
47	44.	221.
	107.	245.
	171.	359.
	130.	129.
48	0.	24.
	0.	47.
	0.	42.
	0.	35.
49	433.	416.
	387.	185.
	895.	378.
	279.	118.
50	0.	0.
	0.	0.
	0.	0.
	0.	0.
51	11.	0.
	12.	0.
	22.	0.
	44.	0.
52	110.	97.
	163.	166.
	286.	324.
	213.	225.
53	1927.	734.
	1500.	695.
	2435.	1552.
	1051.	1025.
54	45.	263.
	24.	252.
	140.	590.
	92.	321.
55	47.	0.
	33.	0.
	14.	56.
	56.	12.
56	10.	35.
	55.	326.
	52.	544.
	49.	301.
57	159.	130.
	169.	120.
	267.	199.
	217.	191.
58	66.	200.
	80.	74.
	351.	155.
	76.	25.
59	65.	175.
	9.	50.
	40.	122.
	64.	28.
60	153.	464.
	306.	322.
	746.	490.
	432.	240.
61	107.	250.
	173.	260.
	267.	383.
	45.	105.
62	218.	359.
	575.	366.
	587.	305.
	389.	75.
63	71.	991.
	287.	663.
	414.	987.
	227.	417.
64	402.	403.
	424.	446.
	427.	474.
	153.	348.
65	229.	219.
	331.	259.
	290.	369.
	291.	201.
66	1504.	695.
	1269.	1173.
	1910.	2084.
	1098.	1871.
67	54.	267.
	175.	214.
	263.	248.
	43.	80.
68	5990.	2240.
	4532.	2939.
	6689.	8893.
	4195.	4711.
69	315.	3095.
	1658.	3895.
	4320.	3483.
	1338.	966.
70	65.	211.
	128.	162.
	299.	468.
	135.	143.
71	224.	572.
	462.	361.
	1273.	370.
	213.	236.
72	141.	11.
	94.	22.
	360.	31.
	50.	11.
73	66.	99.
	95.	59.
	270.	103.
	159.	120.
74	0.	187.
	0.	87.
	0.	74.
	0.	46.

3.5.7 High CBD Orientation, Low Reverse Commutation Metropolitan Area Demand

The demand model for this application area is based on a 1968 home-interview survey of travel behavior in the metropolitan Washington D.C. area. The survey tape was obtained from the Metropolitan Washington Council of Governments and contains 149,905 records which define travel among the region's 1,207 traffic analysis zones.

The demand model generation process for this application is essentially the same four-step process described in Section 3.5.5. Survey records are screened and survey summary files are created. Then demand profiles are generated and used to select demand intervals. Finally, the demand matrices are generated and hourly factors are calculated.

Figure 3-22 shows the temporal variation in demand magnitude for total travel in the Washington D.C. area. Figure 3-23 shows the demand profile for total travel after the survey data has been smoothed using the formula presented in Section 3.5.5. Figures 3-24 and 3-25 are smoothed demand profiles for D.C. core attraction and D.C. core production, respectively. The figures show that the morning peak period extends from 6:00 a.m. to 9:00 a.m. The afternoon peak period extends from about 3:00 p.m. to about 6:30 p.m. for total travel, but it is shorter (4:00 p.m. to 6:00 p.m.) for D.C. core production.

The form of the temporal demand for the High CBD Orientation, Low Reverse Commutation Metropolitan Area Application is illustrated in Figure 3-26. The four spatial demand matrices apply to the following periods:

- Morning peak period — 5:00 a.m. to 10:00 a.m.
- Midday period — 10:00 a.m. to 2:00 p.m.
- Afternoon peak period — 2:00 p.m. to 7:00 p.m.
- Evening period — 7:00 p.m. to 5:00 a.m.

The magnitude of demand is changed each hour by scaling the appropriate spatial demand matrix. These scaling factors are listed over each hour in Figure 3-26, and are representative of the percentage of trips in each hour of any given time period.

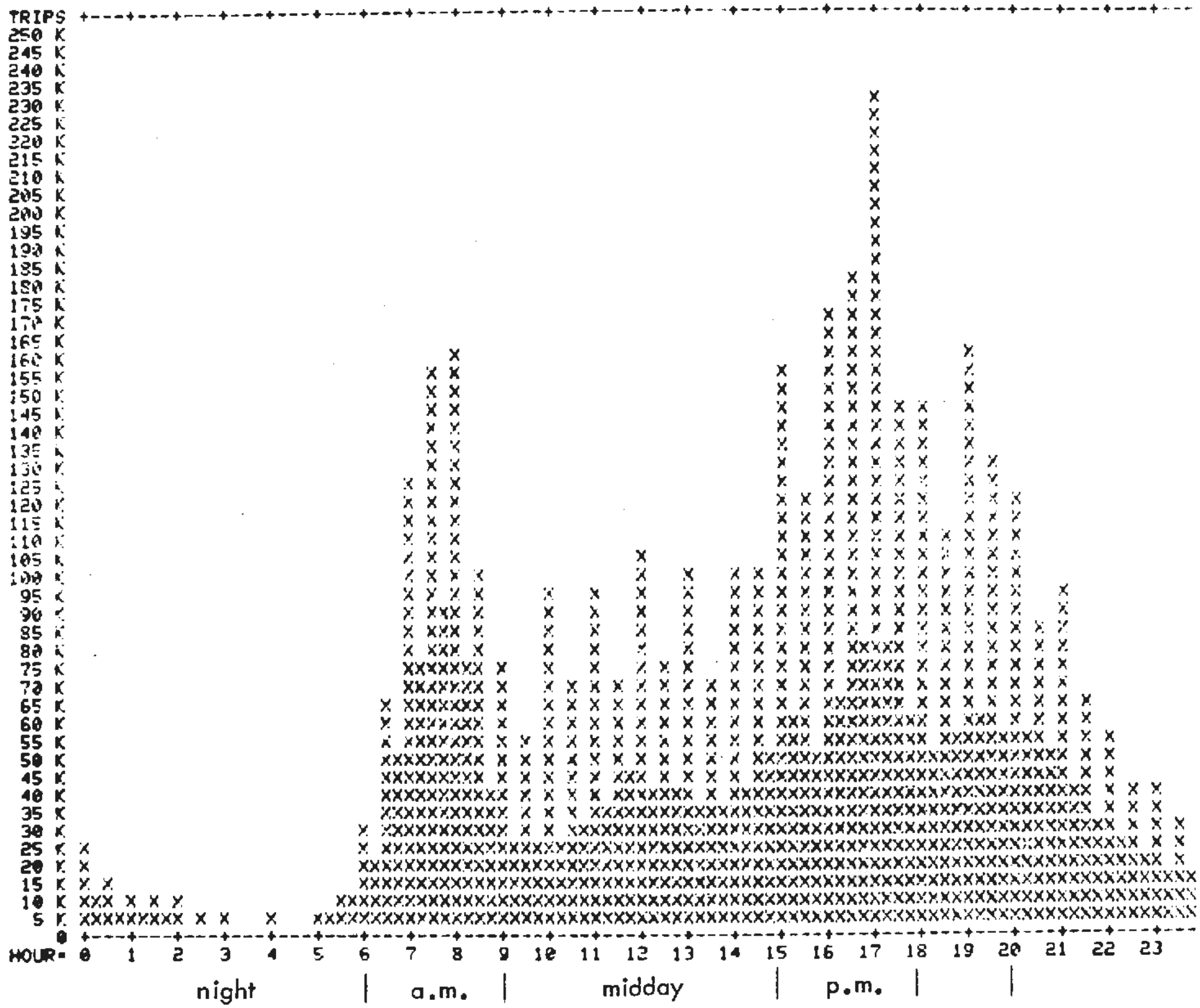


FIGURE 3-22. METROPOLITAN WASHINGTON 1968 SURVEY TRAVEL DEMAND PROFILE (TOTAL METRO AREA TRIPS)

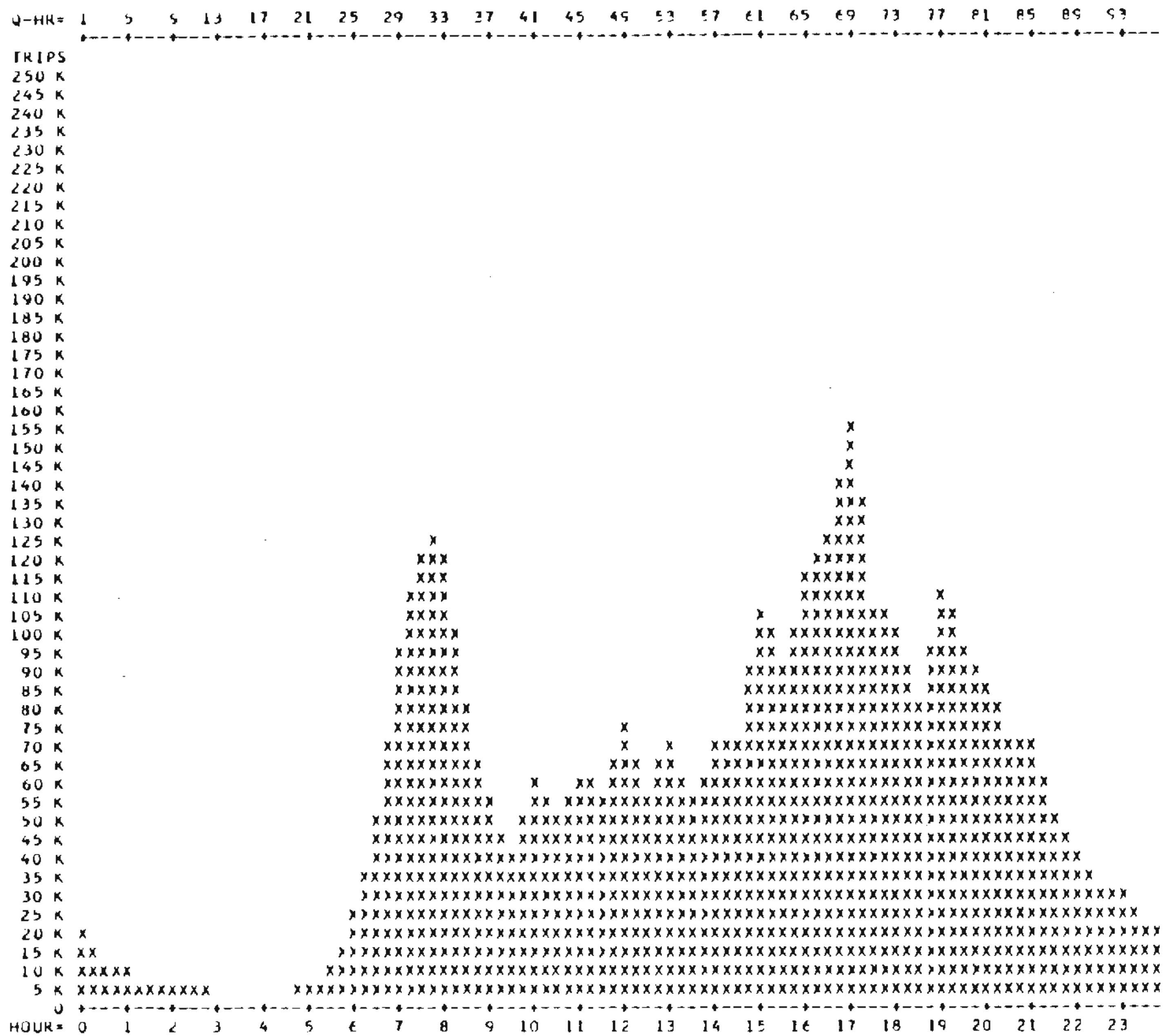


FIGURE 3-23. METROPOLITAN WASHINGTON 1968 SURVEY TRAVEL DEMAND PROFILE, SMOOTHED (TOTAL METRO AREA TRIPS)

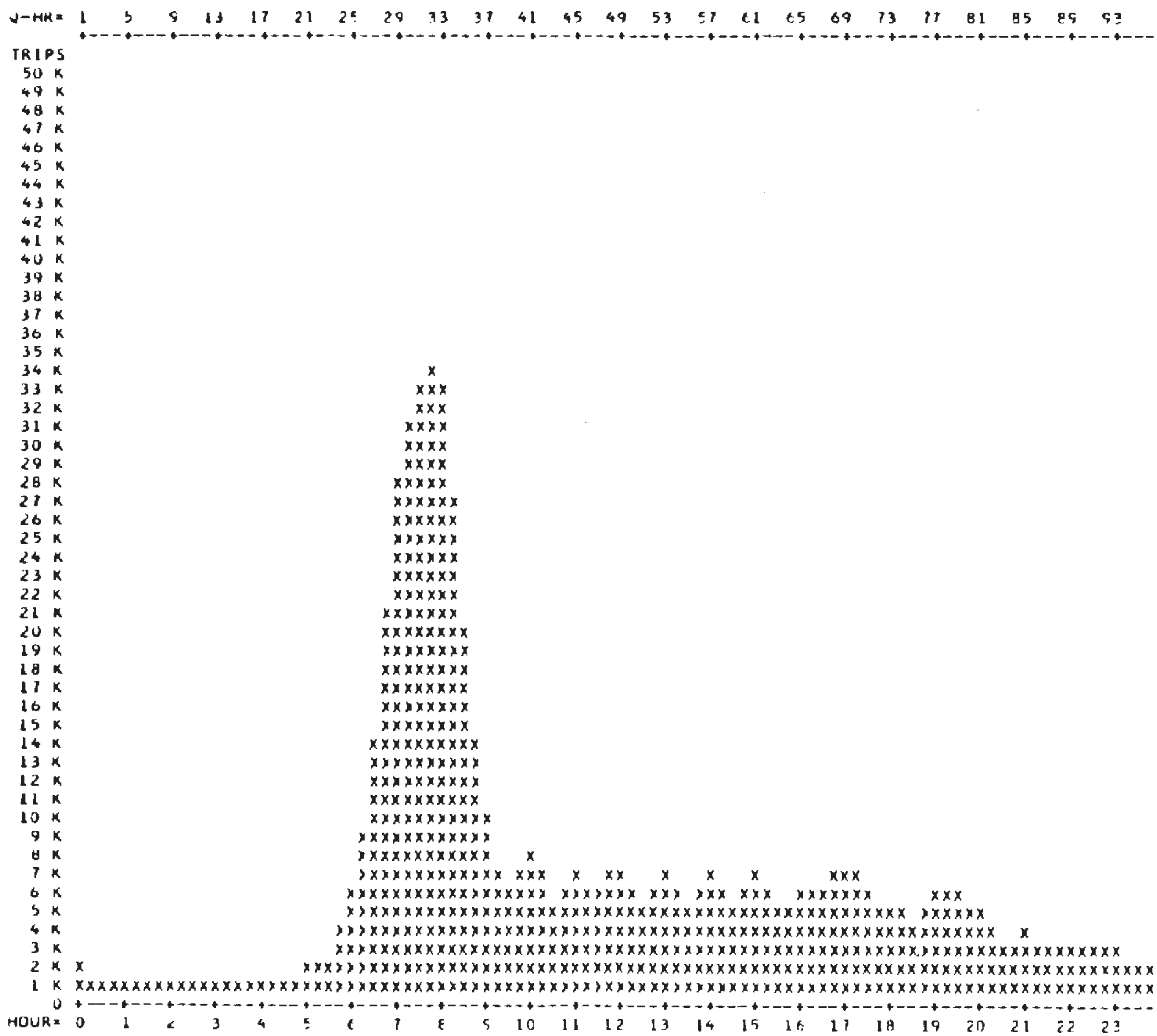


FIGURE 3-24. METROPOLITAN WASHINGTON 1968 SURVEY TRAVEL DEMAND PROFILE, SMOOTHED (D.C. CORE ATTRACTION)

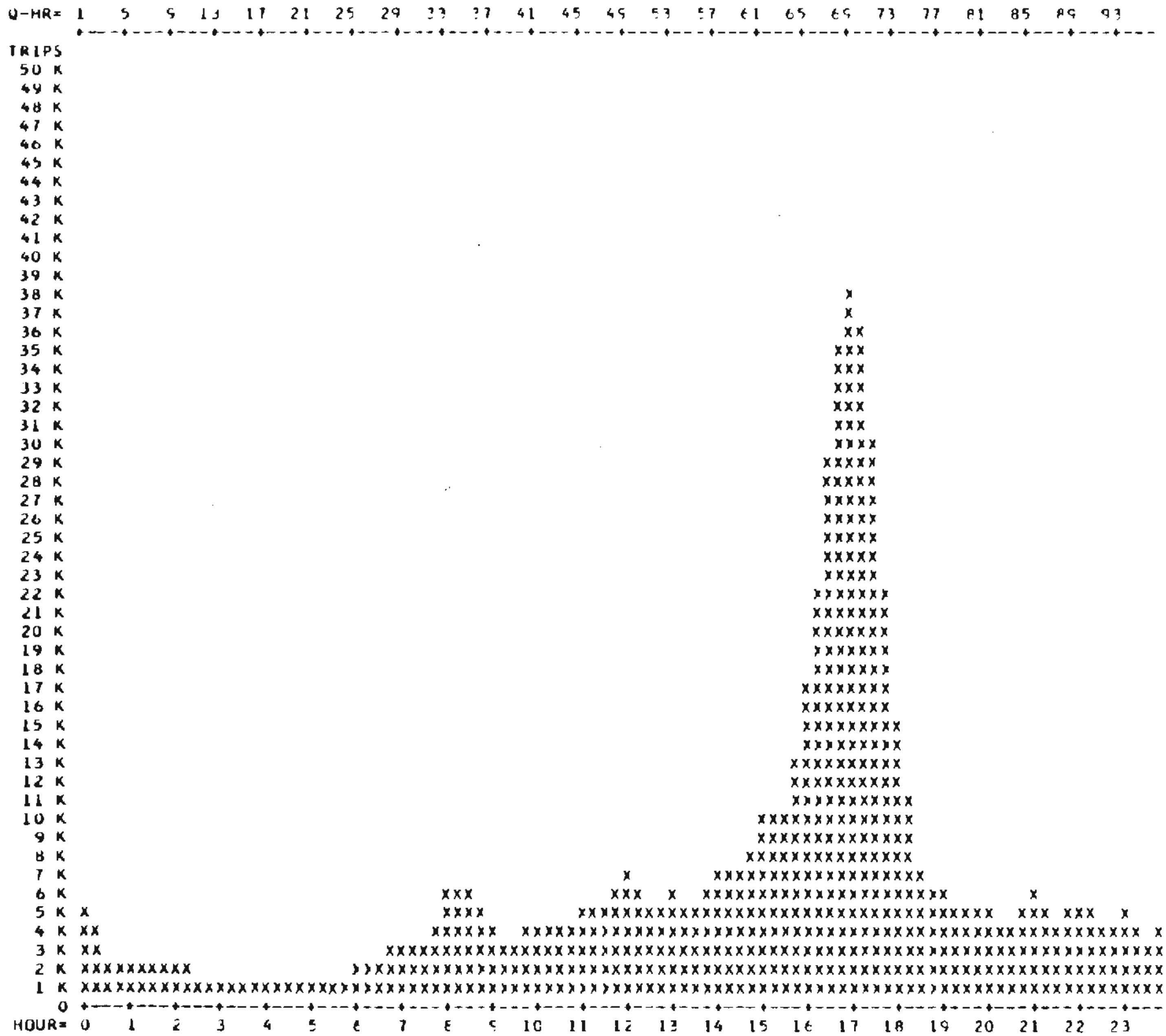


FIGURE 3-25. METROPOLITAN WASHINGTON 1968 SURVEY TRAVEL DEMAND PROFILE, SMOOTHED (D.C. CORE PRODUCTION)

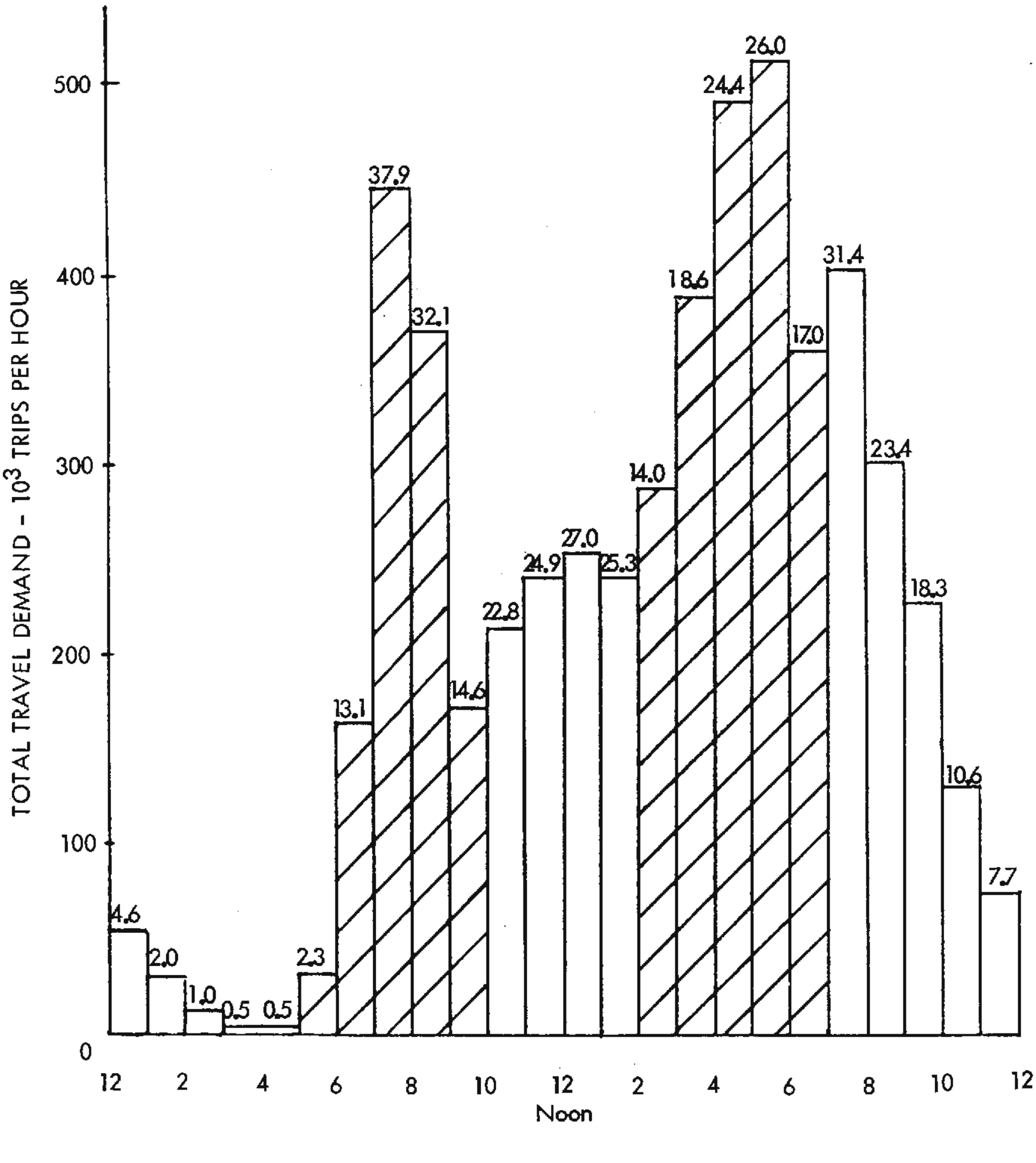


FIGURE 3-26. TRAVEL DEMAND IN THE WASHINGTON D.C. METROPOLITAN AREA

The service area for the High CBD Orientation, Low Reverse Commutation Application was defined by applying the same criterion as was applied in the previous two cases. The service area extends approximately two miles beyond the network coverage. The networks to be considered in this application are illustrated in Figures 4-11 and 4-18. Table 3-50 defines the service area in terms of zones in the metropolitan Washington D.C. area. The service area is basically enclosed by the borders of the Capital District and Alexandria, Virginia.

In this application area, the following assumptions were used to generate the inter-station travel times using the DESM, and then to map the zonal demands for each time period onto each of the two networks pictured in Figures 4-11 (ART 2) and 4-18 (GRT 4):

	ART 2	GRT 4
• Feeder Velocity:		
To Station (km/h)	10.8	10.8
Direct (km/h)	13.8	13.8
• AGT Velocity (km/h)	64.0	54.0
• Initial Wait Time (min)	3	3
• AGT Service Routes (round trip between stations as numbered in Fig. 4-11; stopping at all intermediates)	1-15 41-48 14-43 27-43 14-16	Demand responsive

Of the total daily travel demand assumed in this application area, 35 percent of it (623,146) was found serviceable by the ART 2 network, while the GRT 4 network employing the down-town bypass could service 36 percent (657, 447). The station-to-station demand matrices are stored in the following members of the AGT.IANDD.DEMAND file:

	ART 2 Network	GRT 4 Network
A.M. Peak Period	EART2A	EGRT4A
Midday period	EART2M	EGRT4M
P.M. Peak Period	EART2P	EGRT4P
Evening Period	EART2E	EGRT4E

For these two networks, the total demand accessing and egressing each station is presented in Tables 3-50A and 3-50B. Four values are shown for each station, representing the demand during each of the four time periods of the day. Station numbers refer to the numbering on the networks pictured in Figures 4-11 and 4-18.

TABLE 3-50. ZONES COMPRISING THE SERVICE AREA FOR THE HIGH CBD ORIENTATION, LOW REVERSE COMMUTATION APPLICATION AREA

Sequential Zone Numbers
1-412
418-419
421
431
435
438-442
448-451
454-455
462-466
469
474-475
496-497
505-509
518-522
528
530-533
536-543
555
557
564
574-576
586
591-598
601
607
615
708

TABLE 3-50A. DAILY STATION PATRONAGE - ART 2

STA. NO.	STATION DEMAND ACCESS	STATION DEMAND EGRESS
1	2841.	2084.
	2261.	2285.
	3858.	4882.
	2981.	2142.
2	2766.	2434.
	2954.	2430.
	4618.	5486.
	2371.	2369.
3	4608.	2464.
	2586.	2131.
	4422.	6649.
	2144.	2784.
4	3692.	1343.
	1676.	1091.
	2482.	4355.
	924.	1845.
5	7402.	2648.
	3232.	3158.
	4796.	8846.
	3571.	4310.
6	4918.	5210.
	3693.	3680.
	8837.	7228.
	4748.	5352.
7	848.	13204.
	2798.	3760.
	14348.	3011.
	3902.	2051.
8	915.	12582.
	3842.	5780.
	15547.	4345.
	4486.	2161.
9	1108.	8522.
	3515.	3918.
	12068.	3813.
	2993.	1722.
10	442.	2918.
	948.	1254.
	3937.	969.
	844.	275.
11	4341.	7022.
	2601.	2236.
	7831.	6607.
	4377.	2891.
12	3507.	2945.
	1685.	1560.
	4210.	4407.
	2225.	2224.
13	5487.	2685.
	2272.	2004.
	4587.	6860.
	2698.	3579.
14	9612.	2062.
	2713.	2003.
	4479.	10274.
	2988.	4468.
15	6865.	3345.
	1823.	1770.
	4742.	8254.
	3538.	3650.
16	7220.	1524.
	1852.	1641.
	2648.	8456.
	2807.	3341.
17	9208.	1673.
	1894.	1574.
	3716.	10189.
	3023.	3832.
18	3471.	2224.
	1179.	1085.
	3298.	4318.
	2198.	2400.
19	2824.	2906.
	951.	917.
	4132.	3950.
	2360.	2486.
20	761.	6858.
	951.	996.
	7057.	1944.
	2236.	1073.
21	195.	6324.
	621.	1060.
	6282.	849.
	819.	489.
22	1913.	5787.
	1226.	1544.
	6004.	2816.
	2136.	1651.
23	2655.	3238.
	1965.	1659.
	4018.	3870.
	2734.	2610.
24	2401.	3601.
	1448.	1544.
	3793.	3024.
	2216.	2149.
25	5486.	2011.
	1547.	1220.
	3583.	7279.
	2686.	2887.
26	6892.	2620.
	1964.	1685.
	3685.	8014.
	2546.	3226.

TABLE 3-50A. DAILY STATION PATRONAGE - ART 2 (cont.)

STA. NO.	STATION DEMAND ACCESS	STATION DEMAND EGRESS
27	4795.	740.
	1435.	1215.
	2168.	5664.
	1593.	2674.
28	5815.	983.
	1047.	1141.
	2170.	6314.
	2001.	2313.
29	2218.	2811.
	1213.	1028.
	3485.	3256.
	1963.	1690.
30	3009.	628.
	925.	859.
	1474.	3570.
	704.	1110.
31	2413.	1508.
	948.	1132.
	2087.	2764.
	1484.	1580.
32	840.	3073.
	585.	791.
	3502.	1461.
	945.	716.
33	948.	1405.
	291.	296.
	1734.	956.
	370.	404.
34	54.	2502.
	466.	985.
	3322.	480.
	593.	313.
35	120.	3977.
	565.	640.
	3868.	284.
	271.	301.
36	923.	4087.
	1331.	1468.
	4364.	1607.
	1680.	1256.
37	1053.	7483.
	2174.	1885.
	8510.	1787.
	1636.	901.
38	2146.	3497.
	1473.	1859.
	5064.	2773.
	2585.	2422.
39	4056.	3155.
	1975.	1813.
	4244.	5918.
	2756.	2307.
40	715.	1463.
	1411.	1876.
	2220.	1770.
	1013.	775.
41	844.	541.
	627.	460.
	724.	984.
	325.	597.
42	3667.	918.
	774.	789.
	1416.	3412.
	912.	1318.
43	4871.	2032.
	2705.	2139.
	3920.	6807.
	2842.	3254.
44	1213.	2943
	1607.	1647
	4101.	2777
	2586.	149
45	600.	655.
	567.	446.
	1247.	859.
	753.	641.
46	11040.	2309.
	2731.	2480.
	4040.	12168.
	3602.	5267.
47	1321.	7280.
	1458.	1438.
	7956.	2169.
	1605.	922.
48	2669.	1806.
	1082.	3342.
	1385.	8531.
	923.	3547.
49	6697.	1949.
	4261.	3976.
	6625.	10186.
	4141.	4967.
50	3419.	1885.
	3645.	2601.
	5315.	5389.
	3234.	2723.
51	2592.	1071.
	2548.	2038.
	2817.	4678.
	2210.	1950.
52	2290.	1774.
	2647.	2359.
	4022.	3505.
	2352.	2210.

TABLE 3-50B. DAILY STATION PATRONAGE - GRT 4

STA. NO.	STATION DEMAND ACCESS	EGRESS
	3306.	2346.
1	2638.	2409.
	4189.	5374.
	3164.	2340.
	3471.	2580.
2	3354.	2623.
	4858.	6373.
	2858.	2837.
	3729.	2433.
	2014.	1910.
3	4310.	5773.
	1692.	2360.
	3790.	1430.
	1721.	1165.
4	2553.	4448.
	915.	1844.
	6500.	2572.
	3083.	3128.
	4576.	8351.
5	3631.	4074.
	5459.	5923.
	3734.	3979.
	9679.	7814.
6	4916.	5557.
	661.	8888.
	2380.	2739.
	13144.	2352.
	3395.	1422.
7	992.	11592.
	3489.	5873.
	14051.	4260.
	4492.	2792.
8	404.	4037.
	2335.	2597.
	6222.	2238.
	1396.	431.
	368.	2540.
9	1206.	1435.
	3275.	1246.
	639.	286.
	3548.	9507.
	2714.	2354.
10	9837.	6151.
	4992.	3052.
	3823.	3812.
	2068.	1755.
11	5064.	4907.
	2681.	2589.
	5789.	2933.
	2461.	2067.
	5112.	7207.
13	2886.	3951.

STA. NO.	STATION DEMAND ACCESS	EGRESS
	9336.	2339.
14	2685.	2080.
	4535.	10467.
	2947.	4508.
	6614.	3591.
15	1841.	1873.
	5166.	8096.
	3643.	3753.
	10261.	1815.
	2252.	1932.
16	3393.	11743.
	3350.	4046.
	7010.	1499.
	1705.	1280.
17	3300.	7982.
	2652.	3396.
	3723.	1916.
	1304.	1086.
	3022.	4615.
18	2178.	2492.
	3718.	3317.
	1241.	1130.
	4865.	4922.
19	2770.	2901.
	222.	3300.
	592.	729.
	3806.	1060.
	1423.	519.
20	262.	5892.
	802.	1181.
	6538.	1060.
	1103.	297.
	2334.	3833.
21	1436.	1625.
	4946.	2711.
	2185.	1625.
	2804.	3646.
22	1965.	1733.
	4398.	4444.
	2763.	2321.
	3404.	3393.
	1916.	1946.
23	4319.	3800.
	2601.	2830.
	7058.	2096.
	1880.	1420.
24	4042.	8549.
	2917.	3457.
	8405.	2497.
	2232.	1766.
	3879.	9399.
25	2843.	3340.

TABLE 3-50B. DAILY STATION PATRONAGE - GRT 4 (cont.)

STA. NO.	STATION DEMAND ACCESS	STATION DEMAND EGRESS
27	5292.	947.
	1635.	1267.
	2413.	6065.
	1761.	2980.
28	6862.	1001.
	1176.	1267.
	2205.	7531.
	2195.	2578.
29	3112.	2992.
	1407.	1353.
	4179.	4248.
	2274.	2230.
30	3702.	777.
	1045.	1102.
	1821.	4408.
	917.	1325.
31	2811.	1728.
	1028.	1254.
	2428.	3054.
	1627.	1773.
32	1004.	5031.
	693.	1480.
	5720.	2093.
	1366.	1028.
33	860.	2530.
	412.	379.
	2604.	921.
	744.	552.
34	154.	5344.
	607.	1036.
	5746.	784.
	824.	487.
35	129.	5057.
	779.	893.
	5016.	409.
	416.	413.
36	934.	10130.
	2636.	2460.
	11462.	2547.
	3499.	1856.
37	845.	9329.
	2142.	1931.
	8161.	2069.
	1616.	1142.
38	2185.	6120.
	1707.	2426.
	6513.	3008.
	2650.	2753.
39	3371.	3161.
	1781.	1518.
	4378.	5007.
	2500.	2199.

STA. NO.	STATION DEMAND ACCESS	STATION DEMAND EGRESS
40	669.	2065.
	1925.	2814.
	3870.	1952.
	1560.	1148.
41	908.	606.
	652.	522.
	878.	1169.
	351.	664.
42	3400.	965.
	772.	952.
	1459.	3135.
	1077.	1428.
43	5311.	2111.
	3223.	2329.
	4265.	7460.
	3342.	3610.
44	1017.	3084.
	1614.	1700.
	4237.	2639.
	2689.	1499.
45	614.	731.
	644.	518.
	1422.	960.
	799.	668.
46	10286.	2163.
	2497.	1965.
	3863.	11071.
	3206.	4593.
47	988.	7293.
	1148.	1057.
	7614.	1767.
	1429.	598.
48	2795.	1883.
	1107.	3714.
	1402.	9167.
	937.	3733.
49	8933.	2272.
	5037.	4517.
	7209.	13083.
	4881.	6150.
50	4164.	2204.
	3163.	3247.
	5761.	5999.
	3193.	2863.
51	2019.	988.
	3057.	1819.
	3018.	4049.
	2350.	2174.
52	2934.	2052.
	2866.	2472.
	3601.	4385.
	2436.	2210.

4.0 NETWORK CONFIGURATION

In the Classification and Definition of AGT Systems report,[12] several AGT system characteristics were considered, and ten representative AGT systems were identified and quantified for further analysis. In the preceding chapter of this report, travel demand environments were considered and seven specific demand types were chosen as deployment environments for this study. This section documents the development and selection of 19 AGT deployments. For each of the 19 deployments, the following are identified:

1. The specific demand environment as identified in Section 3.0
2. The specific system type as defined in the Classification and Definition report[12]
3. A network tailored to the specific demand within the constraints of a given network class as discussed in this chapter.

Section 4.1 provides working definitions of network types based upon operational characteristics. Also given are definitions of AGT system deployments which are broader in scope in that they include implications of system operational constraints in addition to the obvious constraints imposed by network geometry. In Section 4.2, the specific combinations of system type, network type, and demand environment initially identified for analysis in the SOS Program are defined along with the rationale for their selection. Section 4.3 presents the rationale used to specify a network configuration for each system deployment, presents the final networks, and presents a network flow analysis of the eleven SLT deployments. Finally, a summary of the network configurations and analyses is presented.

4.1 DEFINITIONS

4.1.1 Network Types

Each operationally distinct portion of a network may be classified into one of three basic simple network types:

1. Shuttle—A guideway on which bidirectional motion occurs during normal operation and which is defined by a single curve connecting two distinct end points.

2. Loop—A guideway on which motion is unidirectional during normal operation except possibly on short segments at stations or at ends of runs, and which is defined by a closed path.

3. Grid—Any guideway on which vehicles are presented with a choice of paths during normal operation.

Thus, it is seen that only one vehicle may operate on a simple shuttle network and no headway or merge control is required. More than one vehicle may operate on a simple loop or a simple grid at the same time; however, headway control is required to prevent collisions and, in the case of a simple grid, some form of merge control must be used.

For the purpose of this study, subcategorizing these network types is useful in defining detailed network configurations. The following standard definitions and abbreviations have been adopted:

1. Shuttle (S) refers to a simple shuttle as defined above and also to any network consisting of two or more simple shuttles, either following the same path or different paths. If passing sections are added to a shuttle, the network becomes a grid since vehicles are presented a choice of paths. Headway and merge control are required to safely utilize such passing sections.

2. Loop (L) is used to refer only to a single simple loop, as defined above, which is elongated to the extent that it encircles no area and thus provides a line-haul type of service.

3. One-Way Loop (L1) is used to refer to a single simple loop which does encircle on area and provides a one-directional circulation service.

4. Two-Way Loop (L2) is used to refer to two simple loops contiguously deployed which do encircle an area. Circulation service in two directions is thus accommodated.

5. Multiple Loop (ML) is used to refer to any network consisting of two or more simple loops which does not qualify as a two-way loop network.

6. Fully Connected Grid (FG) is used to refer to a simple grid as defined above if no network constraint prevents a vehicle currently at one station from proceeding to any other station in the network in a manner which does not require the vehicle to retrace any one- or two-directional portion of guideway.

7. Partially Connected Grid (PG) is used to refer to any simple grid which is not a fully connected grid.

This classification is applied to networks before the question of off- or on-line stations is considered. Usually a non-grid network (not considering stations) has on-line stations. However, in the deployments which follow, one non-grid network (GRT 4 as defined in Table 4-2) has a station type specified as open, to be determined only after link loads are investigated. In this case, should off-line stations be required, the network should be reclassified as either a fully connected grid or a partially connected grid network.

4.1.2 Deployment Types

Five deployment types are defined for the representative systems: SLT, GRT, ART, DMT, and PRT. The latter three deployment types are defined by system type, as detailed in the Classification and Definition report;[12] while the SLT and GRT deployment systems are defined by not only system type but also by network type.

An SLT deployment is a low speed GRT system (as defined in the Classification and Definition report[12]) deployed in an activity center demand environment having any non-grid type network with on-line stations. Only shuttle or loop networks are employed for this deployment; thus, no operational switching occurs, but passengers may be required to transfer.

The GRT deployment is a low- or high-speed GRT system deployed in either an activity center or a metropolitan area demand environment. The network type can be either a grid network (partially or fully connected) or an SLT network. Therefore, the GRT deployment has extensive operational switching capabilities.

In the following section all of the deployments identified for future analysis are classified into one of the five deployment types.

4.2 SYSTEM-NETWORK DEPLOYMENTS

A specific set of representative system deployments are used for system trade-off and comparative analyses. Each deployment consists of a specific system, a specific demand, and a specific network type. Ten system, seven demand, and seven network types have previously been defined. In theory there are 490 possible deployments. The following criteria were used to select and limit the number of deployments for study.

4.2.1 Rationale for Selection

The following points are considered in the selection of system-network deployments:

1. Budget constraints require that a realistic number of deployments be studied.
2. Computational constraints require that the number of distinct large-scale networks deployed in a metropolitan area demand environment be limited. The same or a similar network should be used for different systems in the same demand whenever possible.
3. Only low-speed systems will be deployed in activity centers.
4. Only high-speed systems will be deployed in metropolitan areas.

5. Because of high peaking effects in university and airport demand environments, small capacity vehicles will be de-emphasized.

6. More activity center deployments will be made than metropolitan area deployments because activity center systems will be deployed in a shorter time frame, and thus are of more immediate concern.

7. High-speed SGRT system deployments will be de-emphasized because UMTA's AGRT program is currently funding simulations of this system type.

8. Only the two PRT deployments specified in the RFP will be studied because their high technology requirements are still not completely resolved.

9. The RFP requires that ten SLT systems and six corridor or area-wide line-haul systems be included for analysis.

10. The deployments will allow several trade-offs of vehicle size for fixed-demand and network types.

11. The deployments will allow several trade-offs of network type for fixed-demand and system types.

4.2.2 Deployments

Table 4-1 defines the 19 representative system deployments under study in the SOS program. Summary definitions of these 19 deployments and their identifying names are given in Table 4-2. This selection meets all of the rationale for selection as detailed above. Although ten metropolitan area deployments are indicated, only seven distinct networks are defined in the following section, and even then only four distinct sets of station locations are used. There are eleven SLT systems since all activity center deployments except the PRT 1 deployment qualify as SLT systems. System deployment pairs which differ only as to the system type are deployments SLT5 and SLT6, and SLT9 and SLT 10. System deployment pairs which differ only as to the network class but maintain a fixed network location, as is seen in the following section, are deployments SLT3 and SLT4, and GRT1 and GRT2. Two PRT systems are deployed, one in a CBD demand using a fine grid network and the other in a metropolitan area having disperse travel demands using a medium-density grid network.

TABLE 4-1. REPRESENTATIVE SYSTEM DEPLOYMENTS

SYSTEM TYPES		DEPLOYMENT SCENARIO									
		LOW SPEED							HIGH SPEED		
		ACTIVITY CENTER LINE-HAUL	ACTIVITY CENTER CIRCULATION	CBD CIRCULATION			CBD LINE HAUL		METRO AREA HIGH CBD HIGH REVERSE	METRO AREA LOW CBD HIGH REVERSE	METRO AREA HIGH CBD LOW REVERSE
				LOW DEMAND	MEDIUM DEMAND	HIGH DEMAND	LOW DEMAND	HIGH DEMAND			
SLT	SGRT						L1				
	IGRT		ML	S	L1, L2	L1					
	LGRT	S				L1	ML, L1	L1			
ART									PG		PG
GRT	SGRT										FG
	IGRT								ML, FG	FG	
PRT						FG				FG	

S - SHUTTLE
L1 - OPEN LOOP ONE WAY
L2 - OPEN LOOP TWO WAY
ML - MULTIPLE LOOPS
PG - PARTIALLY CONNECTED GRID
FG - FULLY CONNECTED GRID

TABLE 4-2. SUMMARY OF REPRESENTATIVE SYSTEM DEPLOYMENTS

Deployment Descriptor	System Type Vehicle	Speed	Network Type	Demand Type
SLT-1	LGRT	Low	Shuttle	Activity Center Circulation
SLT-2	LGRT	Low	Multiple loop	Activity Center Line-Haul
SLT-3	IGRT	Low	Open loop, one-way	CBD circulation, medium demand
SLT-4	IGRT	Low	Open loop, two-way	CBD circulation, medium demand
SLT-5	IGRT	Low	Open loop, one-way	CBD circulation, high demand
SLT-6	LGRT	Low	Open loop, one-way	CBD circulation, high demand
SLT-7	IGRT	Low	Shuttle	CBD circulation, low demand
SLT-8	LGRT	Low	Multiple loop	CBD line-haul, low demand
SLT-9	LGRT	Low	Open loop, one-way	CBD line-haul, low demand
SLT-10	SGRT	Low	Open loop, one-way	CBD line-haul, low demand
SLT-11	SGRT	Low	Open loop, one-way	CBD line-haul, high demand
ART-1	ART	High	Partially connected grid	Metropolitan Area - high CBD, high reverse commutation
ART-2	ART	High	Partially connected grid	Metropolitan Area - high CBD, low reverse commutation
GRT-1	IGRT	High	Multiple loop	Metropolitan Area - high CBD, high reverse commutation
GRT-2	IGRT	High	Fully connected grid	Metropolitan Area - high CBD, high reverse commutation
GRT-3	SGRT	High	Fully connected grid	Metropolitan Area - low CBD, high reverse commutation
GRT-4	IGRT	High	Fully connected grid	Metropolitan Area - high CBD, low reverse commutation
PRT-1	PRT	Low	Fully connected grid	CBD circulation, high demand
PRT-2	PRT	High	Fully connected grid	Metropolitan Area - low CBD, high reverse commutation

4.3 STANDARD NETWORK LAYOUT

In this section the network configuration including station locations, merge/diverge locations, and guideway routing is specified for each deployment. For the eleven SLT deployments, a network flow analysis is presented in which each of the deployments is analyzed for its ability to service demands within specified service goals.

The following rationale for obtaining a network configuration was used. Station locations were chosen to agree in decreasing priority with:

1. Station locations of existing transportation systems similar to those being studied in the same demand environment

2. Station locations of transportation systems under construction similar to those being studied in the same demand environment

3. Station locations as given in proposals for systems similar to those being studied in the same demand environment

4. Station locations as given in regional transportation studies or in in-house studies of systems similar to those being studied in the same demand environment.

It may be necessary in some cases to consolidate two close station locations into one location if it facilitates network routing. If a network is desired which is more pervasive than that used to determine station locations, additional stations will be located to serve expected demand in the most logical manner.

Network routings are made considering network type requirements, existing system routes, proposed routes, and highway routes if no system similar to that being studied is available for the specific demand environment.

The network layouts presented in the figures of this section only display as many landmarks as deemed necessary to approximately locate the networks. No detail of guideway and switches associated with possible off-line stations is given. For activity center networks only a unidirectional guideway is shown, while for metropolitan area networks only a bidirectional guideway is shown. At all Y and + junctions in metropolitan area networks, full switching ability between links should be assumed except as noted in the discussion specific to each network.

4.3.1 Representative SLT Deployments

Eleven SLT deployments are defined for analysis in the SOS program. These representative deployments serve four demand types: activity center line-haul, activity center circulation, CBD circulation, and CBD line-haul. For each demand type, the deployment or deployments applied to that demand are identified and the results of a network flow analysis for each deployment is presented.

4.3.1.1. SLT Deployment in an Activity Center Line-Haul Application—The activity center line-haul SLT deployment (SLT1) as shown in Figure 4-1 is deployed using a low-speed LGRT system. The network consists of two simple shuttles, side-by-side, serving the same three on-line stations.

In the SLT1 network flow analysis the deployment is analyzed for its ability to service demands within given service goals. It is assumed that the two shuttles are always operating in opposite directions (i.e., the vehicles on the two shuttles must leave Stations 1 and 3 simultaneously). The following additional information is necessary for analysis:

- Maximum vehicle capacity of 109 passengers/vehicle, minimum of 50
- Maximum two-car train
- Velocity of 48 km/hr
- Acceleration/deceleration rate of 1 m/s^2
- Station dwell time of 45 s.

The station dwell time of 45 s may be too high, but that would result in an underestimation of system capacity rather than an overestimation.

The service goals to be attained by the SLT1 deployment, which are based on the performance specifications for the Morgantown system[13], are:

- Transport 1100 passengers in 20 minutes
- Platform transient time will be ≤ 5 minutes for the scheduled mode.

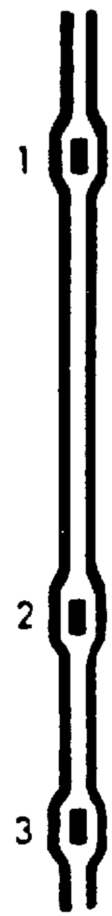
The capacity service goal of 1100 passengers per 20 minutes is equivalent to 825 passengers in 15 minutes, a unit which corresponds to the 15-minute time interval being analyzed (see Section 3.5.1). Platform transient time for the scheduled mode, is defined as the time between paying the fare and boarding the vehicle.

The first step in analyzing whether the SLT1 network, as defined above, can service demands within the specified service goals is to determine link loads. This is accomplished by summing all trips traveling on links (1, 2), (2, 3), (3, 2), and (2, 1) regardless of the shuttle being used. Link loads were calculated through the use of the following equations:

Link load for (1,2) = trips for O-D pair 1 to 2 plus 1 to 3
Link load for (2,3) = trips for O-D pair 1 to 3 plus 2 to 3
Link load for (3,2) = trips for O-D pair 3 to 1 plus 3 to 2
Link load for (2,1) = trips for O-D pair 3 to 1 plus 2 to 1.

These are static equations and do not account for time delays associated with actually serving trips but are equivalent to a desire line representation of the demand. The results are listed in Table 4-3.

To calculate whether the system can accommodate these link loads within the service goals, it is necessary to specify a vehicle capacity and to determine travel times and vehicle headways. A vehicle capacity of 100 is used since this is the nominal vehicle capacity for SLT1 as identified in the Analysis Requirements Report.[14]



Total lane length	- 6.8 km
Double lane guideway length	- 3.4 km
Number of stations	- 3
Type of stations	- On-line

FIGURE 4-1. SLT 1: SHUTTLE NETWORK IN THE ACTIVITY CENTER LINE-HAUL APPLICATION WITH A LOW-SPEED LGRT

TABLE 4-3. SLT 1 LINK LOADS

	Links			
	(1, 2)	(2, 3)	(3, 2)	(2, 1)
Off-Peak Hour				
Q1	104	100	85	89
Q2	73	69	59	62
Q3	84	80	68	71
Q4	121	115	98	102
Total	382	364	310	324
Peak Hours 11:00 - 12:00				
Q1	62	62	73	105
Q2	64	48	69	71
Q3	68	48	81	87
Q4	74	64	273	303
Total	268	222	496	566
12:00 - 1:00				
Q1	307	322	86	313
Q2	120	97	64	99
Q3	125	78	81	100
Q4	165	141	113	104
Total	717	638	344	616
Evening Hour				
Q1 - 4	33	21	31	41
Total	132	84	124	164

Q_n - the n^{th} quarter-hour where n = 1, 2, 3, 4.

Based upon vehicle speed, acceleration/deceleration rates, distance, and station dwell time, the travel times and headways for a vehicle, or train, is determined. Acceleration from 0 to 48 km/hr or deceleration from 48 km/hr to 0 is accomplished in 13.3 s over a distance of 88.5 m. Therefore, a total of 177 m is traversed between each station pair for acceleration and deceleration. Between Stations 1 and 2 the remaining distance of 524 m is traversed in 39.5 s. The remaining 2505 m between Stations 2 and 3 are traversed in 188.5 s. The travel time between Stations 1 and 2 is 66 s, and between Stations 2 and 3 is 215 s. Therefore, round trip travel time is:

$$66 \text{ s} + 45 \text{ s} + 215 \text{ s} + 45 \text{ s} + 215 \text{ s} + 45 \text{ s} + 66 \text{ s} + 45 \text{ s} = 742 \text{ s or } 12.5 \text{ minutes.}$$

Every 12.5 minutes a round trip is completed on each shuttle, resulting in a headway of 6.25 minutes at each station for any given direction of travel. Link capacities, which are a measure of the system's ability to service demands and are determined by dividing vehicle (or train) capacity by the headway, are given as a total for the two shuttles rather than as individual link capacities for each shuttle since the 6.25-minute headway used is a result of vehicles operating on both shuttles.

Using 100-passenger vehicles, as suggested in the System Requirements Report,[14] the maximum link capacity is:

- Single vehicles - 960 pass/hr/link or 240 pass/15 min/link
- Two-car trains - 1920 pass/hr/link or 480 pass/15 min/link.

Table 4-3 shows that the single vehicles are capable of servicing the off-peak and evening hour demand while the two-car trains adequately service the peak hour demands. An excessive link capacity is provided by the 100-passenger vehicles during all time periods. Therefore, the 70-passenger LGRT vehicle appears to be more appropriate since it provides a link capacity of 168 pass/15 min/link with single vehicles and 336 pass/15 min/link with two-car trains.

This system also satisfies the transient time service goal by providing an average platform transient time of 3.12 minutes (one-half the average headway). The system is capable of easily handling the present demands, but whether it can service 825 passengers per 15-minute period depends on the O-D mix. If all trips are between Stations 1 and 3 with no trips to Station 2, the maximum system capacity is 2(336) or 672 trips per 15-minute period (using 70-passenger vehicles in two-car trains) which is well below the service goal of 825. However, if there are no trips between Stations 1 and 3 but all trips either originate or terminate at Station 2, then the maximum system capacity is 4(336) or 1324 trips per 15-minute period. As illustrated in Table 4-3, Link (2,3) is the heaviest loaded link in the system during the period from 12:00-12:15 p.m. Since the nominal traveling unit capacity of the LGRT system is 200 passengers per train (2-car trains with 100 passengers per car), the system can satisfy a demand with a maximum link load of 480 passengers per 15 minutes (240 passengers per shuttle). If the demand were scaled so that the 436 load on Link (2,3) were 480 the demand magnitude would be 1300 passengers per 15 minutes. This number results from multiplying the ratio of maximum nominal capacity (480) to the actual load of the most heavily loaded link (313 per Table 4-3) times the maximum quarter-hour demand (872 per Table 3-5). Assuming the spatial distribution of the activity center line-haul application is constant, this is the maximum demand that the nominal SLT1 system deployment can service. Thus, the SLT1 system, as defined, is capable of servicing demands and meeting the specified service goals. However, a vehicle capacity of 70, rather than 100 as originally suggested, is better suited for the existing demand.

4.3.1.2 SLT Deployments in an Activity Center Circulation Application—SLT2 is deployed with a low-speed LGRT system on a multiple loop network, shown in Figure 4-2. The two stations at each end (Stations 1, 2, 12, and 13), are located in parking facilities; Stations 15 and 16 are used solely as transfer stations where no access or egress is allowed. All of the remaining stations are located at activity center areas. The station locations are identical to those of the Airtrans system with the exception of the two transfer stations, which are additional stations. The two transfer stations are not considered in the O-D matrices because passengers cannot enter or exit the system at these stations. Any passengers having a parking lot station as either an origin or destination must make a transfer at either Station 15 or 16.

The two parking lot loops are single-lane guideways operated in a counter-clockwise direction. The clockwise direction is not considered since the main objective of the system is to transport passengers to the activity center stations within a given time constraint. The shortest and quickest route to these stations is attained by employing counter-clockwise outer loops. However, for the network flow analysis of the center loop, both unidirectional (clockwise and counter-clockwise) and bidirectional configurations are considered.

The characteristics of the SLT2 deployment which are to be used for the network flow analysis are detailed below:

- Vehicle capacity between 70 to 109 passengers
- Maximum of 2 cars per train
- Cruise speed of 48 km/hr
- Station dwell of 45 s.

The service goals which are specified for the Airtrans system[15] are also being applied to the SLT2 system. These goals are:

- Trip time for interline transfers will be ≤ 20 minutes
- Trip time to and from parking lot stations will be ≤ 30 minutes
- Maximum average wait time of 5 minutes (assumed; not given in Reference 15).

Network flow analysis was accomplished by first determining link loads and then determining the system's ability to service those loads. For the two-way center loop alternative, the various O-D trips had to be allocated to one of two routes, either clockwise or counter-clockwise around the center loop; this was accomplished by employing a minimum path algorithm. For simplicity, the travel time for each link was given as an input to the algorithm rather than calculating link travel time from network configuration, speed, and delays. Travel times were manually calculated by assuming a velocity of 48 km/h and a delay of 45 seconds on each link to account for station dwells. The resultant travel times for each link are shown in Table 4-4; all travel times have been rounded to the nearest quarter of a minute.

		1-Way Center Loop	2-Way Center Loop
Total lane length	-	16.6 km	25.4 km
Double lane guideway length	-	0 km	8.8 km
Single lane guideway length	-	16.6 km	7.8 km
Number of stations	-	16	
Type of stations	-	On-line	

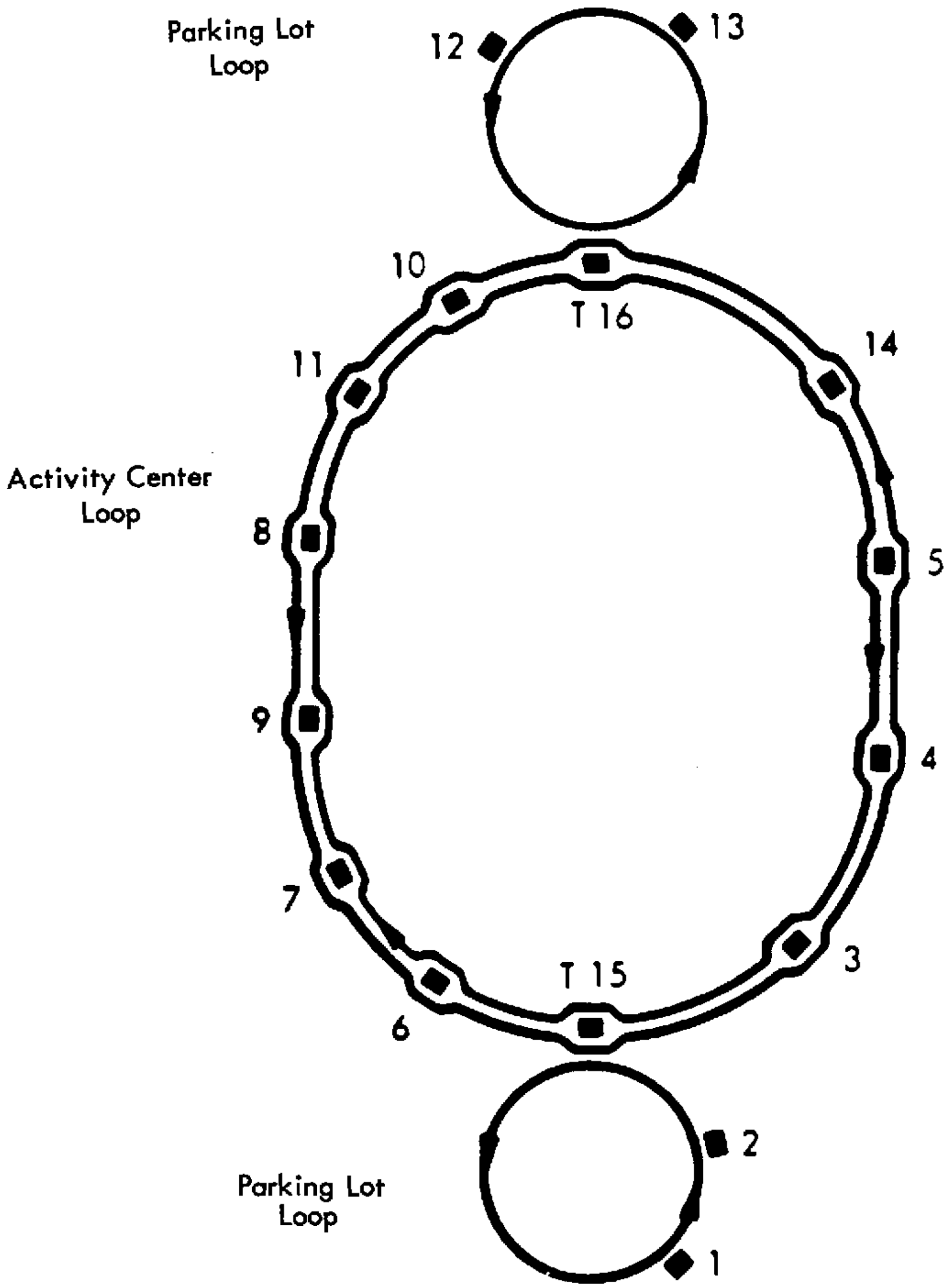


FIGURE 4-2. SLT 2: MULTIPLE-LOOP NETWORK IN THE ACTIVITY CENTER CIRCULATION APPLICATION WITH A LOW-SPEED LGRT

TABLE 4-4. SLT 2 LINK TRAVEL TIMES

	Link From	Link To	Time (min.)	Distance (km)
Outer Loop	1	2	1.50	0.51
	2	15	2.00	1.02
	15	1	3.50	2.24
Clockwise Inner Loop	15	7	1.25	0.45
	7	6	1.25	0.43
	6	9	1.25	1.28
	9	8	1.25	0.34
	8	11	2.25	1.20
	11	10	1.25	0.43
	10	16	1.75	0.85
	16	14	2.75	1.60
	14	5	2.00	0.98
	5	4	1.25	0.41
	4	3	1.25	0.41
	3	15	1.25	0.45
Counter-Clockwise Inner Loop	15	3	1.25	0.45
	3	4	1.25	0.41
	4	5	1.25	0.41
	5	14	2.00	0.98
	14	16	2.75	1.60
	16	10	1.75	0.85
	10	11	1.25	0.43
	11	8	2.25	1.20
	8	9	1.25	0.34
	9	6	2.25	1.28
	6	7	1.25	0.43
	7	15	1.25	0.45
Outer Loop	16	13	3.50	2.24
	13	12	1.50	0.51
	12	16	2.00	1.02

Due to the large number of time intervals being considered in the normalized demand profile, only two time intervals are being analyzed: 11:00 to 11:30 a.m. and 5:00 to 5:30 p.m. These half-hour intervals represent the maximum demand intervals; therefore, if the SLT 2 deployment is capable of servicing these peak demands, then the system is assumed to be capable of servicing the lower demand intervals.

After applying the minimum path algorithm to the station-to-station demand matrices for the two time intervals under consideration, Tables 3-6 and 3-7, the link loads were calculated for the three alternative network configurations. The calculation of link loads for the one-way alternatives are straightforward since only one route is possible for an O-D pair. The link loads for three alternatives during the two peak periods are given in Tables 4-5 through 4-10. The link loads represent the number of passengers per half-hour traversing each link. As expected, the link loads on the one-way loop alternatives are higher than on the two-way alternative; consequently, each alternative is analyzed separately.

From Tables 4-5 through 4-10 it can be seen thot link loads for the two parking lot loops (as identified in Table 4-4) are identical for a given time period, and only the link loads for the center loop are affected by the network configuration alternatives. The link loads for the parking lot loops in passengers per half-hour are:

Link	11:00-11:30 a.m.	5:00-5:30 p.m.
(1, 2)	20	25
(2, 15)	26	27
(15, 1)	18	20
(13, 12)	28	29
(12, 16)	29	27
(16, 13)	30	26

The round trip travel times for a vehicle/train on either outer loop is 7.00 minutes (1.50 + 2.00 + 3.50 minutes, from Table 4-4). Using one vehicle per loop, the headway on each outer loop is six minutes. At this headway, using the 70-passenger LGRT vehicle, a link capacity of 300 passengers per 30 minutes is attained. This capacity is adequate for the demands on the outer loops. The outer loop travel times, as experienced by users, determined by adding link times to the station wait time — one-half the headway — are:

Stations 1 to 15 and 13 to 16	-	7.00 minutes
Stations 2 to 15 and 12 to 16	-	5.50 minutes
Stations 15 to 1 and 16 to 13	-	7.00 minutes
Stations 15 to 2 and 16 to 12	-	8.50 minutes.

Prior to measuring total trip times, which is necessary to determine whether the service goals have been met, the trip times on the center loop must be calculated.

Round-trip travel on the center loop is calculated by summing all of the link travel times of that loop in one direction. Using the data in Table 4-4, the center loop round trip travel time is determined to be 18.75 minutes. Round-trip travel times are identical for all three center loop configurations but total travel times vary among the three network alternatives.

TABLE 4-5. MID-DAY PEAK LINK LOADS FOR THE ACTIVITY CENTER CIRCULATION APPLICATION, TWO-WAY INNER LOOP NETWORK

A C T   N E T W O R K   L I N K   T R I P   L O A D I N G S

LINK ENDS FROM NODE	LINK ENDS TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	20
2	15	LIN	26
3	4	LIN	62
3	15	LIN	65
4	3	LIN	56
4	5	LIN	36
5	4	LIN	37
5	14	LIN	44
6	7	LIN	119
6	9	LIN	103
7	6	LIN	75
7	15	LIN	105
8	9	LIN	112
8	11	LIN	115
9	6	LIN	147
9	8	LIN	101
10	11	LIN	49
10	16	LIN	50
11	8	LIN	78
11	10	LIN	100
12	16	LIN	29
13	12	LIN	28
14	5	LIN	27
14	16	LIN	47
15	1	LIN	18
15	3	LIN	102
15	7	LIN	76
16	10	LIN	68
16	13	LIN	30
16	14	LIN	28

(11:00 a.m. to 11:30 a.m.)

LIN - Line-Haul Link

TABLE 4-6. AFTERNOON PEAK LINK LOADS FOR THE ACTIVITY CENTER CIRCULATION APPLICATION, TWO-WAY INNER LOOP NETWORK

AGT NETWORK LINK TRIP LOADINGS

LINK ENDS FROM NODE	TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	25
2	15	LIN	27
3	4	LIN	68
3	15	LIN	70
4	3	LIN	58
4	5	LIN	45
5	4	LIN	44
5	14	LIN	40
6	7	LIN	99
6	9	LIN	68
7	6	LIN	76
7	15	LIN	95
8	9	LIN	100
8	11	LIN	70
9	6	LIN	129
9	8	LIN	68
10	11	LIN	67
10	16	LIN	62
11	8	LIN	84
11	10	LIN	63
12	16	LIN	27
13	12	LIN	29
14	5	LIN	40
14	16	LIN	37
15	1	LIN	20
15	3	LIN	96
15	7	LIN	76
16	10	LIN	54
16	13	LIN	26
16	14	LIN	46

(5:00 p.m. to 5:30 p.m.)

LIN - Line-Haul Link

TABLE 4-7. MID-DAY PEAK LINK LOADS FOR THE ACTIVITY CENTER CIRCULATION APPLICATION, CLOCKWISE INNER LOOP NETWORK

A G T N E T W O R K L I N K T R I P L O A D I N G S

L I N K FROM NODE	E N D S TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	20
2	15	LIN	26
3	15	LIN	257
4	3	LIN	288
5	4	LIN	295
6	9	LIN	250
7	6	LIN	250
8	11	LIN	331
9	8	LIN	283
10	16	LIN	276
11	10	LIN	345
12	16	LIN	29
13	12	LIN	28
14	5	LIN	277
15	1	LIN	18
15	7	LIN	265
16	13	LIN	30
16	14	LIN	275

(11:00 a.m. to 11:30 a.m.)

LIN - Line-Haul Link

TABLE 4-8. AFTERNOON LINK LOADS FOR THE ACTIVITY CENTER CIRCULATION APPLICATION, CLOCKWISE INNER LOOP NETWORK

A G T   N E T W O R K   L I N K   T R I P   L O A D I N G S

LINK ENDS FROM NODE	TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	25
2	15	LIN	27
3	15	LIN	245
4	3	LIN	261
5	4	LIN	270
6	9	LIN	210
7	6	LIN	248
8	11	LIN	257
9	8	LIN	239
10	16	LIN	279
11	10	LIN	267
12	16	LIN	27
13	12	LIN	29
14	5	LIN	271
15	1	LIN	20
15	7	LIN	252
16	13	LIN	26
16	14	LIN	280

(5:00 p.m. to 5:30 p.m.)

LIN - Line-Haul Link

TABLE 4-9. MID-DAY LINK LOADS FOR THE ACTIVITY CENTER CIRCULATION APPLICATION, COUNTER-CLOCKWISE INNER LOOP NETWORK

A G T N E T W O R K L I N K T R I P L O A D I N G S

LINK ENDS FROM NODE	TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	20
2	15	LIN	26
3	4	LIN	264
4	5	LIN	257
5	14	LIN	275
6	7	LIN	302
7	15	LIN	287
8	9	LIN	269
9	6	LIN	302
10	11	LIN	207
11	8	LIN	221
12	16	LIN	29
13	12	LIN	28
14	16	LIN	277
15	1	LIN	18
15	3	LIN	295
16	10	LIN	276
16	13	LIN	30

(11:00 AM TO 11:30 AM)

LIN - Line-Haul Link

TABLE 4-10. AFTERNOON LINK LOADS FOR THE ACTIVITY CENTER CIRCULATION APPLICATION, COUNTER-CLOCKWISE INNER LOOP NETWORK

AGT NETWORK LINK TRIP LOADINGS

LINK ENDS FROM NODE	TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	25
2	15	LIN	27
3	4	LIN	224
4	5	LIN	215
5	14	LIN	214
6	7	LIN	237
7	15	LIN	233
8	9	LIN	246
9	6	LIN	275
10	11	LIN	218
11	8	LIN	228
12	16	LIN	27
13	12	LIN	29
14	16	LIN	205
15	1	LIN	20
15	3	LIN	240
16	10	LIN	206
16	13	LIN	26

(5:00 p.m. to 5:30 p.m.)

LIN - Line-Haul Link

Two-Way Center Loop

The ability of this network to service demands is dependent on vehicle size and frequency of vehicle arrivals. The ability to meet service goals is measured by trip time which is dependent on frequency of vehicle arrivals and the time to traverse routes. The link loads presented in Tables 4-5 and 4-6 indicate that link (9, 6) is the most heavily loaded (147 passengers per half-hour) during the interval from 11:00 to 11:30 a.m. This demand can be served using two vehicles per loop (operated either trained or individually) with a capacity as low as 74 passengers per vehicle. If service is provided using one two-car train on each loop, the resulting average wait time, one-half the headway, would be about nine minutes. This is well above the service goal of five minutes. If two single vehicles per loop are employed, the average wait time is reduced to approximately 4.7 minutes and a link capacity of 223 passengers per 30 minutes is attained with the 70-passenger vehicle. This capacity can service demands since it exceeds the maximum link load of 147 passengers per half hour.

Now the ability of the system to provide the specified service goals must be determined. One of the longest possible trips to a parking station is from Station 10 to Station 2. The minimum path is identified by the following sequence of links:

- (10, 11)
- (11, 8)
- (8, 9)
- (9, 6)
- (6, 7)
- (7, 15)
- (15, 1)
- (1, 2).

The first six links define the shortest route on the inner loop, and the last two links define the route on the outer loop. Using Table 4-4, total travel time is calculated by summing the average wait time, travel time between Stations 10 and 15, transfer time, and travel time from Station 15 to Station 2 (or 4.70 + 9.50 + transfer time + 8.50 which equals 22.7 minutes plus the transfer time. Average wait time on the outer loop is 3.5 minutes and allowing one minute to walk through the transfer station, the total transfer time can reasonably be expected to average about 4.5 minutes; therefore, the total travel time for the O-D pair (10,2) is 27.2 minutes. The service goal travel time for this trip is 30 minutes; consequently, parking lot trips are serviced within the specified goals.

The interline trips must be serviced within 20 minutes. Clearly, since the parking lot trip, which is considerably longer than any possible minimum path interline trip, is traveled in 27.2 minutes, 13 of which are attributed to the transfer and outer loop trip, the interline trips can be traveled in less than 20 minutes.

In summary, two 70-passenger single vehicles per lane of the two-way loop network more than adequately service the demands within the specified service goals. If smaller average wait times are desired, additional vehicles per lane will be required.

Since the link capacity provided far exceeds the demands, the IGRT rather than the LGRT system type should be considered in future analyses if the two-way center loop configuration is selected. Two 50-passenger IGRT vehicles operating at 9.1-minute headways provide a link capacity of 164 passengers per half-hour.

One-Way Clockwise Center Loop

The link loads for the one-way clockwise center loop are shown in Tables 4-7 and 4-8. The loads are much greater than those of the two-way alternative since there are no route alternatives in this network over which to distribute trips. The round-trip travel time for this configuration is also 18.75 minutes. Two vehicles/trains on the center loop would result in an average wait time of nearly 4.7 minutes which complies with the wait time service goal. However, the travel time service goal would be violated for O-D pair (7, 3), the worst case trip relative to the service goals. The total time for this trip is 20.95 minutes (4.7 minutes wait time plus 16.25 minutes link travel time). Consequently, at least three vehicles/trains are needed in the center loop to satisfy all of the service goals.

By employing three two-vehicle trains, with each vehicle having a capacity of 70 passengers, and assuming that the trains are evenly spaced around the loop, a headway of 6.25 minutes is attained. This results in a link capacity of 672 passengers per half hour, sufficient for servicing demands. The demands can also be serviced by employing three single 90 passenger vehicles which would provide a link capacity of 432 passengers per half-hour. Since link loads never exceed 350 passengers per half-hour for this network alternative, the SLT2 one-way clockwise center loop configuration is capable of servicing demands and providing the specified service goals.

One-Way Counter-Clockwise Center Loop

The analysis of the counter-clockwise loop is identical to that performed on the clockwise loop above. However, the results differ somewhat since the counter-clockwise link loads as shown in Tables 4-9 and 4-10 do not peak to the same high levels of the clockwise network. Three vehicles/trains per loop are still required to meet the service goals but now only 80-passenger single vehicles are needed to service all link loads since the three vehicles provide a total link capacity of 384 passengers per half-hour. Demands can also be serviced by three two-vehicle (70 passengers/vehicle) trains which provides a link capacity of 672 passengers per 30 minutes.

Summary

In summary, the outer or parking lot loops have similar link loads for all three center loop configurations. The headway on these loops is 7 minutes and one vehicle provides sufficient capacity to service demands. Consequently, the average wait time at the parking lot stations is 3.5 minutes with only one vehicle traveling on each loop. The link loads per half-hour are relatively small (less than 30) compared to capacity; therefore, no problem is encountered in providing adequate service on the two outer loops.

The center loop was analyzed for three possible configurations: a two-way loop and two one-way loops, one in each direction. All three configurations can service the demands to be used with the SLT2 deployment; however, the two-way loop reduces total travel time for many O-D pairs and thereby provides better service.

Average wait times are estimated to be one-half of the headway, but those passengers who use the one-way center loop and experience a wait time in excess of one-half the headway may not be able to complete their trip within the specified service goal trip time. Since the two-way network alternative routes passengers over the minimum path, the average travel times are much lower than the average travel times of the one-way alternatives; therefore, the two-way alternative allows longer headways before the service goals are violated.

Another advantage of the two-way network configuration is its ability to provide high service availability. If one of the loops were to become blocked, the remaining loop would be capable of servicing the demand within the specified service goals. However, if the one-way network were to have one link blocked, the system would not be capable of servicing demands within the specified service goals.

To ensure that a variety of system alternatives can be considered and still satisfy trip time and availability goals, only the dual lane center loop configuration is considered for any further SLT2 analyses. The LGRT vehicles were found to provide too much capacity for the two-way center loop configuration. Therefore, the IGRT system rather than the larger system will be used for the SLT2 deployment.

4.3.1.3 <u>SLT Deployments in a CBD Circulation Application</u>—Five representative systems are deployed in the CBD circulation demand environment. The SLT3 deployment (shown in Figure 4-3) is a one-way loop network, low-speed IGRT system in a medium demand CBD environment. The SLT5 and SLT6 deployments use the same network as SLT3 but differ in either their system class or demand level. SLT5 is deployed in a CBD high demand environment while SLT6 employs a low-speed LGRT system; except for these variations the three deployments are identical. Deployment SLT4 is a low-speed IGRT system operating on a two-way loop in a medium demand CBD environment (as shown in Figure 4-4). The final deployment, SLT7, is a low-speed IGRT system operating on shuttles (Figure 4-5), in a low demand CBD environment.

All of the deployments have eleven on-line stations, and these stations are located as described in the Detroit DPM proposal.[7] The routing for all five deployments are identical thereby allowing direct comparisons to be made between the various systems and network configurations. The shuttle network was designed with an even number of shuttles so that synchronous motion of the vehicles could be accomplished to facilitate passenger transfers.

Network flow analysis is performed for each of the five CBD circulation deployments by analyzing link loads and the system's ability to service those loads within given service goals. The service goals for these deployments have not been selected as of the writing of this report; therefore, a maximum average station wait time of five minutes has been

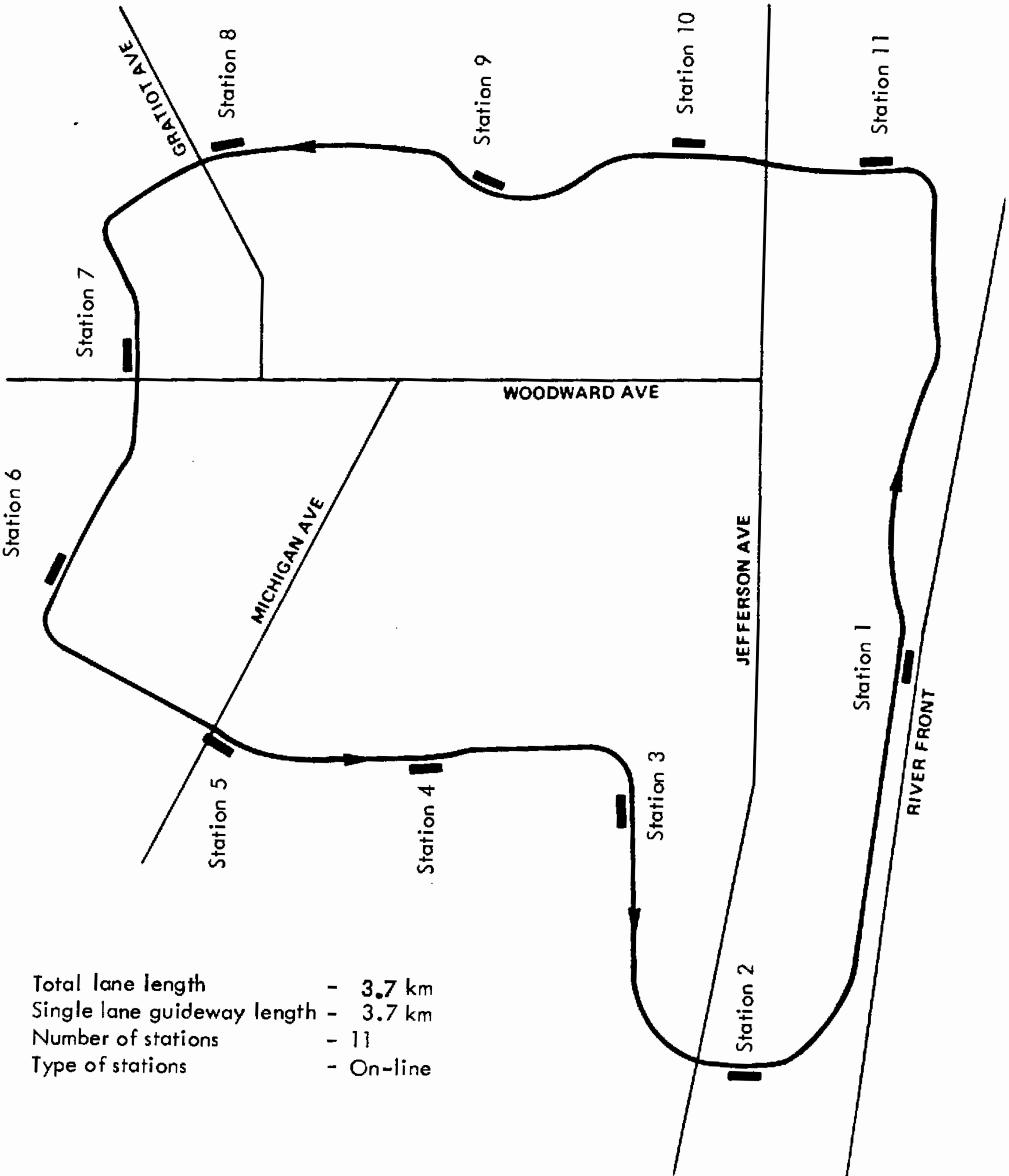


FIGURE 4-3. SLT DEPLOYMENT IN A CBD CIRCULATION APPLICATION (SLT 3: low-speed IGRT, medium-demand level; SLT 5: low-speed IGRT, high-demand level; SLT 6: low-speed LGRT, high-demand level)

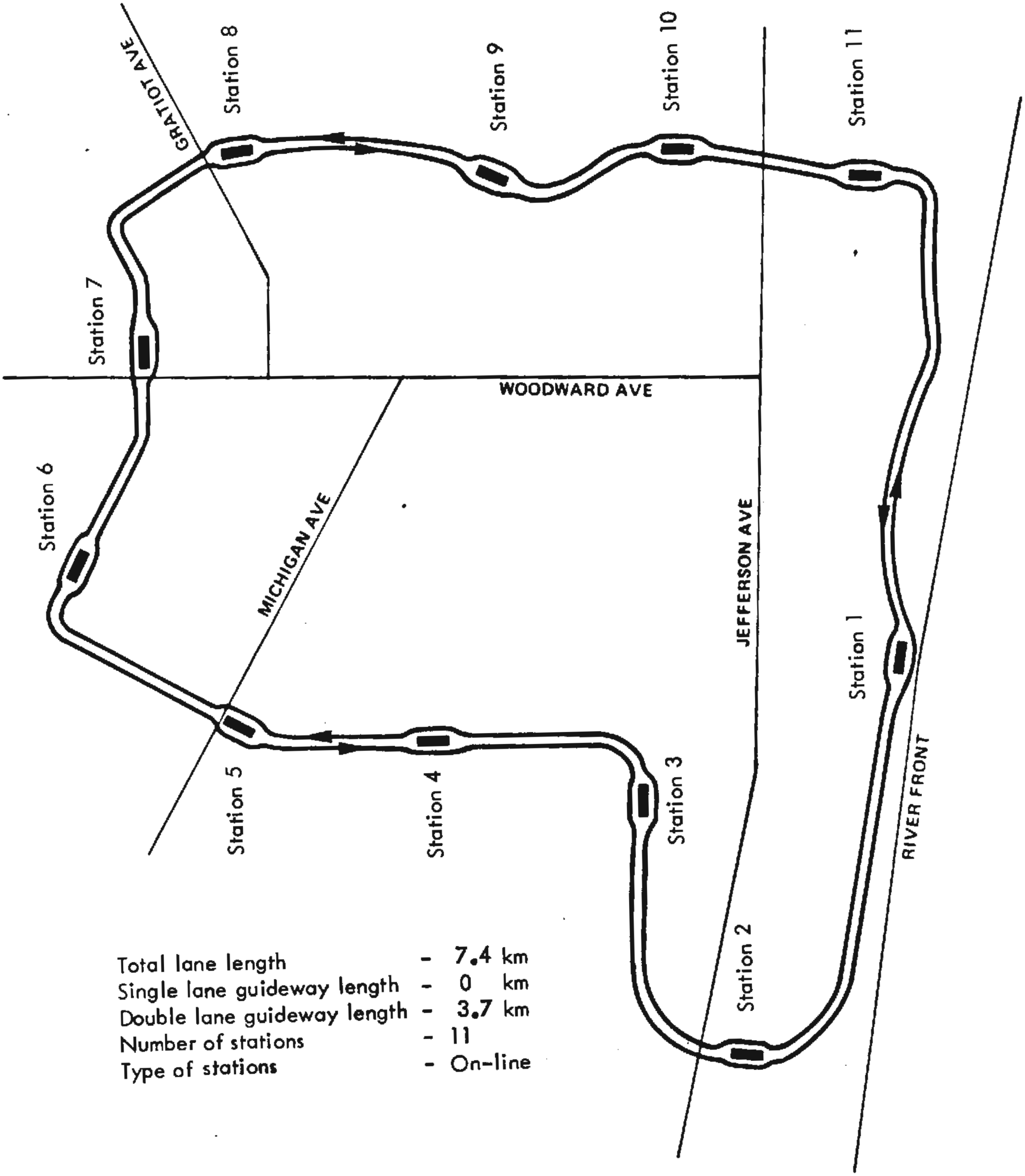


FIGURE 4-4. SLT 4: MEDIUM-DEMAND CBD CIRCULATION APPLICATION USING A LOW-SPEED IGRT ON A TWO-WAY LOOP

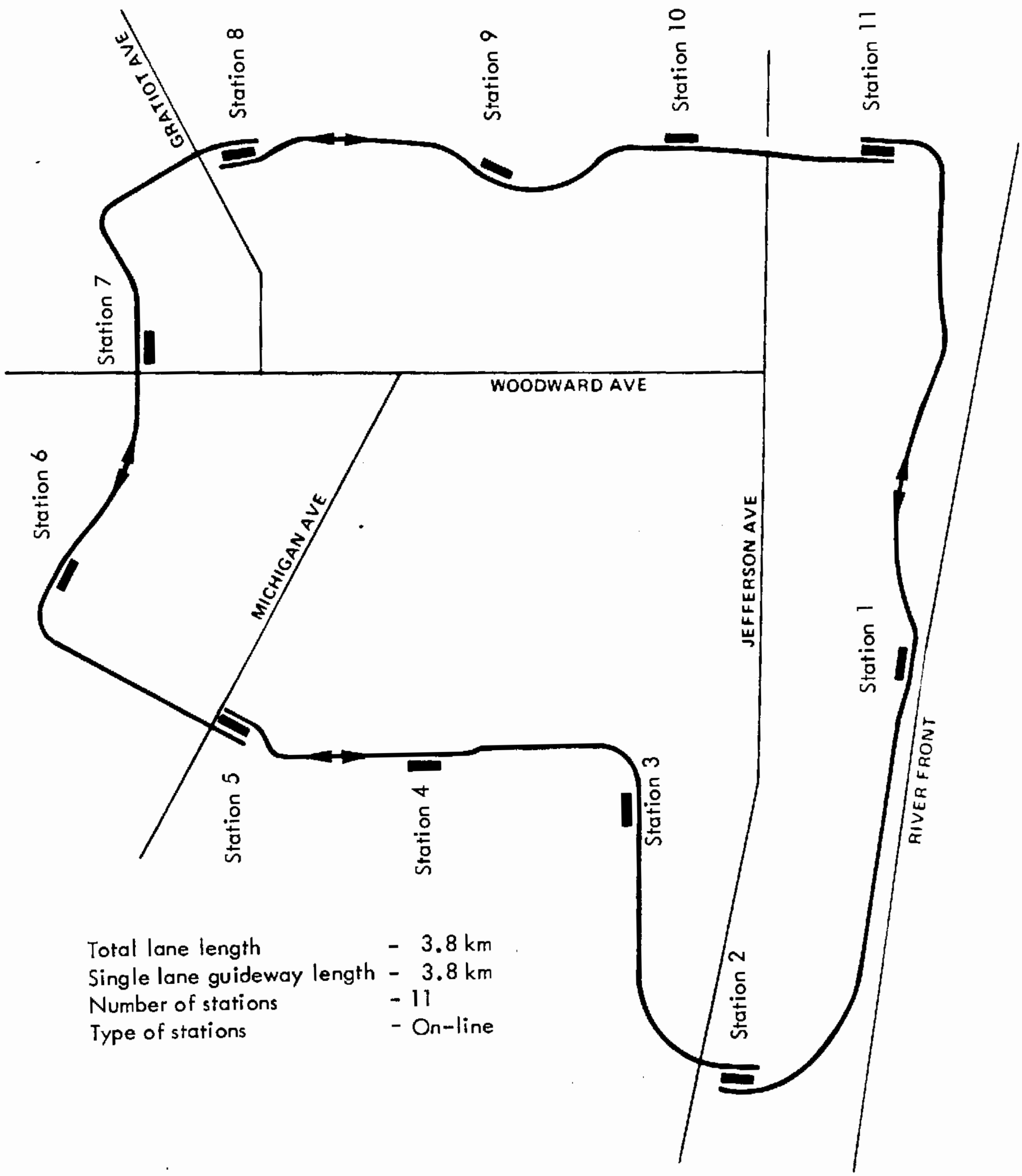


FIGURE 4-5. SLT 7: LOW-DEMAND CBD CIRCULATION APPLICATION USING A LOW-SPEED IGRT

established based on the service goals identified for SLT1 and SLT2. Also, no criteria for maximum trip time has been selected concerning the system's ability to service demands within a specified time interval. When these service goals have been selected, the results of the network flow analysis will be reviewed to ensure the service goals have not been violated.

For the purpose of determining link loads, passenger trip links were added to the guideway representation to allow for proper modeling of passenger flows. Since passengers are assigned to minimum paths, it is necessary to include station wait times as part of the trip time for passengers entering the system but not for passengers who pass through a station on-board a vehicle. Consequently, a passenger access link was added to the network definition at each station. This access link has a distance of zero and a wait time penalty which is assumed to be two minutes (a headway of four minutes was assumed,and wait time is defined as one-half the headway). In this manner each passenger receives only one wait time penalty for each trip. This access link is used at each station for the deployments SLT3 through SLT6. The link loads for these access links are equivalent to the number of passengers entering that station (the "to" node number of the link is equivalent to the station number as identified in the network figures). Several additional passenger links were necessary at transfer stations in the SLT7 deployment to properly represent passenger flows through these stations, as will be discussed in detail later.

The following paragraphs present a representative system definition and the results of the network flow analysis for each of the five SLT deployments in the CBD circulation demand application. The station-to-station demands generated in the demand model generation task (Section 3.5.3) are used to calculate the link loads for the five deployments.

SLT 3

The SLT3 deployment depicted in Figure 4-3 is characterized as a one-way loop network, low-speed IGRT system, in a medium level CBD demand. The nominal values of system parameters to be used for the network flow analysis, as defined in the analysis requirements,[14] are as follows:

- Nominal vehicle capacity of 40
- 1 to 4 cars per train
- Nominal minimum headway of 18 s
- Nominal cruise velocity of 27 km/hr
- Acceleration/deceleration rate of 1 m/s^2
- Prescheduled service.

For the purpose of the network flow analyses, an average station dwell time of 30 s is assumed. These characteristics may be varied, within the bounds set by the IGRT definition, to determine if a different set of characteristics could better service the demands. However, for this preliminary analysis the only parameters which are to be varied are vehicle capacity, operating headway, and the number of cars per train since these parameters have the greatest effects on a system's capacity.

As detailed in Section 3.5.3, the demand matrices for the clockwise and counter-clockwise alternatives are identical. Consequently, the link loads for the two alternatives are also identical. Table 4-11 shows peak link loads in terms of passengers per hour for the single-lane loop configuration. Since the counter-clockwise configuration was proposed by SEMTA in their DPM proposal for Detroit, this alternative is used for the SLT3 analysis.

By totaling the link travel times in Table 3-8, it can be seen that the round-trip travel time for a vehicle is 16.17 minutes; if only one vehicle is used, an average wait time of 8.08 minutes would result. Since the average wait time is not to exceed five minutes, at least two vehicles will be required for this network, resulting in a four-minute average wait time. With a headway of eight minutes and a vehicle capacity of 40, the maximum link capacity which can be serviced is 300 passengers per hour. The demands in Table 4-11 are far in excess of this link capacity, so it is likely that the vehicle capacity, number of vehicles per train, and the number of trains will all have to be increased.

By increasing the number of trains, the level of service is improved since wait times are decreased and link capacity is very rapidly increased. Doubling the number of trains to four and using two-vehicle trains, the average wait time becomes two minutes (four-minute headways), and the train capacity becomes 80 passengers. This results in a link capacity of 1200 passengers per hour, which is still less than the required 5000 passengers per hour. Doubling the number of vehicles in a train from two to four doubles the link capacity to 2400 passengers per hour. Since vehicle capacity can only be increased 72.5 percent (from 40 to 69 passengers per vehicle for IGRT), while the link capacity needs to be increased by at least 100 percent; and the maximum train length, as defined by the nominal system parameters, is already being employed; it follows that more trains are needed on the loop in order to service demands.

By increasing vehicle capacity to 45 and the number of trains to eight (resulting in two-minute headways) the link capacity is increased to 5400 passengers per hour, enough to service demands on all links. Consequently, this deployment is capable of servicing the demand, but the costs associated with the large number of vehicles required during the peak period and trade-off between larger but fewer vehicles still needs to be analyzed. It may be possible to use 60 to 69 passenger vehicles and reduce the required fleet size, but the capacity provided during low demand time periods may far exceed demand. These issues will be addressed in the traveling unit capacity trade study.

SLT 4

The SLT4 deployment has the same station location as SLT3, but the network is a two-way loop rather than a one-way loop, as shown in Figure 4-4. Both the system type, low-speed IGRT, and the demand type, medium level CBD circulation, are identical to the SLT3 deployment. The nominal system parameters used for the network flow analysis are identical to those defined for SLT3.

The peak hour link loads calculated for this deployment are shown in Table 4-12. Even through the SLT4 deployment attracts more trips as a result of its shorter travel times, the

TABLE 4-11. MID-DAY LINK LOADS FOR THE MEDIUM DEMAND CBD CIRCULATION APPLICATION, COUNTER-CLOCKWISE NETWORK

A G T N E T W O R K L I N K T R I P L O A D I N G S

L I N K FROM NODE	E N D S TO NODE	LINK TYPE	LINK LOAD
1	11	LIN	3263
2	1	LIN	3291
3	2	LIN	3332
4	3	LIN	3094
5	4	LIN	4209
6	5	LIN	5088
7	6	LIN	5035
8	7	LIN	3984
9	8	LIN	5206
10	9	LIN	4251
11	10	LIN	4313
12	2	ACC	223
13	3	ACC	376
14	4	ACC	869
15	5	ACC	820
16	6	ACC	1881
17	7	ACC	1841
18	8	ACC	725
19	9	ACC	1576
110	10	ACC	908
111	11	ACC	2277
121	1	ACC	0

(12 noon to 1:00 p.m.)

*LIN - Line-Haul Link
ACC - Access Link

TABLE 4-12. MID-DAY LINK LOADS FOR THE MEDIUM DEMAND CBD CIRCULATION APPLICATION, TWO-WAY NETWORK

A G T   N E T W O R K   L I N K   T R I P   L O A D I N G S

LINK ENDS FROM NODE	TO NODE	LINK TYPE*	LINK LOAD
1	2	LIN	532
1	11	LIN	504
2	1	LIN	532
2	3	LIN	531
3	2	LIN	531
3	4	LIN	480
4	3	LIN	480
4	5	LIN	1904
5	4	LIN	1904
5	6	LIN	3213
6	5	LIN	3213
6	7	LIN	3858
7	6	LIN	3858
7	8	LIN	3031
8	7	LIN	3031
8	9	LIN	3696
9	8	LIN	3696
9	10	LIN	2339
10	9	LIN	2339
10	11	LIN	1529
11	1	LIN	504
11	10	LIN	1529
12	2	ACC	271
13	3	ACC	239
14	4	ACC	2012
15	5	ACC	1827
16	6	ACC	2317
17	7	ACC	2199
18	8	ACC	1949
19	9	ACC	1611
110	10	ACC	1006
111	11	ACC	1719
121	1	ACC	28

(12 noon to 1:00 p.m.)

*LIN - Line-Haul Link
ACC - Access Link

link loads are significantly lower than the loads on the one-way network (SLT3) as a result of two lanes being available for servicing the demand rather than only one, as was the case for the SLT3 deployment.

Since round trip travel time is just over 16 minutes for each lane, at least two traveling units per lane are required to meet the average wait time service goal. Using two single vehicles, having a 40-passenger capacity and operating at eight-minute headways, a link capacity of 300 passengers per hour is attained, which is at least a factor of ten toa low. However, by increasing vehicle capacity to 64, training four vehicles and doubling the number of trains from two to four (resulting in four-minute headways) a link capacity of 3840 passengers per hour is provided. This is sufficient to service the demand; however, the larger vehicle might be providing too much capacity during the off-peak hours. A system using 33-passenger vehicles, trains of four vehicles operating at two-minute headways (eight trains per lane) would also be capable of servicing the demands with a link capacity of 3960 passengers per hour. The major conclusion that can be drawn from the SLT4 network flow analysis is that the IGRT system deployed in a dual-lane loop network is capable of serving the medium-level CBD circulation demand, and analysis of the deployment should be continued.

SLT 5

The fifth SLT deployment is identical to SLT3 (as noted in Figure 4-3) except that now the high CBD demand level is applied to the network. As discussed previously, only the counter-clockwise configuration is considered for the CBD circulation one-way loop network. The nominal system characteristics used for the network flow analysis are identical to the characteristics used for the SLT3 analysis. The link loads resulting from applying the high CBD demand level to the one-way loop network are given in Table 4-13. From the SLT3 analysis it is obvious that the 40-passenger vehicles are incapable of servicing demands. However, eight four-vehicle trains (operating at two-minute headways), with vehicles having a capacity of 55 passengers, provide a link capacity of 6600 passengers per hour. This link capacity is sufficient to satisfy the peak hour demands when the high CBD demand is applied to the one-way loop network. By using larger vehicles, say 69 passengers, and four-vehicle trains, six trains would provide a link capacity of 6100 passengers per hour while seven trains would provide a link capacity of 7200 passengers per hour. Six trains provide too little capacity, but seven provide too much. However, by reducing vehicle capacity to 65 passengers and using seven trains, the link capacity becomes 6800 passengers per hour.

In conclusion, the SLT5 counter-clockwise deployment is capable of servicing the high-level CBD circulation demand, and further analysis of this deployment is warranted.

SLT 6

The SLT6 deployment (depicted in Figure 4-3) is identical to SLT5 except that LGRT vehicles rather than IGRT vehicles are employed. The nominal system parameters

TABLE 4-13. MID-DAY LINK LOADS FOR THE HIGH DEMAND CBD CIRCULATION APPLICATION, COUNTER-CLOCKWISE NETWORK

AGT NETWORK LINK TRIP LOADINGS

LINK ENDS FROM NODE	TO NODE	LINK TYPE*	LINK LOAD
1	11	LIN	4089
2	1	LIN	4123
3	2	LIN	4176
4	3	LIN	3878
5	4	LIN	5272
6	5	LIN	6373
7	6	LIN	6303
8	7	LIN	4986
9	8	LIN	6522
10	9	LIN	5332
11	10	LIN	5404
12	2	ACC	278
13	3	ACC	475
14	4	ACC	1089
15	5	ACC	1026
16	6	ACC	2355
17	7	ACC	2307
18	8	ACC	913
19	9	ACC	1970
110	10	ACC	1133
111	11	ACC	2855
121	1	ACC	0

(12 noon to 1:00 p.m.)

*LIN - Line-Haul Link
ACC - Access Link

to be used for analysis, as defined in the Analysis Requirements,[14] are as follows:

- Nominal vehicle capacity of 100 passengers
- 1 to 2 cars per train
- Nominal cruise velocity of 48 km/hr
- Acceleration/deceleration rate of 1 m/s^2
- Minimum headway of 90 s
- Prescheduled service.

A station dwell time of 30 s is assumed throughout the network flow analysis of SLT6.

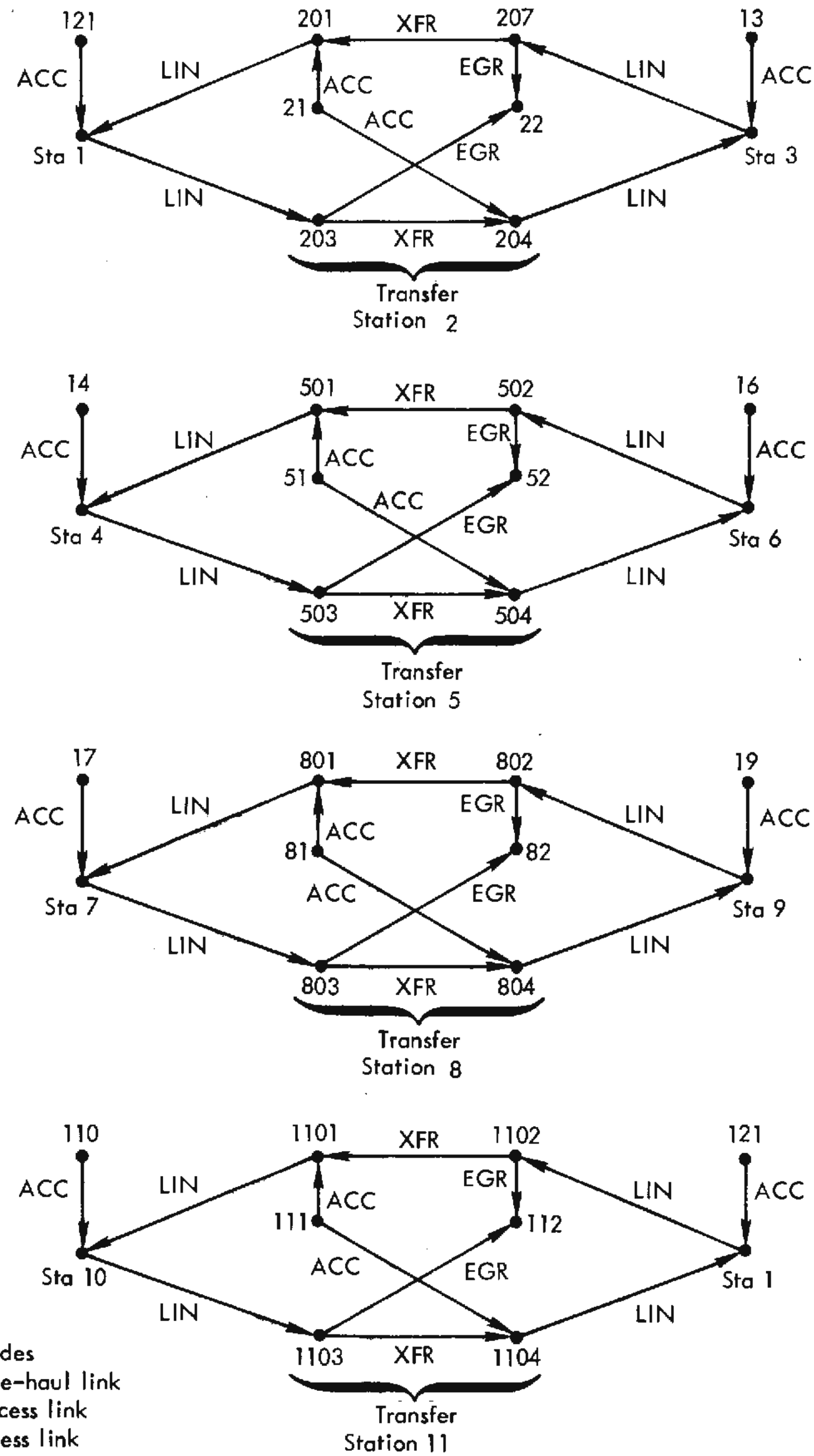
Since SLT5 and SLT6 have similar operational characteristics and they both use the same demands, the link loads for these two deployments are identical (Table 4-13). Using eight two-vehicle trains (operating at two-minute headways), with each vehicle having a capacity of 100, a link capacity of 6000 passengers per hour is attained, too low for peak-hour demands. By increasing vehicle capacity to 109 passengers, the link capacity is raised to 6540 passengers per hour, sufficient for servicing demands. Consequently, the SLT6 deployment is capable of servicing the high level CBD circulation demands and should undergo further analysis.

SLT 7

The seventh SLT deployment is a shuttle system using IGRT vehicles deployed in the low level CBD circulation demand environment. The nominal system characteristics are identical to those detailed for SLT3. As discussed previously, it is necessary to include additional links so as to properly compute station-to-station travel times for calculating minimum paths. The shuttle system (as shown in Figure 4-5) is much more difficult to model accurately due to the various time penalties which can be incurred at transfer stations. Access links are added to the network definition at each station to account for the station wait time of passengers who access the system at each station. Two additional link types are added to the network definition at transfer stations (as shown in Figure 4-6). Egress links are used to allow passengers to disembark at transfer stations without receiving any time penalties. Transfer links are used to add a transfer time penalty to the trip time of transferring passengers.

The vehicles on the shuttles can be operated in either non-synchronized or synchronized mode. By synchronizing the vehicles, transfer times are minimized. However, in order to synchronize vehicle arrivals at transfer stations, the vehicle speed on the shorter shuttles must be reduced, or dwell times at intermediate stations increased, so that the travel times on all shuttles are equal. Round trip travel times for the individual shuttles, as derived from the link travel times of Table 3-8, are:

Shuttle	Time (min.)
2-3-4-5	8.70
5-6-7-8	8.78
8-9-10-11	7.18
11-1-2	7.70



● : Nodes
LIN: Line-haul link
ACC: Access link
EGR: Egress link
XFR: Transfer link

FIGURE 4-6. TRANSFER STATION SCHEMATIC

These round trip travel times, which include 30 second dwells at all stations, must be equivalent in order to synchronize the shuttles. By increasing the dwell times on the shuttles with lower travel times this equivalence, within a few seconds, can be attained. By increasing the dwell at Station 1 to 60 seconds and at Stations 9 and 10 to 55 seconds, the following round trip travel times are achieved:

Shuttle	Synch. Travel Times (min.)
2-3-4-5	8.70
5-6-7-8	8.78
8-9-10-11	8.83
11-1-2	8.70

These travel times are all within 8 seconds of each other. By requiring that vehicles leave transfer stations simultaneously, a round trip travel time of approximately 8.80 minutes is attained. As a result of synchronizing the shuttles, some of the link travel times of the synchronized shuttle, as shown in Table 3-12A, are greater than the corresponding link travel times on the unsynchronized shuttle, shown in Table 3-8.

Transfer times, like link travel times, vary for the two alternatives of the shuttle network. Transfer times for the unsynchronized shuttle are assumed to be equivalent to one-half the headway (or the round trip travel time) since, on the average, this is the length of time passengers must wait for the arrival of a vehicle. In other words, transfer times and wait times for the unsynchronized shuttle are identical, as shown in Tables 3-12 and 3-13. No transfer time penalty is associated with the synchronized alternative since vehicles arrive simultaneously and remain 30 seconds, the dwell time. Passengers deboard their vehicle, walk across the station, and board a waiting vehicle. Since this transfer is accomplished within the vehicle's dwell time, which has been included in link travel times, no additional time penalty is required.

The link loads for the two systems which are derived from the station-to-station demands of Tables 3-22 and 3-23, are shown in Tables 4-14 and 4-15 for the non-synchronized and synchronized deployments, respectively. The maximum link loads for the individual shuttles are:

Shuttle	Non-synchronized	Synchronized
2-3-4-5	755	1430
5-6-7-8	1974	2462
8-9-10-11	1804	1957
11-1-2	384	432

Since only one traveling unit (vehicle or train) can be used on any shuttle, the only parameters which can be varied to accommodate passenger loads are vehicle capacity and the number of vehicles per train. The effective headway for the vehicles operating on the non-synchronized system varies from shuttle to shuttle, but for the synchronized system the headways are constant. Using a single vehicle, having a capacity of 40 passengers, the following link capacities are provided by each of the two shuttle alternatives:

Shuttle	Non-synchronized	Synchronized
2-3-4-5	276	273
5-6-7-8	273	273
8-9-10-11	334	273
11-1-2	312	273

None of the shuttles are provided with sufficient capacity to service demands although shuttle 11-1-2 does not require a very large increase in capacity. Shuttle 5-6-7-8 which has the longest headway and the largest link loads, 1974 and 2462 for the non-synchronized and synchronized alternatives, respectively, cannot be adequately serviced by the largest IGRT vehicle operating in four-car trains; consequently, more than four vehicles per train are required for this shuttle during the peak hour. It is assumed that the vehicle capacity for any given alternative must be similar for all four shuttles (i.e., one shuttle cannot use a 40 passenger vehicle while another shuttle uses a 60 passenger vehicle). Under this assumption the following vehicle sizes and train consists are required to service demands:

		Link Capacity (Pass/Hr)	
Shuttle	No. Veh. Per Train	Non-Synch. 50 Pass. Veh.	Synch. 58 Pass. Veh.
2-3-4-5	2	692	793
5-6-7-8	6	2052	2381
8-9-10-11	5	2092	1984
11-1-2	1	390	397

TABLE 4-14. MID-DAY LINK LOADS FOR THE LOW DEMAND CBD CIRCULATION APPLICATION, NON-SYNCHRONIZED SHUTTLE NETWORK

AGT NETWORK LINK TRIP LOADINGS

LINK ENDS FROM NODE	LINK ENDS TO NODE	LINK TYPE	LINK LOAD
1	203	LIN	346
1	1102	LIN	384
3	4	LIN	151
3	202	LIN	171
4	3	LIN	151
4	503	LIN	755
6	7	LIN	1574
6	502	LIN	1265
7	6	LIN	1573
7	803	LIN	1421
9	10	LIN	1618
9	802	LIN	1804
10	9	LIN	1618
10	1103	LIN	1086
13	3	ACC	120
14	4	ACC	712
16	6	ACC	860
17	7	ACC	606
19	9	ACC	456
21	201	ACC	222
21	204	ACC	47
51	501	ACC	589
51	504	ACC	1100
81	801	ACC	707
81	804	ACC	1090
110	10	ACC	532
111	1101	ACC	1030
111	1104	ACC	328
121	1	ACC	38
201	1	LIN	346
202	22	EGR	47
202	201	XFR	124
203	22	EGR	222
203	204	XFR	124
204	3	LIN	171
501	4	LIN	754
502	52	EGR	1100
502	501	XFR	165
503	52	EGR	589
503	504	XFR	166
504	6	LIN	1266
801	7	LIN	1421
802	82	EGR	1090
802	801	XFR	714
803	82	EGR	707
803	804	XFR	714
804	9	LIN	1804
1101	10	LIN	1086
1102	112	EGR	328
1102	1101	XFR	56
1103	112	EGR	1030
1103	1104	XFR	56
1104	1	LIN	384

(12 NOON TO 1:00 PM)

LIN - Line-Haul Link
ACC - Access Link
EGR - Egress Link
XFR - Transfer Link

TABLE 4-15. MID-DAY LINK LOADS FOR THE LOW DEMAND CBD CIRCULATION APPLICATION, SYNCHRONIZED SHUTTLE

AGT NETWORK LINK TRIP LOADINGS

LINK FROM NODE	ENDS TO NODE	LINK TYPE	LINK LOAD
1	203	LIN	432
1	1102	LIN	423
3	4	LIN	431
3	202	LIN	458
4	3	LIN	422
4	503	LIN	1430
6	7	LIN	2462
6	502	LIN	2150
7	6	LIN	2441
7	803	LIN	2033
9	10	LIN	1110
9	802	LIN	1862
10	9	LIN	1077
10	1103	LIN	641
13	3	ACC	159
14	4	ACC	1355
16	6	ACC	1352
17	7	ACC	1186
19	9	ACC	861
21	201	ACC	62
21	204	ACC	97
51	501	ACC	222
51	504	ACC	999
81	801	ACC	431
81	804	ACC	355
110	10	ACC	465
111	1101	ACC	664
111	1104	ACC	347
201	1	LIN	423
202	22	EGR	97
202	201	XFR	361
203	22	EGR	62
203	204	XFR	370
204	3	LIN	467
501	4	LIN	1418
502	52	EGR	954
502	501	XFR	1156
503	52	EGR	262
503	504	XFR	1168
504	6	LIN	2167
801	7	LIN	1967
802	82	EGR	326
802	801	XFR	1536
803	82	EGR	431
803	804	XFR	1602
804	9	LIN	1957
1101	10	LIN	750
1102	112	EGR	337
1102	1101	XFR	66
1103	112	EGR	556
1103	1104	XFR	65
1104	1	LIN	432

(12 NOON TO 1:00 PM)

LIN - Lin-Haul Link
ACC - Access Link
EGR - Egress Link
XFR - Transfer Link

Note: Access link 121 to 1 has a link load of zero.

One shuttle, synchronized 2-3-4-5, is slightly under serviced (100 passengers per hour), but it is assumed that the unserviced demand is small enough to be serviced by using vehicle crush capacities in lieu of nominal capacities. As an alternative, the location of transfer stations in the shuttle network could be reconsidered so that the demand is more evenly distributed among the shuttles.

The SLT7 deployment is capable of serving the low CBD circulation demand, and further analysis should be undertaken. Since the synchronized shuttle attracts more trips than the non-synchronized configuration, the former should be considered in future analyses of this application.

Summary

All five of the SLT deployments analyzed were found to be capable of serving their demands. However, the loop configurations could employ either large vehicles with fewer trains or smaller vehicles with more trains, assuming that the number of vehicles per train is constant. Only a preliminary analysis is documented in this report, and these issues will be addressed in greater detail in the traveling unit capacity trade study.

No difference was found to exist between the link loads of the clockwise and counter-clockwise alternatives of the one-way loop networks (SLT 3, 5, and 6). It is recommended that in the future analyses only the counter-clockwise network be considered since this network was the one proposed by SEMTA in their Detroit DPM proposal.[7]

The shuttle network configuration alternatives, synchronized and non-sychronized, were considered in SLT7, and it is recommended that only the synchronized alternative be used in future analyses since it services more trips. However, it is necessary to increase the allowable number of vehicles per train from four to six in order to provide adequate service.

4.3.1.4 SLT Deployments in a CBD Line-Haul Application - Four representative systems are deployed in the CBD Line-Haul demand environment. The network of Figure 4-7 displays the SLT8 deployment which is a multiple loop, low-speed LGRT system deployed in a low-demand CBD line-haul application. Figure 4-8 illustrates the network for deployments SLT9, SLT10, and SLT11; this network is identical to the network proposed for the Downtown People Mover system in the city of Houston. The open loop network contains eight stations, two of which are also bus transfer stations, on a one-way loop which collapses to line-haul service through the business area. In addition to the two intra-city bus terminals, extensive parking facilities are provided at both ends of the network.

The multiple loop network employs the same stations as the open loop network (except for some slight relocation, as discussed in Section 3.5.4 and two additional stations located in the business and retail areas which are not serviced by the DPM network as proposed by Houston). Travel from one end of the network to the other end has been somewhat inconvenienced, when compared to the open loop network, at the gain of additional area coverage and expected improvement of service within each loop area.

As in the previous SLT analyses, the deployments in the CBD line-haul application are to be evaluated with an average wait time service goal of five minutes. If the average wait time exceeds this limit, the deployment's operational characteristics are adjusted so as to reduce the wait time. Additional service goals have not been identified; however, the intense peaking of the bus transfer data (as discussed in Section 3.5.4) is expected to require such a high level of service that any service goal specifications would automatically be met.

The remainder of this section is divided into five segments. The first four segments contain the descriptions and network flow analyses of the four SLT deployments. The final segment contains a summary of the network flow analyses for deployments in this application and a discussion of the multiple loop network's two additional stations.

SLT 8

The eighth SLT deployment, as illustrated in Figure 4-7 is a multiple loop network deployed in a low CBD demand level environment with low-speed LGRT vehicles. One station at each end of the network, Stations 3 and 8, simultaneously serve as AGT stations and bus transfer stations. Consequently, these stations service a very large number of passengers during the morning and evening peak hours when the bus transfer passengers change modes in Stations 3 and 8.

Total lane length - 3.6 km
Single lane guideway length - 3.6 km
Number of stations - 10
Type of stations - On-line

BT – bus transfer station

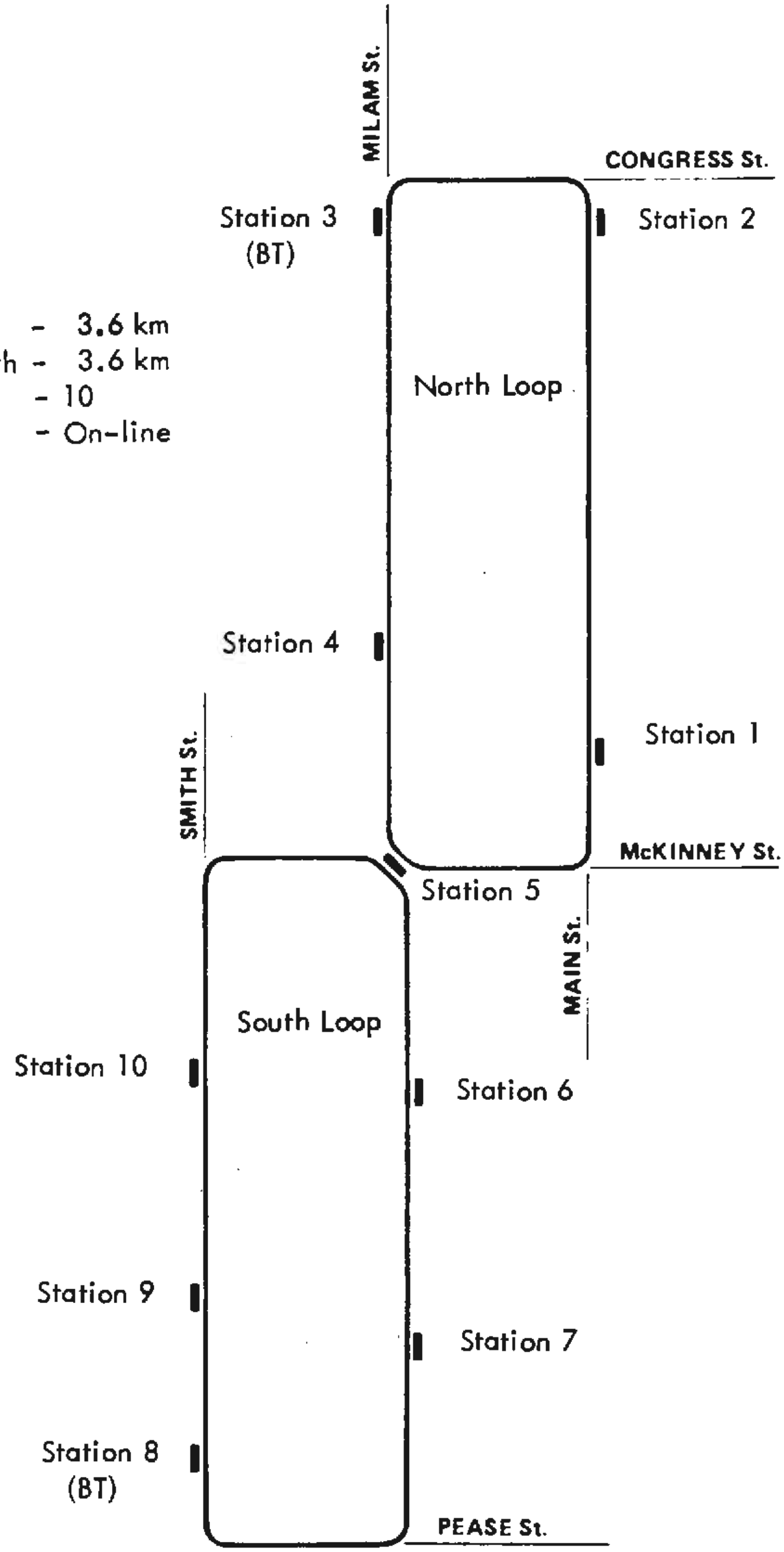


FIGURE 4-7. SLT 8: LOW-DEMAND CBD LINE-HAUL APPLICATION USING A LOW-SPEED LGRT

Total lane length - 3.6 km
Double lane guideway length - 0.9 km
Single lane guideway length - 1.8 km
Number of stations - 8
Type of stations - On-line

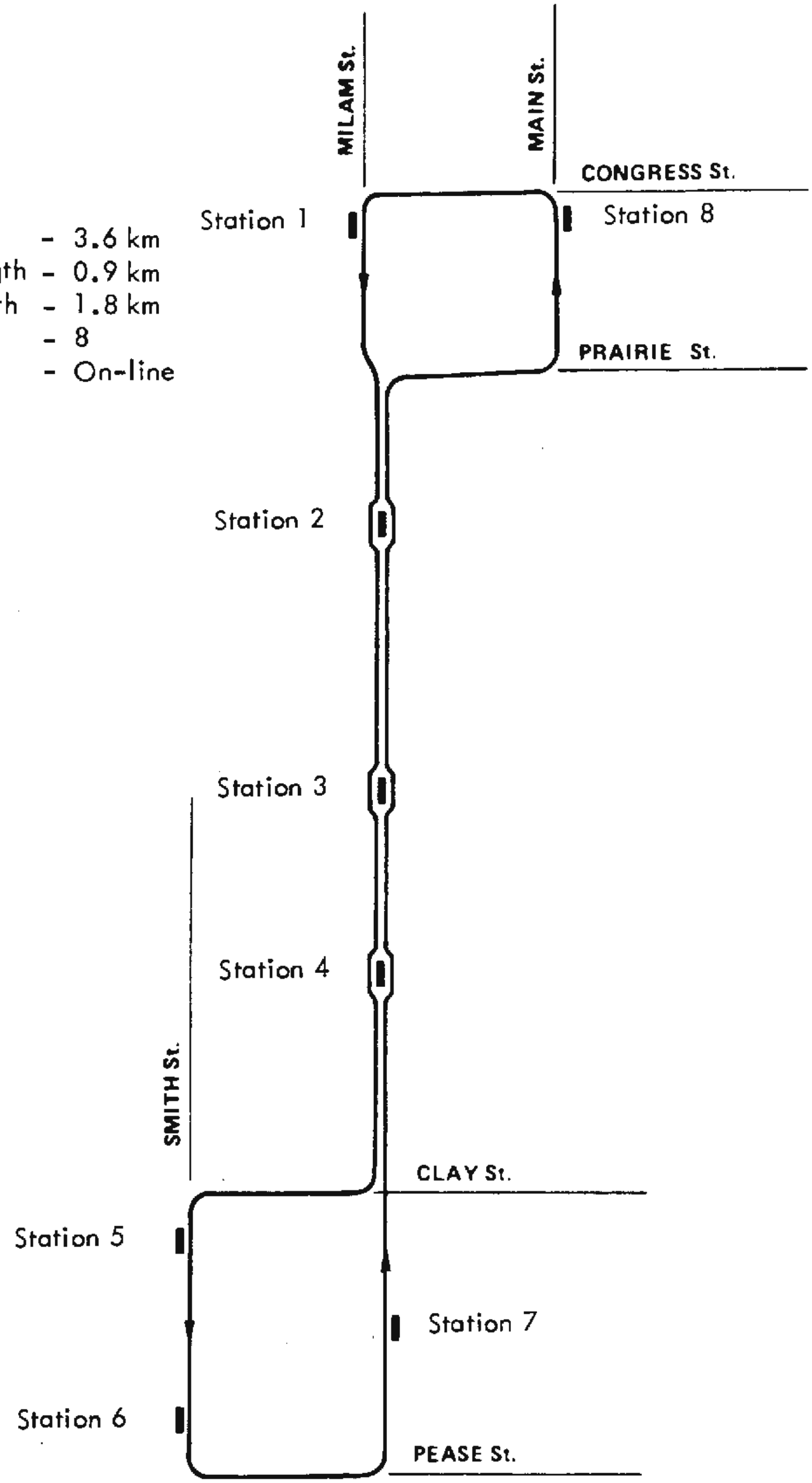


FIGURE 4-8. SLT DEPLOYMENT IN A LOW-DEMAND CBD LINE-HAUL APPLICATION (SLT 9: low-speed LGRT, low-CBD demand level; SLT 10: low-speed SGRT, low-CBD demand level; SLT 11: low-speed SGRT, high-CBD demand level)

Network flow analysis is accomplished by first determining link loads, then calculating the system's ability to service those loads. The system characteristics upon which the network flow analysis is based are:

- Vehicle capacity between 70 and 109 passengers
- Maximum of two cars per train
- Cruise velocity of 48 km/h
- Acceleration/deceleration rate of 1.0 m/s^2
- Station dwell time of 30 s.

For the multiple loop alternative, various deployments of the individual loops are possible. Vehicles on the two loops can be synchronized to better facilitate transfers at Station 5. As detailed below, the demands are such that one vehicle per link is required on each loop and, to better facilitate vehicle flows, all vehicles leave their stations simultaneously. Consequently, vehicle synchronization at Station 5 is automatic. The second alternative which should be considered is the direction of travel on the loops. Each loop can be traversed in either a clockwise or counter-clockwise direction, resulting in four possible combinations of network deployment. In order to restrict the number of necessary analyses while simultaneously considering all of the combinations, two network deployments are analyzed:

1. Clockwise travel on the north loop and counter-clockwise travel on the south loop

2. Counter-clockwise travel on the north loop and clockwise travel on the south loop.

These combinations allow both directions of travel to be analyzed and permit fairly accurate assumptions to be made about the two remaining combinations.

As in the CBD circulation analysis, certain links were added to the network so that accurate assignment of trip time penalties to passenger travel times could be accomplished during the modeling of link loads. Figure 4-9 illustrates a schematic of the transfer station and its four adjoining stations. The results of implementing the link load analysis are shown in Tables 4-16 and 4-17 for the north loop clockwise/south loop counter-clockwise alternative during the a.m. peak hour (7:00 - 8:00) and the p.m. peak hour (4:00 - 5:00), respectively. Tables 4-18 and 4-19 detail the link loads for the north loop counter-clockwise/south loop clockwise alternative for the a.m. and p.m. peak hours, respectively. The station-to-station demands from which these link loads are derived are detailed in Tables 3-44 through 3-47.

Analyzing the data in Tables 4-16 and 4-17 first, it can be seen that the maximum link load occurs on Link (8,7) in the morning rush hour (3,932 passengers per hour) and on Link (9,8)(3,825 passengers per hour) during the evening rush hour. This is as expected since the station-to-station demand matrices, Tables 3-44 and 3-45, show that more passengers access Station 8, one of the bus transfer stations, in the morning and egress it in the

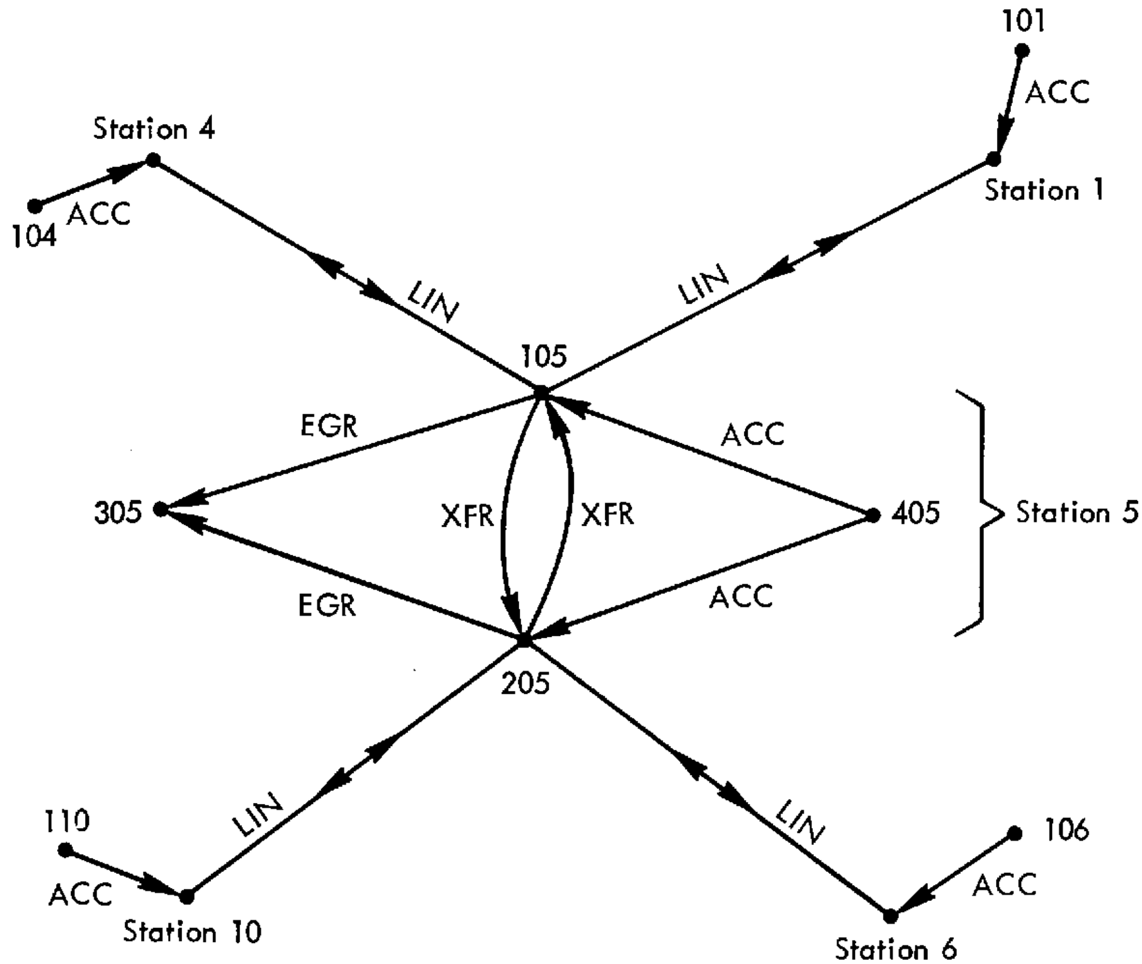


FIGURE 4-9. SLT 8 TRANSFER STATION SCHEMATIC

TABLE 4-16. 7:00 A.M. TO 8:00 A.M. LINK LOADS FOR THE LOW DEMAND CBD LINE-HAUL MULTIPLE LOOP APPLICATION USING LGRT VEHICLES (SOUTH LOOP C-C/NORTH LOOP C)

A G T N E T W O R K L I N K T R I P L O A D I N G S

LINK ENDS FROM NODE	LINK ENDS TO NODE	LINK TYPE	LINK LOAD
1	105	LIN	2539
2	1	LIN	2895
3	2	LIN	3162
4	3	LIN	390
6	205	LIN	2475
7	6	LIN	3561
8	7	LIN	3932
9	8	LIN	721
10	9	LIN	920
101	1	ACC	47
102	2	ACC	30
103	3	ACC	2894
104	4	ACC	19
105	4	LIN	1180
105	205	XFR	888
105	305	EGR	1077
106	6	ACC	40
107	7	ACC	159
108	8	ACC	3548
110	10	ACC	16
205	10	LIN	1462
205	105	XFR	569
205	305	EGR	1372
405	105	ACC	37
405	205	ACC	40

LIN - Line-Haul Link
ACC - Access Link
EGR - Egress Link
XFR - Transfer Link

TABLE 4-17. 4:00 P.M. TO 5:00 P.M. LINK LOADS FOR THE LOW DEMAND CBD LINE-HAUL MULTILOOP APPLICATION USING LGRT VEHICLES (NORTH LOOP C/SOUTH LOOP C-C)

A G T N E T W O R K L I N K T R I P L O A D I N G S

LINK ENDS FROM NODE	TO NODE	LINK TYPE	LINK LOAD
1	105	LIN	587
2	1	LIN	398
3	2	LIN	140
4	3	LIN	2519
6	205	LIN	2128
7	6	LIN	804
8	7	LIN	573
9	8	LIN	3825
10	9	LIN	2742
101	1	ACC	208
102	2	ACC	286
103	3	ACC	115
104	4	ACC	343
105	4	LIN	2215
105	205	XFR	220
105	305	EGR	54
106	6	ACC	1353
107	7	ACC	267
108	8	ACC	327
109	9	ACC	1087
110	10	ACC	672
205	10	LIN	2079
205	105	XFR	877
205	305	EGR	59
405	105	ACC	1025
405	205	ACC	667

LIN - Line-Haul Link
ACC - Access Link
EGR - Egress Link
XFR - Transfer Link

TABLE 4-18. 7:00 A.M. TO 8:00 A.M. LINK LOADS FOR THE LOW DEMAND CBD LINE-HAUL MULTILOOP APPLICATION USING LGRT VEHICLES (NORTH LOOP C-C/SOUTH LOOP C)

AGT NETWORK LINK TRIP LOADINGS

LINK NODES FROM NODE	TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	628
2	3	LIN	362
3	4	LIN	3141
4	105	LIN	2396
6	7	LIN	1110
7	8	LIN	593
8	9	LIN	3898
9	10	LIN	3709
10	205	LIN	3153
101	1	ACC	20
102	2	ACC	30
103	3	ACC	2897
104	4	ACC	42
105	1	LIN	1039
105	205	XFR	907
105	305	EGR	1057
106	6	ACC	29
107	7	ACC	37
108	8	ACC	3644
109	9	ACC	5
110	10	ACC	9
205	6	LIN	2219
205	105	XFR	551
205	305	EGR	1351
405	105	ACC	56
405	205	ACC	61

LIN - Line-Haul Link
ACC - Access Link
EGR - Egress Link
XFR - Transfer Link

TABLE 4-19. 4:00 P.M. TO 5:00 P.M. LINK LOADS FOR THE LOW DEMAND CBD LINE-HAUL MULTILOOP APPLICATION USING LGRT VEHICLES (NORTH LOOP C-C/SOUTH LOOP C)

AGT NETWORK LINK TRIP LOADINGS

LINK ENDS FROM NODE	LINK ENDS TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	2387
2	3	LIN	2646
3	4	LIN	271
4	105	LIN	618
6	7	LIN	3771
7	8	LIN	3953
8	9	LIN	659
9	10	LIN	1790
10	205	LIN	2440
101	1	ACC	182
102	2	ACC	287
103	3	ACC	117
104	4	ACC	364
105	1	LIN	2249
105	205	XFR	238
105	305	EGR	35
106	6	ACC	1343
107	7	ACC	243
108	8	ACC	327
109	9	ACC	1091
110	10	ACC	666
205	6	LIN	2467
205	105	XFR	860
205	305	EGR	39
405	105	ACC	1044
405	205	ACC	688

LIN - Line-Haul Link
ACC - Access Link
EGR - Egress Link
XFR - Transfer Link

evening than any other station. The link loads on the downstream link of Station 3, the north loop bus transfer station, are also quite significant at 3162 passengers per hour during the morning rush hour, and an upstream link load of 2519 passengers per hour during the evening peak. To accommodate these loadings, it is necessary to employ either several vehicles (or trains) with intermediate capacities or fewer large-capacity trains. The smaller vehicles operating at short headways are preferable to large trains running at longer headways for the following reasons:

- Smaller vehicles are more appropriate for the low, off-peak demands.

- Shorter headways prevent large numbers of passengers from queuing in the stations, thereby reducing the station size requirements.

Single 70-passenger vehicles operating at one-minute headways provide a link capacity of 4200 passengers per hour, which is greater than any of the expected link loads. However, to attain 60-second headways it is necessary to have six vehicles on the north loop and seven vehicles on the south loop since the round trip travel times for the loops are 6.4 minutes and 7.22 minutes, respectively. With six vehicles on the north loop, it is possible that a vehicle may be required to come to a halt on the guideway since there are only five stations and travel times between stations vary significantly, as shown in Table 3-29. To prevent this kind of stoppage, only five vehicles will be used on the north loop and six vehicles on the south loop, or one vehicle per link. With one vehicle per link the headway becomes 1.47 minutes on both the north and south loops, assuming that vehicles leave their stations simultaneously. (As shown in Table 3-40, the longest link travel times on both loops is approximately 88 seconds or 1.47 minutes; therefore, vehicles on the shorter links will have longer station dwell times.) With a headway of 1.47 minutes, the 97-passenger vehicles provide a link capacity of 3959 passengers per hour. Clearly then, the SLT8 deployment is capable of servicing the peak demands but may be providing excess capacity during the off-peak periods.

From Table 3-42 it can be seen that the off-peak station-to-station demands are very small in comparison to the peak period demands. The 97-passenger vehicle operating at a headway of 6.4 minutes and 7.22 minutes on the north loop and south loop, respectively (these headways are obtained by employing one vehicle per loop), provides a link capacity of 909 passengers on the north loop and 806 passengers on the south loop. Since there are only 4193 passengers traveling during the entire off-peak interval of 12 hours (Table 3-42), the link capacity provided by a single 97-passenger vehicle operating on each loop is assumed to be quite adequate. However, two vehicles per loop might be required in order to comply with any specified passenger trip time service goals.

Analysis of the north loop counter-clockwise/south loop clockwise alternative is very similar to the analysis above in that the vehicle headway is 1.47 minutes and only five vehicles can be used on the north loop and six vehicles on the south loop. Using the link loads shown in Table 4-18 and 4-19, it can be seen that the loads on the south loop are higher than those on the north loop. The maximum load of 3953 passengers per hour occurs on Link (7, 8) during the evening rush hour. The 97-passenger vehicle, operating at a headway of 1.47 minutes, is capable of servicing this demand since it provides a link capacity of 3959 passengers per hour.

As discussed in Section 3.5.4, there is essentially no variation between the number of trips made on the north loop clockwise/south loop counter-clockwise alternative and the north loop counter-clockwise/south loop clockwise alternative. Therefore, the direction of travel which results in the lower peak link load on the individual loops is to be considered in future analyses of the SLT8 deployment. During the a.m. peak hour, the maximum link loads for the north loop are almost identical at 3162 and 3142 passengers per hour for the clockwise and counter-clockwise alternatives, respectively (taken from Tables 4-16 through 4-19). During the p.m. peak hour, the clockwise direction of travel results in the lower link load per hour (2519 versus 2646). Therefore, in future SLT8 analyses the clockwise alternative is considered for the north loop.

The peak link loads for the south loop are detailed below (taken from Tables 4-16 through 4-19):

	Clockwise	Counter-Clockwise
a.m.	3898	3932
p.m.	3953	3825

The difference in the link loads is greater during the p.m. peak hour than during the a.m. peak hour. The counter-clockwise direction of travel results in a lower link load during the p.m. peak. Therefore, the counter-clockwise direction of travel for the south loop is used in future analyses of the SLT8 deployment.

In summary, the LGRT system operating on a multiple loop network does provide adequate service for the low demand CBD environment. The direction of travel which best services demand is for travel to flow in the clockwise direction on the north loop and the counter-clockwise direction on the south loop.

SLT 9

The SLT9 deployment, as illustrated in Figure 4-8, consists of an open loop network deployed in a low-demand level CBD environment with low-speed LGRT vehicles. The network and station locations are identical to those proposed by the city of Houston for their DPM system. All stations are on-line with Stations 1 and 6 also serving as bus transfer stations where passengers can transfer from bus service to the AGT system. A portion of the guideway closes on itself to form two-way line-haul links where center platform stations are employed.

Using the same system characteristics as defined for SLT8, the station-to-station demands for this network (as shown in Tables 3-36 and 3-37 for the a.m. and p.m. peak hours) were used to generate the link loads shown in Tables 4-20 and 4-21 for the a.m. and p.m. peak hours, respectively.

There are several links which have loadings in excess of 3000 passengers per hour; however, the maximum loading occurs on Link (6, 7), during the a.m. peak, which carries 3793 passengers per hour. Therefore, as in the SLT8 analysis, one vehicle per link is

TABLE 4-20. 7:00 A.M. TO 8:00 A.M. LINK LOADS FOR THE LOW DEMAND CBD LINE-HAUL OPEN LOOP APPLICATION USING LGRT VEHICLES

A G T   N E T W O R K   L I N K   T R I P   L O A D I N G S

L I N K FROM NODE	E N D S TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	3035
2	3	LIN	2555
2	8	LIN	415
3	2	LIN	1090
3	4	LIN	1542
4	3	LIN	2413
4	5	LIN	794
5	6	LIN	590
6	7	LIN	3753
7	4	LIN	3324
8	1	LIN	151
101	1	ACC	3010
102	2	ACC	58
103	3	ACC	129
104	4	ACC	51
105	5	ACC	6
106	6	ACC	3541
107	7	ACC	62
108	8	ACC	33

LIN - Line-Haul Link
ACC - Access Link

TABLE 4-21. 4:00 P.M. TO 5:00 P.M. LINK LOADS FOR THE LOW DEMAND CBD LINE-HAUL OPEN LOOP APPLICATION USING LGRT VEHICLES

AGT NETWORK LINK TRIP LOADINGS

LINK ENDS FROM NODE	TO NODE	LINK TYPE	LINK LOAD
1	2	LIN	147
2	3	LIN	170
2	8	LIN	2940
3	2	LIN	2477
3	4	LIN	805
4	3	LIN	1497
4	5	LIN	2050
5	6	LIN	3129
6	7	LIN	554
7	4	LIN	784
8	1	LIN	3201
101	1	ACC	123
102	2	ACC	544
103	3	ACC	1744
104	4	ACC	2019
105	5	ACC	1093
106	6	ACC	328
107	7	ACC	267
108	8	ACC	291

LIN - Line-Haul Link
ACC - Access Link

employed in order to provide consistent service and reduce the probability of developing long passenger queues. It is assumed that these vehicles will be controlled so as to depart simultaneously from their stations. Since the longest link travel time is 88 seconds, as detailed in Table 3-29, the headway for this network is 88 seconds (i.e., 1.47 minutes). Using 93-passenger vehicles operating at this headway, a link capacity of 3795 passengers per hour is attained--sufficient capacity to service even the maximum link load. Since the off-peak demands are relatively low, it is assumed that the 95-passenger vehicle can provide adequate capacity to service these demands, and that the service goal requirements, rather than demand, determine the number of vehicles to be operated.

SLT 10

The SLT10 deployment employs the same network as SLT9, as defined in Figure 4-8, in a low CBD demand environment. But, instead of employing LGRT vehicles, SGRT vehicles are used. The SGRT vehicles have a capacity range of 7 to 24 passengers, as opposed to the 70 to 109 passenger capacities of the LGRT vehicles, and can train up to three vehicles. As discussed in Section 3.5.4, the station-to-station demand matrices for the SLT9 and SLT10 deployments are identical; therefore, the link loads for the two deployments are identical. Consequently, the maximum link capacity which must be serviced is 3793 passengers per hour (as determined from Tables 4-20 and 4-21). As in the analysis of SLT8 and SLT9, only one vehicle or train per link is employed, resulting in a headway of 1.47 minutes. Using 24-passenger vehicles in four-vehicle trains, an hourly link capacity of 3918 passengers is attained. This capacity is capable of servicing the peak hour demands and, based upon analysis of the previous CBD line-haul applications, it is assumed that the off-peak demands can also be serviced within the specified service goals. However, it is necessary to increase the number of SGRT vehicles allowed to operate in a train from three vehicles to four. Alternatively, the number of three-car trains can be increased to serve the demand. Reducing the headway to 1.14 minutes with three-car trains results in adequate capacity being provided. However, the operational implications of this headway with an on-line station configuration must be evaluated. These alternatives will be analyzed during the trade-off analysis of this deployment.

SLT 11

This deployment is identical to the SLT10 deployment except that a high demand level rather than a low demand level is employed. As discussed in Section 3.5.4, the peak period station-to-station demand matrices of the SLT9 deployment (which are also the matrices for the SLT10 deployment) need only be multipled by a factor of two in order to obtain the SLT11 station matrices. Consequently, the peak hour link loads are a factor of two greater for the SLT11 deployment than the SLT9 deployment (i.e., doubling the link loads in Tables 4-20 and 4-21 results in the link loads for SLT11 during the a.m. and p.m. peak hours).

To service these doubled demands, the system capacity of SLT 10 must be doubled. This is accomplished by either doubling the vehicle capacity or doubling the number of vehicles per train. Vehicle capacity cannot be doubled without changing the system type. Increasing the train length to eight vehicles is not practical for this network. Consequently, the system type is changed from SGRT to LGRT so that the high CBD demands can be serviced by this deployment.

Note that the SLT 11 deployment is identical to the SLT 9 deployment except for the difference in demand levels. By doubling the capacity of the SLT 9 deployment, the demands of the SLT 11 deployment can be serviced. By increasing the number of vehicles per train from one to two while maintaining the same headway, the desired increase in capacity is achieved.

In conclusion, it appears that the SLT 11 deployment, if redefined to deploy LGRT rather than SGRT vehicles, can service the applied demand.

Summary

The four SLT deployments identified to serve the CBD line-haul application were all found to warrant further analysis. The SLT8 multiple loop deployment will be analyzed further with a clockwise north loop and a counter-clockwise south loop. The three open loop deployments will be analyzed further with a counter-clockwise direction of travel. All of the deployments were found to require one vehicle or train per link in order to service demands.

Two deployments required possible modifications in their definitions or system characteristics. The maximum number of vehicles per train for the SLT10 deployment may be changed from three to four to increase its capacity sufficiently to service demands. The SLT11 deployment is redefined to employ LGRT rather than SGRT vehicles since the small vehicles are incapable of servicing the high-demand level.

The value of the two additional stations on the multiple loop network is to be considered. From Tables 3-41 through 3-43, it can be seen that the demands to and from Stations 1 and 10, the additions, are small (but within the same range as the other station demands, with the exception of the bus transfer stations). Since the main objective of analyzing different network configurations is to compare their service characteristics, and since no data is available on how many bus transfer trips the additional stations would generate, the two extro stations will not be deleted at this time.

4.3.2 Representative ART Deployments

Two ART deployments, as defined in Table 4-2, have been identified for analysis in the SOS project. The first deployment is analyzed in the High CBD Orientation, High Reverse Commutation Metropolitan demand environment while the second deployment is analyzed in the High CBD Orientation, Low Reverse Commutation Metropolitan demand environment.

4.3.2.1 ART Deployment in a High CBD, High Reverse Metropolitan Application - The ART 1 representative system is deployed in a High CBD Orientation, High Reverse Commutation metropolitan application represented by the demand environment of Cincinnati. This partially connected grid is intended to serve the station locations and travel corridors identified in the long-range transportation plan [16] for the Cincinnati metropolitan area. The network, as shown in Figure 4-10 has 28 on-line stations and three Y junctions which allow travel only in the direction pictorially implied. In this network each link represents dual-lane guideway.

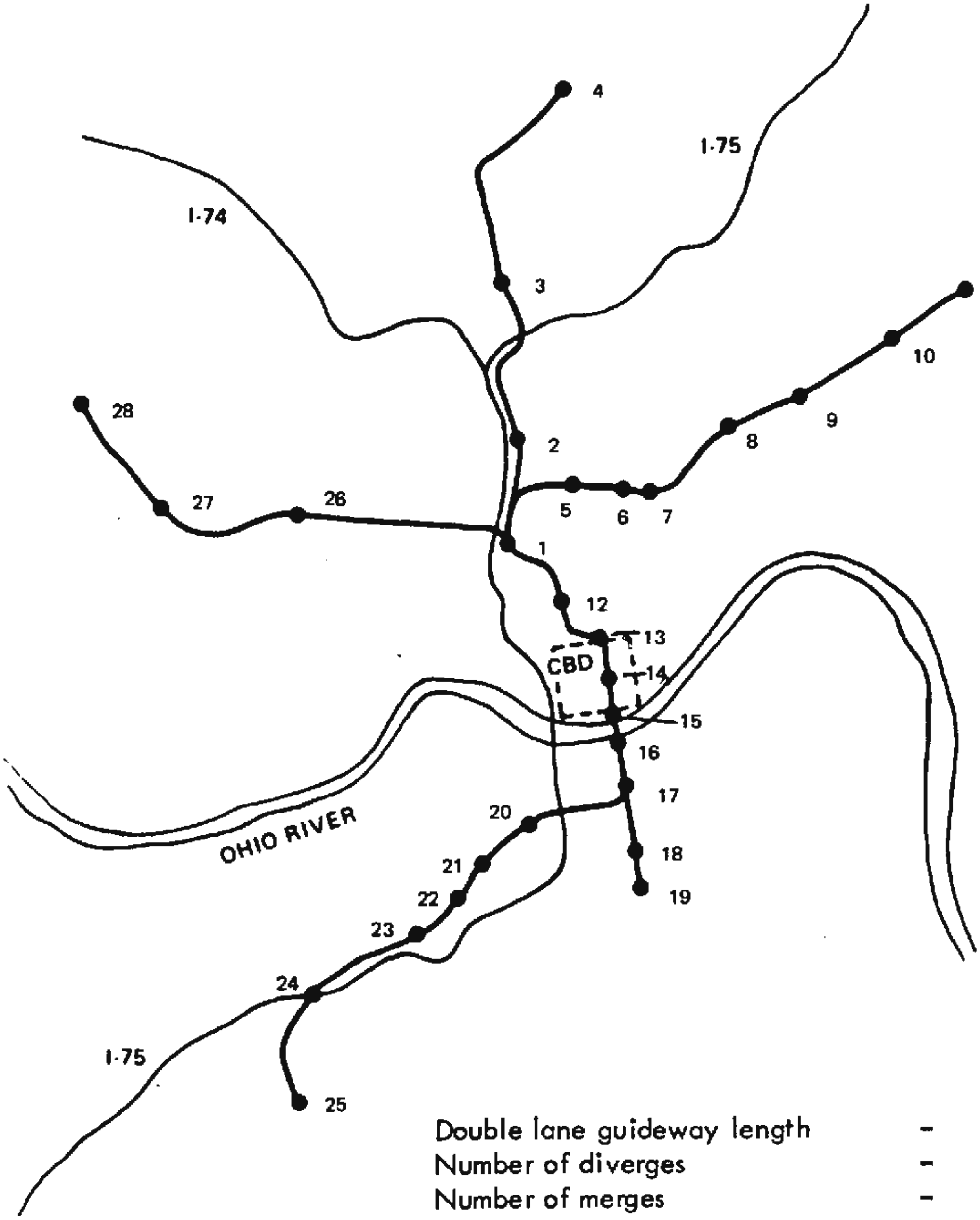
4.3.2.2 ART Deployment in a High CBD, Low Reverse Metropolitan Application - The ART 2 representative system depicted in Figure 4-11, is deployed in a High CBD Orientation, Low Reverse Commutation metropolitan application which is represented by the demand environment of Washington, D.C. The partially connected grid for this deployment is identical to a portion of the network of the planned Washington, D.C. Metro System. In this particular network there is no switching at + junctions, and switching capabilities at Y junctions are only in the directions pictorially implied.

4.3.3 Representative GRT Deployments

A total of four GRT deployments are defined for analysis in the SOS program. These deployments contain networks which are either fully or partially connected grids and employ GRT vehicles of either the small or intermediate size in metropolitan area environments.

4.3.3.1 GRT Deployments in a High CBD, High Reverse Metropolitan Application - Two representative GRT systems are deployed in the High CBD Orientation, High Reverse Commutation Metropolitan demand environment which is modeled after the Cincinnati demands. The first deployment, GRT 1, is a multiple loop network, Figure 4-12, deployed with a high-speed IGRT system. This network is based on the station locations and travel conditions identified in the long-range transportation plan for the Cincinnati metropolitan area.[16] The cluster of four dots represents one station where passenger transfers are made between the four separate loops. Transfers also occur between two loops at another location, as indicated in the figure. This arrangement of loops is proposed because each corridor is expected to have distinctly different demand densities, and each one can be operated to obtain a unique link capacity.

The second representative system, GRT 2, is deployed in a High CBD Orientation, High Reverse Commutation Metropolitan application on a fully connected grid network (Figure 4-13)using high-speed IGRT vehicles. Full switching capabilities are provided at all three of the Y intersections. The station locations are identical to the station locations of the GRT 2 deployment described above.



Double lane guideway length	-	49 km
Number of diverges	-	3
Number of merges	-	3
Number of stations	-	28
Type of stations	-	On-line

FIGURE 4-10 ART 1: HIGH CBD ORIENTATION - HIGH REVERSE COMMUTATION METROPOLITAN AREA APPLICATION

Double lane guideway length	-	104 km
Number of diverges	-	5
Number of merges	-	5
Number of stations	-	52
Type of stations	-	On-line

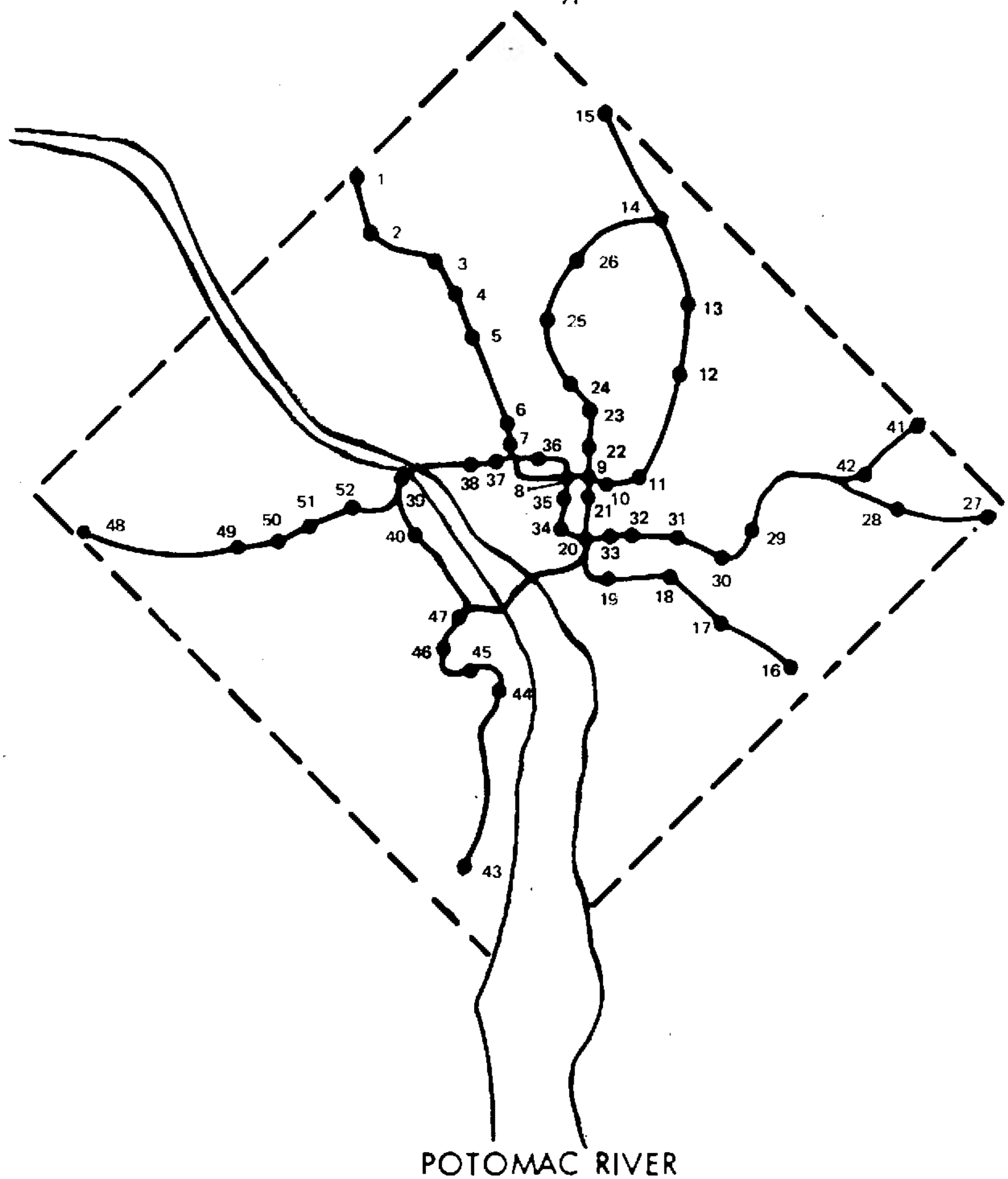


FIGURE 4-11. ART IN HIGH CBD ORIENTATION - LOW REVERSE COMMUTATION METROPOLITAN AREA APPLICATION (ART 2: high-speed ART, partially connected grid)

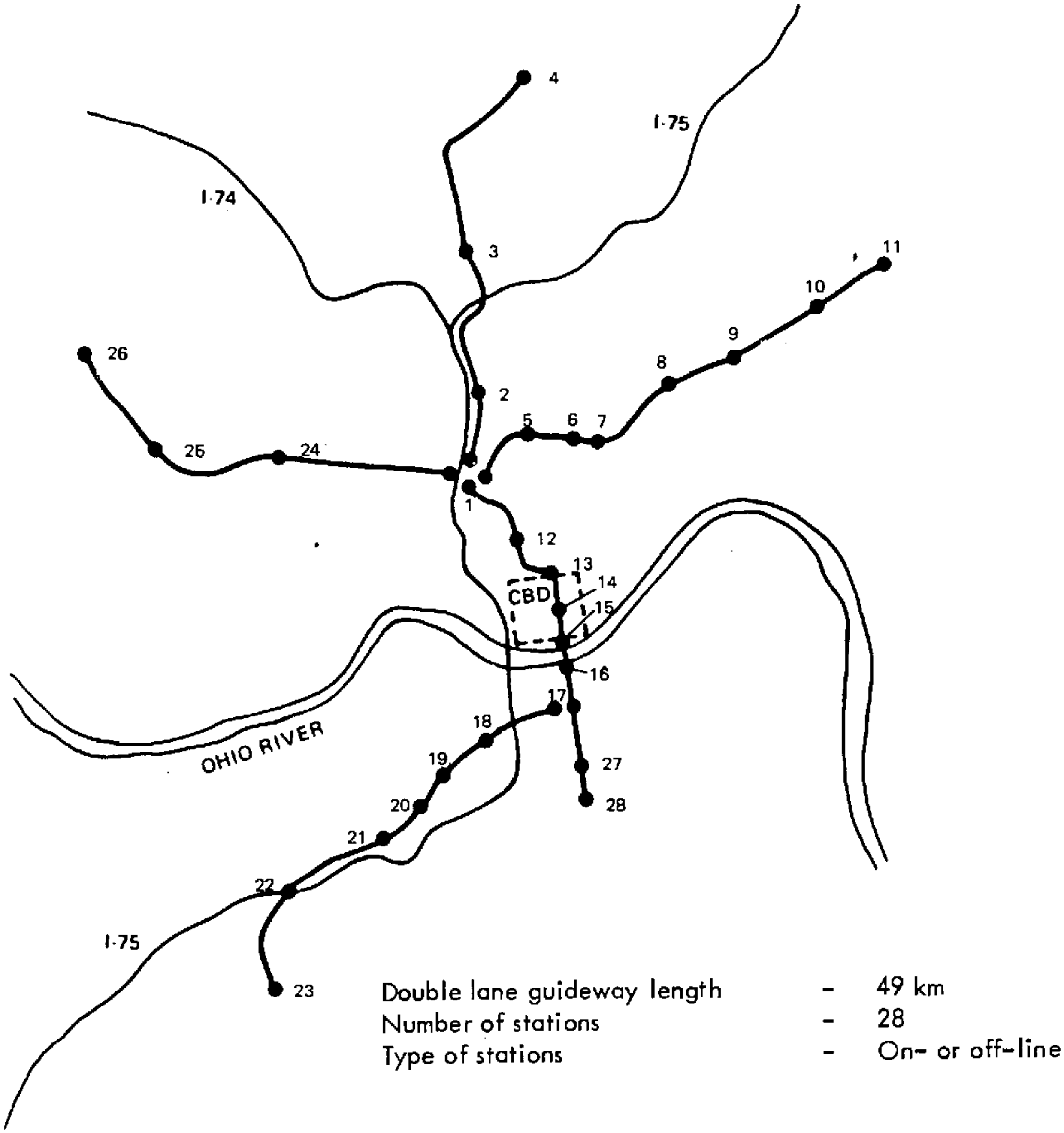
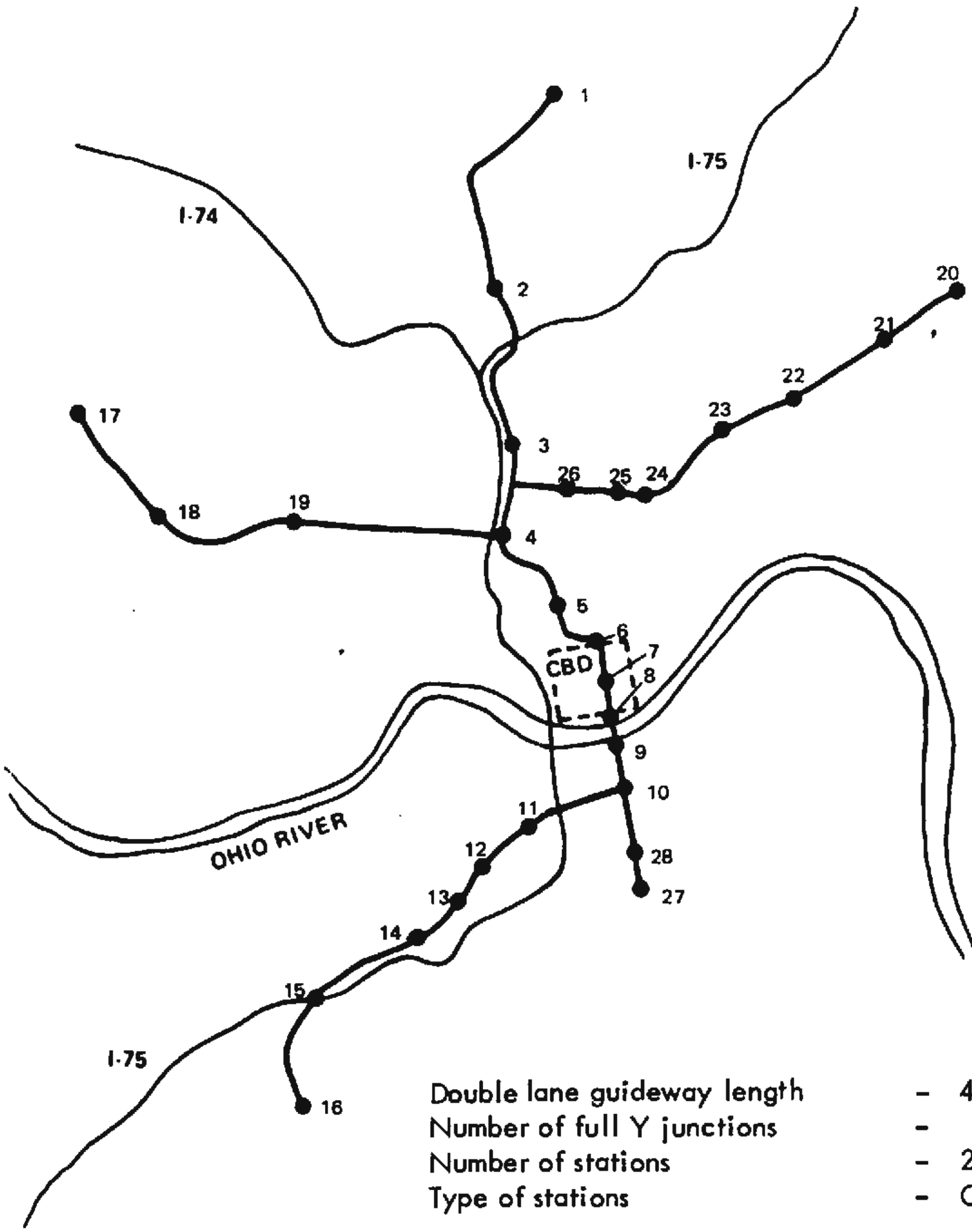


FIGURE 4-12. GRT 1: HIGH CBD ORIENTATION - HIGH REVERSE COMMUTATION METROPOLITAN AREA APPLICATION USING A HIGH-SPEED IGRT ON A MULTIPLE-LOOP NETWORK



Double lane guideway length - 49 km
Number of full Y junctions - 3
Number of stations - 28
Type of stations - On- or off-line

FIGURE 4-13. GRT 2: HIGH CBD ORIENTATION - HIGH REVERSE COMMUTATION METROPOLITAN AREA APPLICATION USING A HIGH-SPEED IGRT ON A FULLY CONNECTED GRID NETWORK

4.3.3.2 GRT Deployment in a Low CBD, High Reverse Metropolitan Application - One representative system, GRT 3, is deployed in a Low CBD Orientation, High Reverse Commutation Metropolitan application which is represented by the Detroit metropolitan demand environment. The network of Figure 4-14 is deployed with a high-speed IGRT system and is a coarse density, area-wide fully connected grid. All Y and + junctions are fully connected. All guideway is dual-lane except the loop around the CBD (connecting stations 6, 7, 8, 9, 10, 11, 12, 13, and 14) which is single-lane guideway.

4.3.3.3 GRT Deployments in a High CBD, Low Reverse Metropolitan Application - The GRT 4 deployment, as shown in Figure 4-15, is a fully connected grid network deployed with high-speed SGRT vehicles. The network is almost identical to the ART 2 network except for the downtown bypass line and the full switching capability. All Y and + junctions in this network are fully connected.

4.3.4 Representative PRT Deployments

Two PRT representative systems are defined for analysis. These systems are deployed in two very different demand environments: a High Demand CBD Circulation application and a Low CBD Orientation, High Reverse Commutation Metropolitan application.

4.3.4.1 PRT Deployment in a CBD Circulation Application - The representative system PRT 1 is deployed in a High-Demand CBD Circulation application derived from the Detroit CBD demand environment. The deployment consists of a fully connected grid network (shown in Figure 4-16), with a low-speed PRT system. Stations 1 through 11 are identical to the Stations 1 through 11 in the SLT 3-7 networks (shown in Figure 4-3). The outside stations for the two networks are located in approximately the same locations, but the three additional stations of PRT 1 provide service to an intra-city bus terminal area and a park and office area which are not serviced by the SLT networks.

4.3.4.2 PRT Deployment in a Low CBD, High Reverse Metropolitan Application - The representative system PRT 2 is deployed in a Low CBD Orientation, High Reverse Commutation Metropolitan application as represented by the Detroit metropolitan demand environment, and it employs a high-speed PRT system. Figure 4-17 illustrates the medium density, area-wide, fully connected PRT 2 network. All Y and + junctions are fully connected. The network is a grid composed of single-lane guideway, and because of this, a preliminary analysis of link directionality was performed.

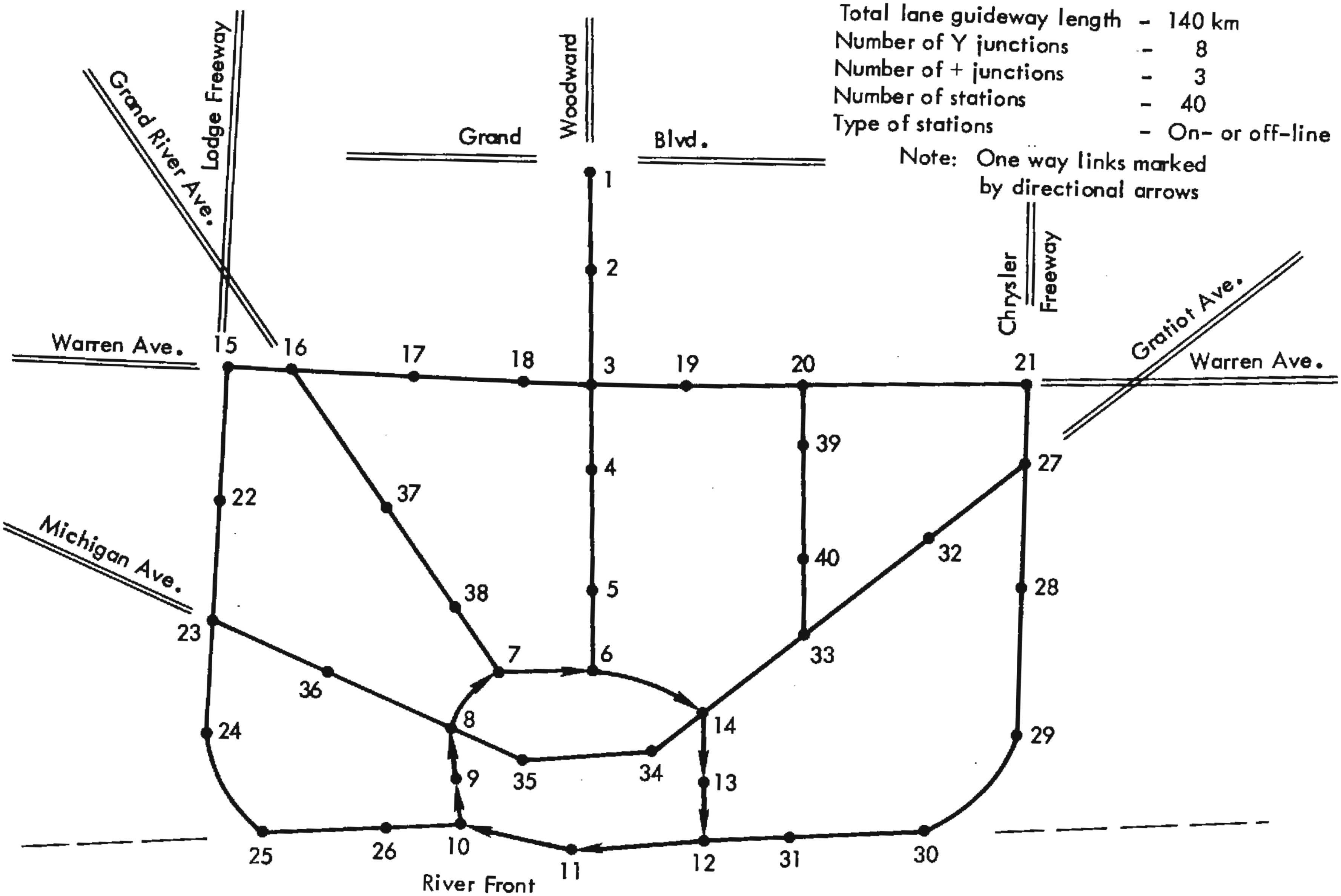


FIGURE 4-14. GRT 3: LOW CBD ORIENTATION - HIGH REVERSE COMMUTATION METROPOLITAN AREA APPLICATION USING A HIGH-SPEED IGRT

Double lane guideway length - 109 km
Number Y junctions - 7 (2 merges each)
Number X junctions - 7 (8 merges each)
Number of stations - 52
Type of stations - Off-line

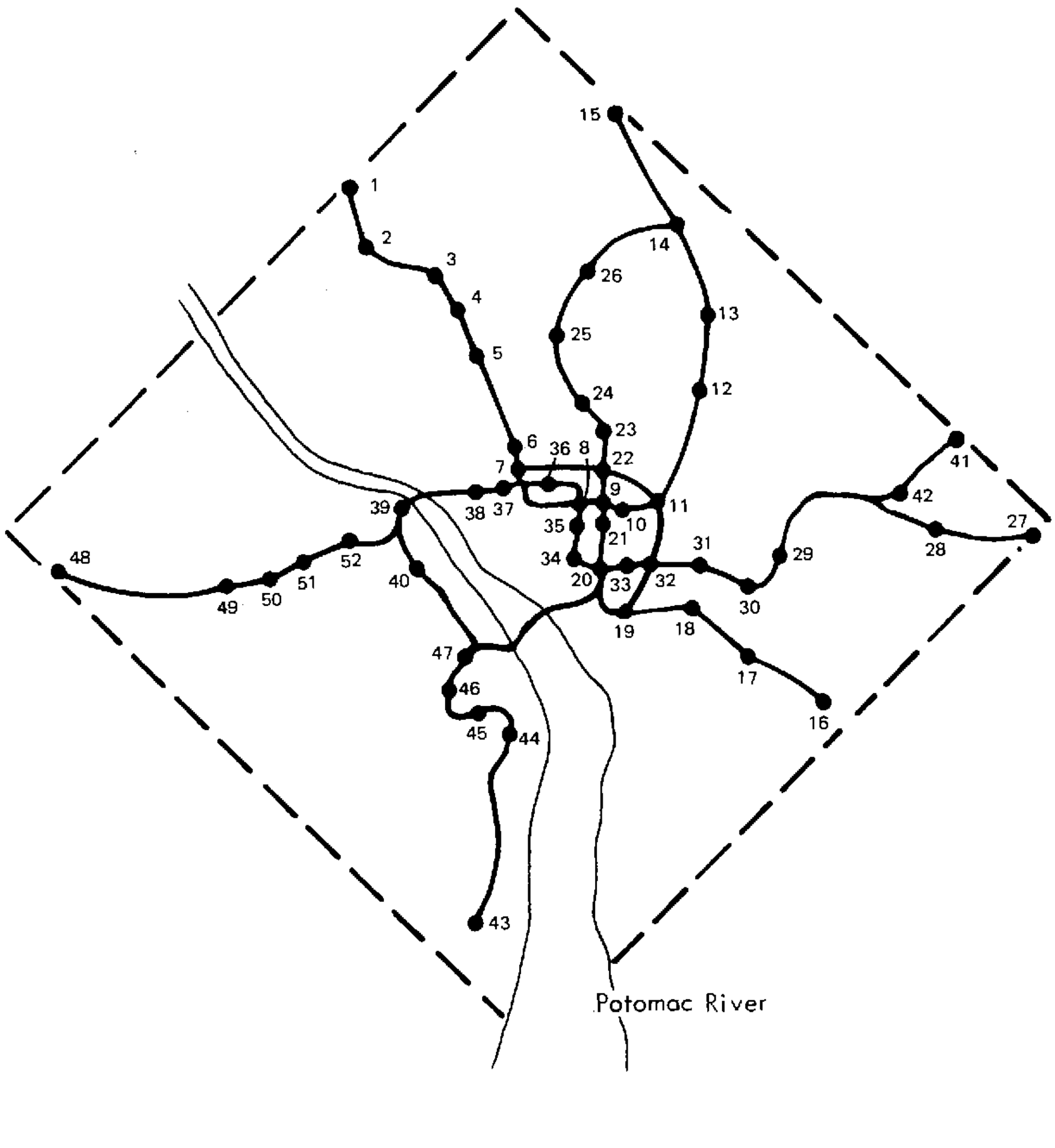


FIGURE 4-15. GRT IN HIGH CBD ORIENTATION - LOW REVERSE COMMUTATION METROPOLITAN AREA APPLICATION (GRT 4: high-speed IGRT, fully connected grid)

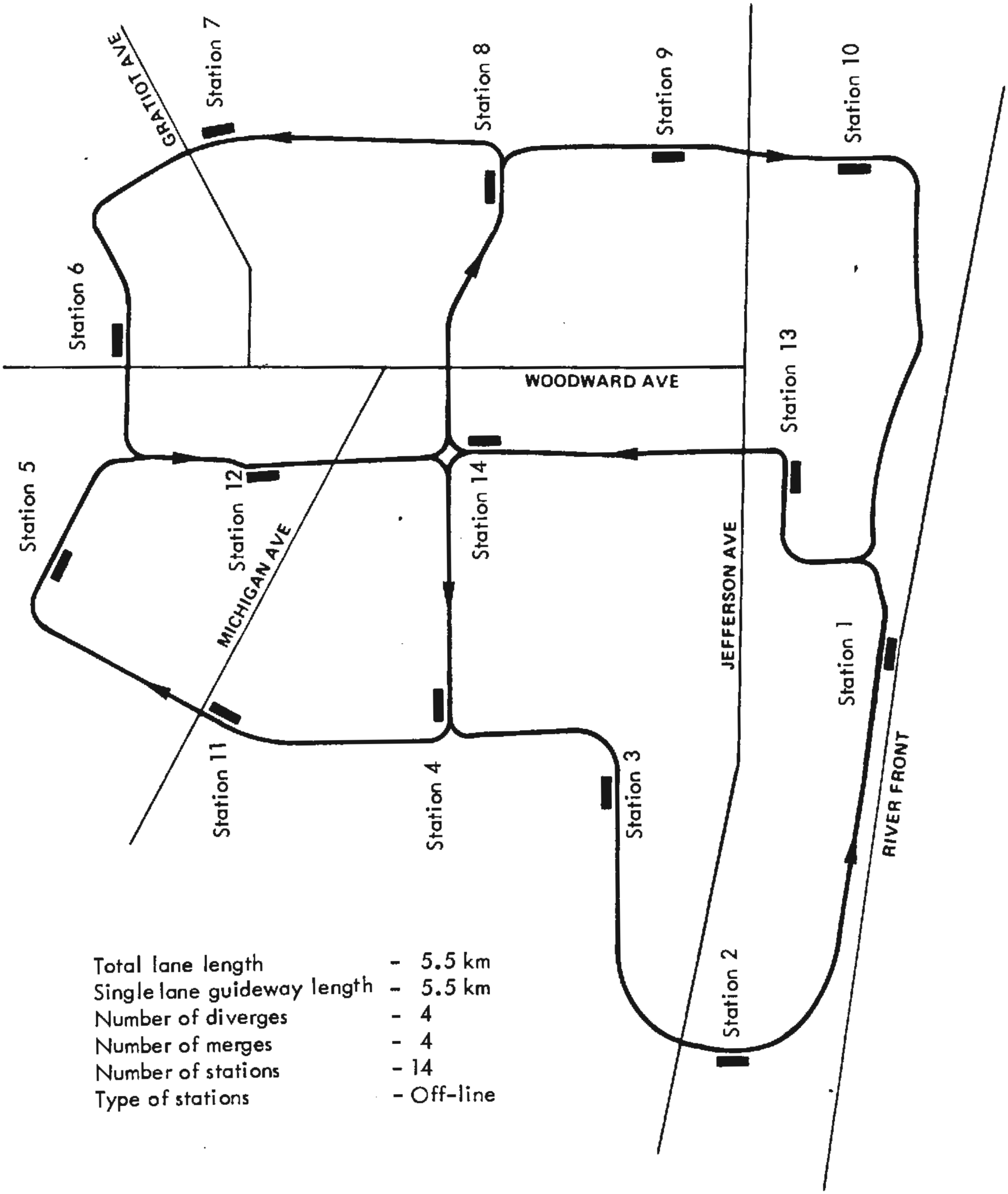


FIGURE 4-16. PRT 1: LOW-SPEED PRT IN HIGH-DEMAND CBD CIRCULATION APPLICATIO

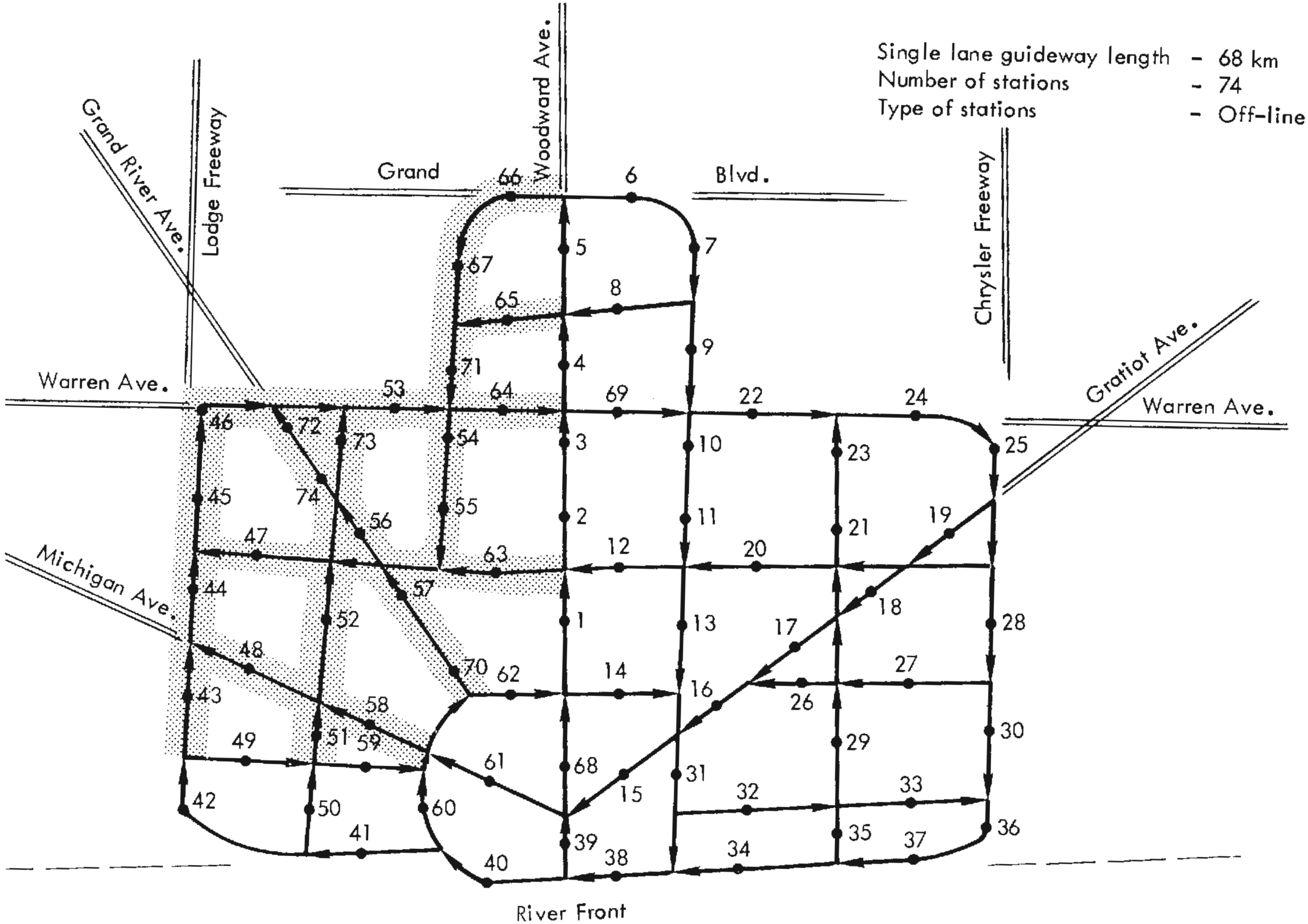


FIGURE 4-17. PRT 2: HIGH-SPEED PRT IN LOW CBD ORIENTATION - HIGH REVERSE COMMUTATION METROPOLITAN AREA APPLICATION (ORIGINAL VERSION)

In a high level flow analysis of the original PRT 2 network shown in Figure 4-17, it was discovered that the orientation of the links in the network are such that all the flow-out of a large portion of the network is funnelled through a single link. The particular link is that which contains station 64, and the region it influences is shown as the shaded portion in Figure 4-17. This link experiences high flow rates and will limit the overall system capacity as well as provide a likely site for failures with serious consequences. The likelihood of failures follows from the high density of vehicles on the link and hence the increased opportunity for failure. The seriousness of the consequences follows from the large fraction of the total station-to-station paths which are broken by the stoppage of flow on this link.

Ideally, the links of a network should be oriented so that stoppage of flow on a single link will not disconnect the network. That is, there should be at least two distinct paths from each station to every other station. Unfortunately this is not possible since each station is located on a stretch of single guideway and not at a junction of the network. However, it is feasible to try to orient the links so each junction which connects four links has at least two paths to every other such junction. One way to ensure this connectivity is to orient the links in the network so that a subset of these links forms two sets of loops; one set oriented horizontally and the other vertically, as shown below in Figure 4-18, so that the network junctions lie at the cross-over points of the loops. Using this schema, all the junction points have the property that they remain connected when any single link is removed. For a network with a radial shape such as the PRT 2 network the analogous arrangement is shown below in Figure 4-19.

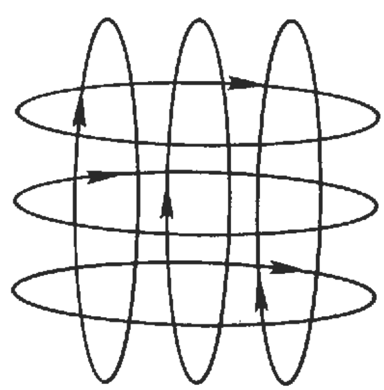


FIGURE 4-18. HORIZONTAL/VERTICAL NETWORK ORIENTATION

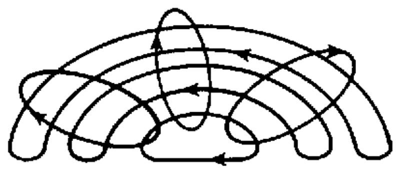


FIGURE 4-19. RADIAL NETWORK ORIENTATION

Unfortunately, for several reasons, it is not possible to strictly apply the above schema to the PRT 2 network. For example, one problem is that the network has an odd number of 'spokes'. Using the schema in Figure 4-19 as a guide the new network shown in Figure 4-20 was generated. The shaded links in Figure 4-20 are the links which were reoriented to form the new network. This network still has a few links whose removal will disconnect the network but the consequences of such removals are much less than those for the original network.

Indeed, the most critical link in the new network is the one near the top which serves station 4. Its failure will disconnect the upper lobe of the network. However, since this upper lobe is connected to the main network with just three links, no reorientation of the link directions could prevent this section of the network from being vulnerable to a single link failure.

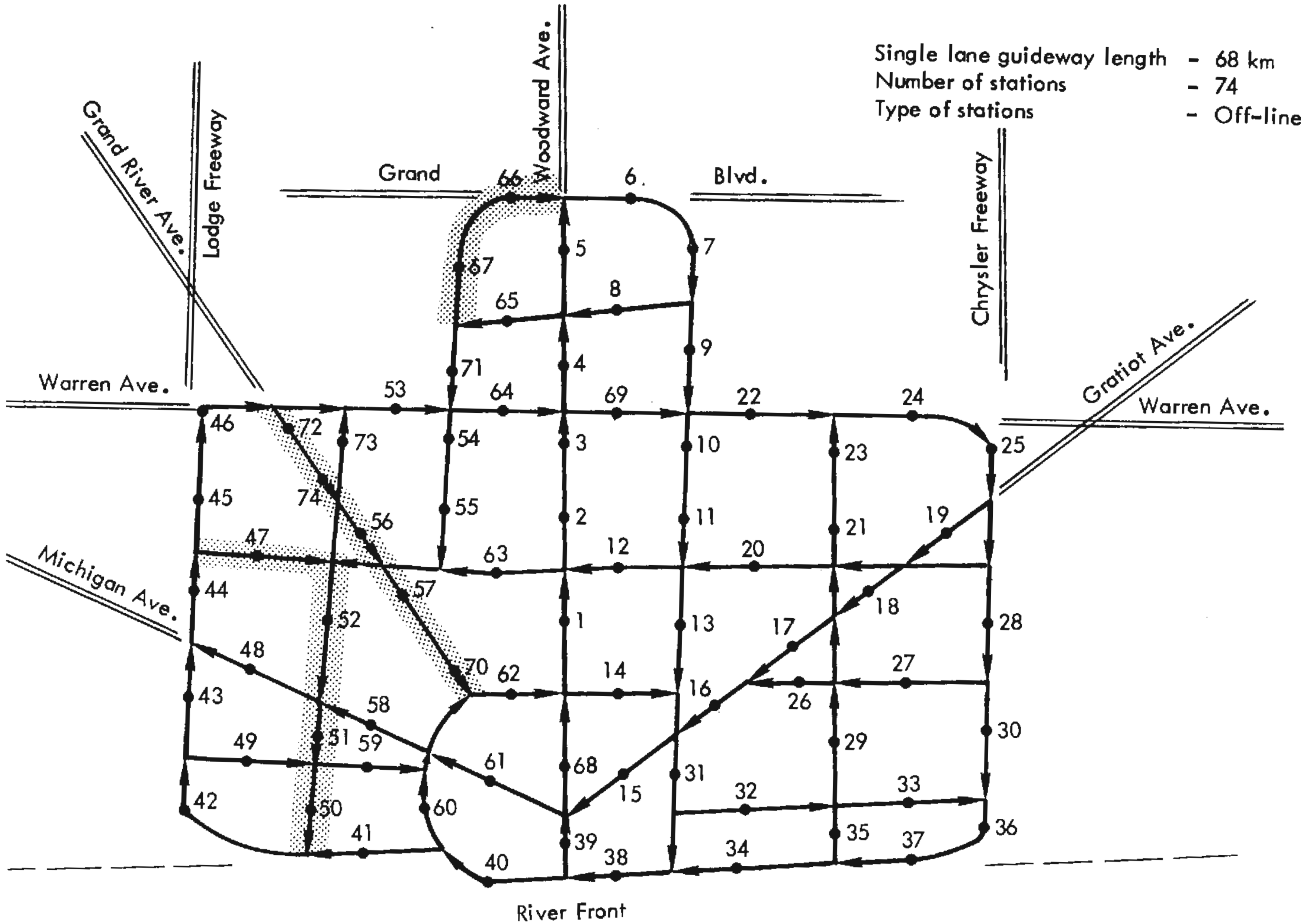


FIGURE 4-20. PRT 2: HIGH-SPEED PRT IN LOW CBD ORIENTATION - HIGH REVERSE COMMUTATION METROPOLITAN AREA APPLICATION (MODIFIED VERSION)

4.4 SUMMARY OF NETWORK CONFIGURATIONS

Nineteen representative systems have been defined for analysis in the SOS program. These deployments are categorized into four deployment types:

1. Shuttle Loop Transit (SLT) - 11 deployments
2. Automated Rail Transit (ART) - 2 deployments
3. Group Rapid Transit (GRT) - 4 deployments
4. Personal Rapid Transit (PRT) - 2 deployments.

A network flow analysis of the SLT deployments is documented in Section 4.3.1, and two changes in the initial deployment definitions resulted from the analyses. The LGRT system of the SLT 2 deployment provides an excess capacity during all time periods; consequently, the representative system is redefined to employ an IGRT system. The SLT 11 deployment is incapable of servicing the high CBD line-haul demands with a SGRT system; therefore, the representative system is redefined to use a LGRT system. Table 4-22 contains the revised summary of the representative system deployments. As a result of the network flow analysis for the SLT 10 deployment, it may be desirable to increase the maximum train consist for SGRT systems from three to four vehicles. No further changes in definitions are indicated for any of the other representative systems.

The SLT network flow analyses have resulted in the selection of a single network flow alternative for each representative system. Table 4-23 summarizes the conclusions. No alternatives were considered for the SLT 1 and SLT 4 deployments since no other alternative is possible without altering the network type.

The ART deployments and the GRT deployments are all area wide two-way branching or grid networks. The PRT 1 deployment is a cog arrangement of four small one-way loops. The PRT 2 deployment is an area-wide one-way grid where preliminary link directional analysis has revealed bottleneck situations and necessitated a link reorientation.

TABLE 4-22. REVISED SUMMARY OF REPRESENTATIVE SYSTEMS DEPLOYMENTS

Deployment Descriptor	System Type Vehicle	Speed	Network Type	Demand Type
SLT-1	LGRT	Low	Shuttle	Activity Center Line-Haul
SLT-2	IGRT	Low	Multiple loop	Activity Center Circulation
SLT-3	IGRT	Low	Open loop, one-way	CBD circulation, medium demand
SLT-4	IGRT	Low	Open loop, two-way	CBD circulation, medium demand
SLT-5	IGRT	Low	Open loop, one-way	CBD circulation, high demand
SLT-6	LGRT	Low	Open loop, one-way	CBD circulation, high demand
SLT-7	IGRT	Low	Shuttle	CBD circulation, low demand
SLT-8	LGRT	Low	Multiple loop	CBD line-haul, low demand
SLT-9	LGRT	Low	Open loop, one-way	CBD line-haul, low demand
SLT-10	SGRT	Low	Open loop, one-way	CBD line-haul, low demand
SLT-11	LGRT	Low	Open loop, one-way	CBD line-haul, high demand
ART-1	ART	High	Partially connected grid	Metropolitan Area - high CBD, high reverse commutation
ART-2	ART	High	Partially connected grid	Metropolitan Area - high CBD, low reverse commutation
GRT-1	IGRT	High	Multiple loop	Metropolitan Area - high CBD, high reverse commutation
GRT-2	IGRT	High	Fully connected grid	Metropolitan Area - high CBD, high reverse commutation
GRT-3	SGRT	High	Fully cannected grid	Metropolitan Area - low CBD, high reverse commutation
GRT-4	IGRT	High	Fully connected grid	Metropolitan Area - high CBD, low reverse commutation
PRT-1	PRT	Low	Fully connected grid	CBD circulation, high demand
PRT-2	PRT	High	Fully connected grid	Metropolitan Area - low CBD, high reverse cammutation

TABLE 4-23. SLT FINAL NETWORK FLOW ALTERNATIVES

Deployment Description	Network Type	Final Network Flow Alternative
SLT 1	Shuttle	No alternative
SLT 2	Multiple loop	Center loop is two-way
SLT 3	Open loop, one-way	Counter-clockwise travel
SLT 4	Open loop, two-way	No alternative
SLT 5	Open loop, one-way	Counter-clockwise travel
SLT 6	Open loop, one-way	Counter-clockwise travel
SLT 7	Shuttle	Unsynchronized
SLT 8	Multiple loop	North loop clockwise, south loop counter-clockwise
SLT 9	Open loop, one-way	Counter-clockwise travel
SLT 10	Open loop, one-way	Counter-clockwise travel
SLT 11	Open loop, one-way	Counter-clockwise travel

5.0 REFERENCES

1. Benjamin, P., et al, "Urban Transportation Alternatives--A Macro Analysis, Transportation Systems Center," Report No. DOT-TSC-OST-74-19, Cambridge Massachusetts, December 1974.

2. Bronitsky, L., et al, "Urban Data Book," Volumes I and II, Transportation Systems Center, Report No. DOT-TSC-OST-75-45, Cambridge, Massachusetts, November 1975.

3. UTPS Reference Manual, Volume I, UMTA Office of Research, Development, and Demonstration, Software Systems Division, Report No. URD.70.74.1.4, Washington, D.C., April 1974.

4. Elias, S.E.G., et al, "PRT Impact Study Pre-PRT Phase," Volume II, West Virginia University, Report No. UMTA/MA-06-0026-76/1, II Morgantown, West Virginia, March 1976.

5. "1974 Airtrans Passenger Flow Study," Summary as supplied to GM TSD by the Transportation Systems Center.

6. "CBD Distribution System - Activity Center Systems," Gannett Fleming Corddry & Carpenter of Michigan, Inc., Technical Report No. 5, prepared for SEMTA, December 1973.

7. "Downtown People Mover Proposal-Detroit," SEMTA, June 1976.

8. "New-Tran Basic Project Plan, Detroit CBD People Mover," Gannett Fleming Corddry & Carpenter of Michigan, Inc., prepared for SEMTA, December 1973.

9. Linden, T.M., "Feeder System Model Functional Specification," GM Transportation Systems Division, EP-706065, Final Report, November 1976.

10. Downtown Houston Transit Needs Analysis, Rice Center for Community Design and Research, February 1976.

11. Houston Downtown People Mover Proposal, City of Houston, June 1976.

12. Lee, R., Alberts, F., "Classification and Definition of AGT Systems," GM Transportation Systems Division, EP-77002, Final, January 1977.

13. "Performance/Design Qualification for the Morgantown Operational Personal Rapid Transit System," Boeing Company, November 6, 1973.

14. Bender, J. G., Lee, R. A., and Oglesby, R. N., "AGT System Analysis Requirements," GM Transportation Systems Division, EP-77019A, February 1977.

15. "Assessment of Operationally Automated Guideway Systems - Airtrans (Phase 1)," U.S. DOT, Transportation Systems Center, September 1976.

16. "Exclusive Guideway Transit Element of the Long-Range Transportation Plan," Ohio-Kentucky-Indiana Regional Council of Governments, Cincinnati, Ohio, August 1976.

6.0 GLOSSARY

Asynchronous

Operation of vehicles under velocity control or in the vehicle-follower mode with speed changes allowed to prevent potential merge conflicts.

Automated Guideway Transit (AGT)

Computer-controlled transit system operating in demand or scheduled service on a fixed, exclusive guideway.

Automated Rail Transit (ART)

A class of AGT systems which provides multiple-stop service, carries at least 100 passengers in its minimum train consists, operates at speeds equal to or greater than 55 km/h, and generally runs at headways of more than 1 minute.

Availability-Factor Relationships

The sensitivity of the vehicle and passenger availability measures to changes in parameters which affect either system reliability or failure management strategy.

Average Queue Transit Time (TQ)

Average time required to move through a platform boarding queue during a period of congestion such as the peak hour. For a particular station the value is calculated as the difference between the average wait time and one-half the average route headway.

Capital Cost (base year)

The initial cost of deploying a system expressed in base year (1977) dollars. Capital cost is the sum of guideway construction cost, passenger station construction and equipment cost, AGT vehicle cost, central control construction and equipment cost, maintenance facility construction and equipment cost, power distribution system installation cost, and feeder system costs including vehicles, maintenance facilities, and control facilities.

Catalogued Procedure

A pre-coded set of Job Control Language (JCL) statements that is assigned a name, placed in a data set, and may be retrieved and executed by one JCL statement.

Central Business District (CBD)

The downtown retail trade area of a city. As defined by the Census Bureau, the CBD is an area of very high land valuation characterized by a high concentration of retail business offices, theaters, hotels, and service businesses, and by a high traffic flow.

Central City (CC) of an SMSA

The largest city in an SMSA. One or two additional cities may be secondary Central Cities in the SMSA.

Central City (CC) of an Urbanized Area (UA)

A city of at least 50,000 persons within closely settled incorporated and unincorporated areas that meet the criteria for urbanized ring (fringe) areas. A few UAs contain twin cities with a combined popualtion of at least 50,000.

Central City Ring (CCR)

The portion of a Central City not included in the CBD.

Checkpoint File

A file created at a user-specified time by the Model Processor and containing all data necessary to restart the MP from that time.

Closed-Loop Control

Advancement of vehicles under generated control based upon the estimated system state.

Control Block

A specific section of guideway corresponding to a single control segment of a fixed block vehicle regulation and/or headway protection system.

Cruise Speed

The constant velocity at which a vehicle travels after acceleration and prior to braking. This velocity is usually less than the maximum design speed, but can be equal to it.

Crush Load Capacity

The maximum total capacity which a vehicle is designed to accommodate. This limitation is defined by either a vehicle weight limitation or a passenger comfort criterion.

Demand Activated Service Policy

A service policy in which routes, which may include intermediate station stops, are generated in real time on the basis of passenger demand, i.e., point-to-point routing with demand stop.

Demand Responsive Service Policy

A service policy in which non-stop routes are generatedin real time on the basis of passenger demand, i.e., point-to-point routing with no intermediate stops.

Demand Stop Service Policy

A service policy in which vehicles travel on predetermined routes but stop at stations along the route only in response to specific passenger demand.

Demand Type

A system deployment parameter which specifies the demand environment on which a detailed demand model will be specified. Three metropolitan area demands and four activity center demand types are identified:

1. Metropolitan area - high CBD, high reverse commutation
2. Metropolitan area - high CBD, low reverse commutation
3. Metropolitan area - low CBD, low reverse commutation.

1. Activity Center Line-Haul
2. Activity Center Circulation
3. Activity Center in High Demand CBD
4. Activity Center in Low Demand CBD.

Design Load per Vehicle

The nominal passenger capacity of each vehicle.

Deterministic

A strategy by which all merge conflicts are resolved before launch, and barring failures, each vehicle is assured of traversing the network in a predetermined time.

Dial-A-Ride Service

Transit service operated by generating vehicle paths in continual response to demand.

Downtown People Mover (DPM)

An AGT system deployed in a CBD environment, or the UMTA demonstration program to implement such systems.

Empty Vehicle Management (EVM)

A set of strategies which govern the disposition of active, empty vehicles not assigned to a fixed route nor enroute to service a passenger demand. Alternative strategies include:

Circulation

Vehicles are circulated on the network until needed to satisfy a demand. The distribution of circulating vehicles may be based on historical demand or on current demand patterns.

Station storage - historical

Vehicles are routed to stations for storage based on historical demand data.

Station storage - real time

Vehicles are either stored in the station when they become empty or are routed to other stations and stored based on current demand patterns.

Event Model

A representation of an entity (a subsystem or process) in terms of discrete states of the entity and the time required to change from one state to another for use in a discrete event simulation.

Fixed Block

A longitudinal control or headway protection mechanization wherein blocks are hardwired to the guideway and each block transmits velocity or braking commands to the vehicle based on the occupancy of preceding blocks. For longitudinal control, the commands may be altered by central or local control. For headway protection the blocks transmit either braking or velocity limit commands to vehicles which establish upper bounds for any other commands.

Fixed Route Service

Transit service operated on predetermined paths.

Flow Capacity (ρ_c)

A measure of system capacity in terms of passenger spaces per second past a point; the ratio of traveling unit capacity to average route headway.

Fully Connected Grid (FG)

A grid network in which vehicles proceed directly from one station to any other station without retracing any one- or two-directional portion of the guideway.

Global Variables

Variables stored in a common area and known by one name to all segments included in the program.

Grid

Any guideway on which vehicles are presented with a choice of paths during normal operation.

Grid Transit (GT)

A transit system deployed in any demand environment which uses an FG or PG network and has more extensive operational switching capability than an MSLT. Generally shorter headways result than in MSLT. This category includes PRT systems and many systems which are often referred to as Group Rapid Transit (GRT).

Guideway Interface

The vehicle components which contact the guideway for support. Usually the interface is wheels; but in some cases, it is an air or magnetic levitation force.

Headway

A frequency of service measure: the mean time between vehicles passing a point along a route of known configuration.

Headway Equation

An analytic function which expresses the relationship between minimum headway and system parameters such as traveling unit (vehicle or train) length, cruise speed, acceleration, communication delay, and expected position error.

Intermediate Vehicle Group Rapid Transit (IGRT)

A class of AGT systems which provides multiple-stop service and carries from 25 to 69 passengers in its minimum train consist. Low speed IGRT systems have a maximum operating speed of 13 to 54 km/h and tend to run at 15 to 60 s headways. High speed IGRT systems operate at speeds greater than 54 km/h and at headways which usually fall between 15 and 90 s.

Intersection

An X-type merge with 2 input links, 2 output links, 4 ramp links, 4 through paths, and either 2 or 4 queuing areas.

Large Vehicle Group Rapid Transit (LGRT)

A class of AGT systems which provides multiple-stop service, has a minimum train consist capacity of 70 to 109 passengers, operates at a maximum speed of 13 to 54 km/h, and usually runs at headways of 30 to 90 s.

Lateral Control Interface

Vehicle and guideway components that interface to control the vehicle's lateral movement.

Loop

A guideway on which motion is unidirectional during normal operation (except possibly at short station segments or at ends of runs) and which is defined by a closed path.

Loop of Closed Geometry (S)

A simple loop as defined above which encircles no area.

Macro

A standard code segment that is generated in-line at compile time by specification of single statement.

Maximum Operating Speed

The maximum speed at which a vehicle can travel. This limit is imposed by vehicle and propulsion system design constraints.

Merge Strategy

A strategy for resolving merge conflicts. Three strategies are considered·

1. FIFO (first-in, first-out)
2. Prescheduled
3. Priority

Metro Shuttle Loop Transit (MSLT)

A transit system deployed in a metropolitan environment and having high speed capability but no or limited operational switching capability. The network may be of any type. If it is a grid network, however, the switching is of limited capability. This category includes most guideway transit systems currently deployed in metropolitan areas.

Minimum Traveling Unit

The minimum number of vehicles with which a train can operate. For some systems the minimum traveling unit is a single vehicle.

Minimum Traveling Unit Capacity

The nominal capacity (not crush capacity) of a single vehicle times the number of vehicles in a minimum train consist.

Moving Block

A headway protection mechanization wherein an emergency protection zone which moves along with the vehicle is established around each vehicle. Emergency braking commands are issued to the traveling vehicle whenever its emergency protection zone infringes upon that of a leading vehicle.

Multiple Loop (ML)

Any network consisting of two or more loops requiring that passengers transfer from a vehicle constrained to one loop to a vehicle constrained to another loop, if they wish to travel between two points not served by a single loop.

Network Element

Either a link, merge, or an intersection modeled in the DOCM.

Network Type

A system deployment parameter which specifies network configuration. Seven network types are identified:

1. Shuttles (S)
2. Loop of closed geometry (L)
3. Open loop, one-way (L1)
4. Open loop, two-way (L2)
5. Multiple loop (ML)
6. Partially connected grid (PG)
7. Fully connected grid (FG).

Nominal Capacity

Vehicle capacity including seated and standing passengers as specified by the manufacturer according to a passenger comfort criterion. The average area allotted to each standee is generally at least 2.5 square feet.

Non-deterministic

A strategy by which potential conflicts at merges are not considered before launch but are resolved locally in the vicinity of each merge.

Off-Vehicle Feeder Travel Time for Access

The mean time per person enroute to a specific AGT station for delay or non-vehicle travel (including any walking to feeder route or waiting for feeder bus, transferring between vehicles, parking a car, or walking all the way), while going from zone centroids to a specific station.

Off-Vehicle Feeder Travel Time for Egress

The mean time per person enroute from a specific AGT station for delay or non-vehicle travel (including waiting at stations for bus, walking from route to destination, transferring between vehicles, or walking all the way), while going from a specific station to zone centroids.

On-Vehicle Feeder Time for Access

The mean time per person enroute to a specific AGT station spent aboard a feeder vehicle (including feeder bus or private auto), while going from zone centroids to a specific station.

On-Vehicle Feeder Travel Time for Egress

The mean time per person enroute from a specific AGT station spent aboard a feeder vehicle (including the feeder bus or private auto), while going from a specific station to zone centroids.

Open-Loop Control

Advancement of vehicles by user-specified control independent of system state.

Open Loop, One-Way (L1)

A single loop encircling an area and providing one-way circulation.

Open Loop, Two-Way (L2)

Two loops deployed side-by-side encircling an area and providing two-way circulation.

PARAFOR

A superset of FORTRAN utilizing PL/1 macros to add structured programming facilities to standard FORTRAN.

Partially Connected Grid (PG)

A grid network which does not qualify as a Fully Connected Grid (FG).

Partitioned Data Set

A type of file organization in which independent groups of sequentially organized records, called members, are on direct-access storage.

Path

A sequence of guideway links used by a vehicle to travel between two points on a network.

Personal Rapid Transit (PRT)

A class of PRT systems which provides non-stop point-to-point service, has a minimum traveling unit capacity of 3 to 6 passengers, and runs at very short headways, usually 3 s or less. Low speed PRT has a maximum operating speed of 13 to 54 km/h, while high speed PRT has a maximum operating speed exceeding 54 km/h.

Platoon Movement

Simultaneous advancement of a row of vehicles or trains.

Practical Minimum Headway

The minimum headway at which vehicles can operate under normal conditions.

Prescheduled Pathing

A vehicle pathing strategy in which the primary path from origin to destination is predetermined and specified for all station pairs.

Precision Stopping Tolerance

The tolerance within which a vehicle can stop at a given point.

Quasi-deterministic

A strategy by which merge conflicts are not resolved prior to launch, but information about the future state of the network is used to launch vehicles at times that provide a high probability of efficient merging.

Quasi-synchronous

Operation of vehicles under point-follower control but with change of control points allowed to resolve potential merge conflicts by advancing or slipping one or more slots.

Reliability Block Diagram

A diagram that illustrates what equipment or combinations of equipment are required for successful system operation.

Representative System

A collection of values for the following system characteristics and strategies

1. Vehicle characteristics
2. Guideway characteristics
3. System management strategies
4. Reliability characteristics
5. Cost characteristics.

The range of values are chosen to be interrelated in such a way as to represent a general class of state-of-the-art systems for the purpose of conducting system analyses within the SOS program.

Representative System Deployment

A specific combination of a representotive system, demand type, and network configuration defined for the purpose of conducting system analyses within the SOS program.

Response Time

A frequency of service measure; the mean time between a request for and the arrival of a dial-a-ride service vehicle.

Ripple Movement

Advancement of vehicles and trains one at a time for a row of stationary vehicles/trains.

Route

A designated set of destinations, usually defined by stations, to which a vehicle must travel. The path, or links, to be traversed between any two destinations is not specified.

Routing Strategy

A strategy which identifies routes for vehicles/trains. Two alternatives are fixed routing and real time select routing. Real time routing is used only with demand responsive service and demand activated service, while fixed routing is employed for demand stop and fixed route service policies.

Rural and Scattered Urban (R&SU)

The remaining rural and urban portions of counties not included as part of the urbanized ring of the UA, but still within the boundaries of the SMSA. Thus, with the exception of the New York and Los Angeles SMSAs, the SMSA consists of two components — the UA and the Rural and Scattered Urban. Both New York and Los Angeles Urbanized Areas (UA's) extend into counties outside the boundaries of the SMSA.

Scheduled, Real Time Pathing

A vehicle pathing strategy in which the primary path from origin to destination is selected from among specified alternatives just prior to departure from the origin station on the basis of current traffic conditions on the network.

Sector

An area serviceable by one vehicle in subscription service during a prescribed time interval for a specific demand density.

Service Type

Either non-stop (personal transit) or multiple-stop (group transit) service.

Shuttles (S)

A guideway on which bi-directional motion occurs during normal operation and which is defined by a single curve connecting two distinct end points. Also, any network consisting of two or more simple shuttles, either following the same path or different paths.

Shuttle Loop Transit (SLT)

A low speed AGT system deployment in an activity center demand environment having any non-grid type of network. Thus, SLT system deployments require no operational switching but may require passenger transfers.

Small Vehicle Group Rapid Transit (SGRT)

A class of AGT systems which provides multiple-party service, has a capacity of 7 to 24 passengers in its minimum train consist, and usually operates at headways between 3 and 15 s. Low speed SGRT has a maximum operating speed of 16 to 54 km/h, and high speed SGRT a maximum of over 54 km/h.

Standard Metropolitan Statistical Area (SMSA)

A county or group of counties containing at least one city (or twin cities) with a population of 50,000 or more, plus adjacent counties which are metropolitan in character and integrated economically and socially within the central city.

Switching Mechanism

The mechanism, located either on the vehicle or the guideway, by which vehicles/trains are switched.

Synchronous

Operation of vehicles under point-follower control with no changes allowed in control points during a given guideway trip.

Theoretical Minimum Headway

The minimum headway at which two vehicles can travel, assuming there are no merges or on-line stations.

Total Value Capital Cost

The sum of all capital costs except interest expense over the life cycle period expressed in base year dollars.

Urbanized Area (UA)

An area containing a central city (or twin cities) of 50,000 or more population, plus the surrounding closely settled incorporated and unincorporated areas which meet certain criteria of population size and density (urbanized ring). UAs differ from SMSAs in that UAs exclude the rural portions of counties composing the SMSAs, as well as places that were separated by rural territory from the densely populated fringe around the central city. The components of the UAs include the central city, as defined above, and the urbanized rings, as defined below.

Urbanized Ring (UR)

Various areas contiguous to a central city or cities, which together constitute its urbanized ring, or "urban fringe," as termed by the Census Bureau.

Variable Cost (base year)

The annual cost of operating and maintaining a system expressed in base year (1977) dollars. Variable costs include maintenance costs, energy costs, and administrative costs for both the AGT and feeder systems.

Vehicle Capacity

When used in correlations of vehicle dimensions and cost to capacity, nominal vehicle capacity is assumed. However, the system simulations interpret vehicle capacity as the maximum number of passengers which can occupy a vehicle at one time.

APPENDIX: REPORT OF NEW TECHNOLOGY

Work performed by GM Transportation Systems Division under contract DOT-TSC-1220 in the area covered by this report resulted in the definition of a new set of travel demands and guideway networks for a group of representative Automated Guideway Transit (AGT) system deployments.

Seven demand types are defined for these new scenarios and a representative locale of each type is chosen. Line-haul and circulation demands are prepared for both activity center and Central Business District (CBD) applications. Metropolitan area demands are computed for the first time using an approach based upon the degree of commutation into the CBD (CBD orientation) and commutation away from the CBD (reverse commutation). The three combinations with high CBD orientation and/or high reverse commutation are used here. Station-to-station demands are generated from zone-to-zone demands for the metropolitan area applications based on processes presented in this report.

Seven guideway network types are defined: shuttle, loop, one-way loop, two-way loop, multiple loop, partially connected grid, and fully connected grid. Network representations for use in the computer studies using the newly created software are developed for the selected applications. The results of network flow analyses, in which the compatibility between the network and the station-to-station demand is evaluated, are presented for the representative SLT deployments.

☆U.S. GOVERNMENT PRINTING OFFICE: 1980—700-403/244