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U.S. Department of Transportation
Urban Mass Transportation Administration

planning for downtown circulation systems

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volume 2

october 1983

final report

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16. Abstract

This document provides a compendium of state-of-the-art methods and data for planning downtown circulation systems. The report is divided into three volumes.

Volume 1 -- Planning Concepts comprises the first six sections of the report. Its focus is on the concept stage of the downtown circulator planning process. Included are sections on the development of goals and objectives, generation of alternative conceptual designs, familiarization with important planning issues, and crude feasibility studies of alternative systems. An additional section is included on institutional factors related to downtown circulator planning.

Volume 2 -- Analysis Techniques contains the last five sections of the report. Its emphasis is on the analysis and refinement stages of downtown circulator planning. Included are sections on methods for estimating patronage, costs, revenues, and impacts, and a section on methods for performing micro-level analyses.

Volume 3 -- Appendices contains worksheets for estimating circulator patronage, costs, revenues and travel impacts, detailed discussions of estimation and application procedures for the demand models developed, and a case study of the models' application using a Los Angeles downtown people mover example.

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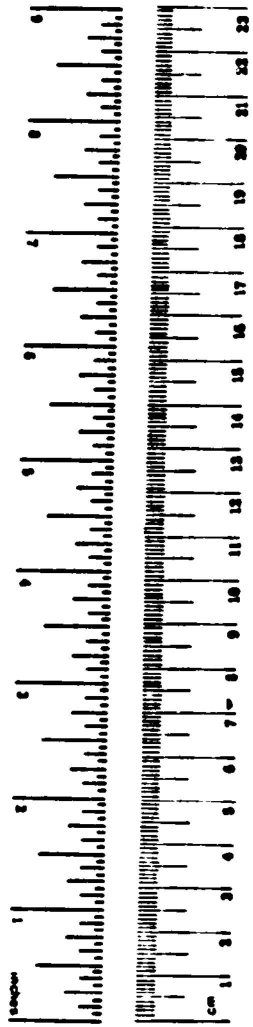
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

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

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



Approximate Conversions from Metric Measures

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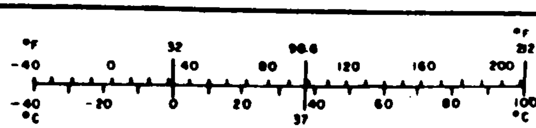
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

In response to widespread interest, yet general lack of knowledge of Downtown People Mover (DPM) systems in the mid to late 70's, the Urban Mass Transportation Administration (UMTA) sponsored the production of a comprehensive compendium of state-of-the-art planning concepts and methods applicable to DPM systems. The compendium, which for expedience was published in draft report form in 1979 under the title, DPM -- Planning for Downtown People Mover Systems, was distributed to numerous local, state and federal agencies, public libraries and private consultants. The draft report received favorable reviews regarding its usefulness and breadth of coverage of downtown circulation planning. Many valuable suggestions were also received with respect to possible improvements to the methods and descriptions in the report.

Based on the responses received and the large expressed demand for a revised version of the report, the report presented herein was produced. It incorporates: fully revised, more easily understood sections and appendices on demand estimation, including a new appendix covering computer-aided demand model application and an updated Los Angeles case study; updated cost estimation techniques and cost tables; and other suggested revisions, updates and corrections to the earlier draft. In recognition of the general applicability of the methods described in the report to downtown circulation planning, the title and portions of the text have been broadened. Thus, although DPM examples remain dominant in the discussions, other potential circulator methods such as shuttle bus, light rail, busways and paratransit can also be considered in the context of the planning concepts and techniques presented.

This three-volume report was prepared by the Urban and Regional Research Division of the Transportation Systems Center under project funding from the Urban Mass Transportation Administration's Office of Planning Methods and Support. Project direction and coordination were the responsibility of Donald Ward and Michael Couture. Thomas Dooley was a major contributor. Other TSC participants were Simon Prensky, Samuel Schiff, and Michael Jacobs.

Major portions of the report were prepared by the firm of Cambridge Systematics, Inc. under the direction of William Loudon. Other major contributors were Earl Ruiter, Wendy P. Stern, Ellyn Eder, and Lajos Heder of Moore-Heder Architects (under subcontract to Cambridge Systematics). Also contributing to the report were Richard Albright and James Wojno.

Peat, Marwick, Mitchell & Co. had major responsibility for preparing the revised sections and appendices on circulator demand estimation. Mark Goldman was project manager and Lawrence Bowman was a principal participant.

A major section of the report was developed by the Regional Plan Association under the direction of Jeffrey Zupan. Robert Cumella was also a major contributor. Also participating was Boris Pushkarev.

Project specification, overall program guidance and valuable suggestions were provided by Granville E. Paules, Acting Director of the Office of Planning Methods and Support, Urban Mass Transportation Administration.

The final report was designed and produced under the direction of Michael Couture of TSC. Major editorial assistance was provided by Theresa McTague. Donna D'Alessandro and Vera Ward also assisted in the preparation of the manuscript.

The Urban Mass Transportation Administration would appreciate hearing of applications of the approaches or information contained in this report. Also, please address any comments and suggestions you may have to:

Mr. Granville E. Paules, Chief
Methods Division
Office of Methods and Support
Urban Mass Transportation Administration (URT-41)
U.S. Department of Transportation
Washington, DC 20590

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7. CIRCULATOR DEMAND ESTIMATION

7.1 Introduction

The demand estimation process provides quantitative forecasts which are used to design downtown transportation projects. The types of projects of interest, their objectives, and the criteria for measuring the accomplishment of their objectives are discussed in Sections 2.1 through 2.3.

The techniques presented in this section for estimating downtown travel demand are intended to address travel behavior within relatively homogeneous travel markets. It is therefore assumed that market segmentation has already been performed. Market segments for downtown circulation travel are discussed in Section 2.4.

The Overview of Planning Issues, Section 2.0, presented an assessment of the types of trips that might be attracted to a downtown circulation system and the likely peaking characteristics of each of those trip types. The overview included a discussion of the determinants of travel choice behavior that should be considered in any attempt to model CBD circulation travel. This section builds on that information and presents specific techniques for predicting CBD circulation travel.

Subsequent sections on the estimation of the costs, revenues, and other impacts of CBD circulator systems will rely heavily on the ridership predictions produced by these procedures. Reference will be made in those sections to specific models in this section and to the output that is necessary for the assessment of impacts.

7.1.1 Analytical Techniques

The planning of CBD circulator systems introduces several very specialized travel demand forecasting needs. First, these systems frequently represent technologies which are significantly different than any which has been implemented in a downtown setting and, therefore, no models have been estimated on actual, observed behavior. Second, CBD circulator systems are being designed to provide circulation and distribution travel within the CBD, a type of travel for which there has been limited modeling experience. Third, CBD circulator systems are designed to serve trips presently made by walking as well as in vehicles. Finally, these systems are meant to introduce new trips by increasing accessibility within the CBD and stimulating downtown economic activity.

When available models are compared with these unique requirements, few are found to be entirely appropriate for forecasting the demand for travel on CBD circulator systems. With their orientation to regional-scale travel by auto and transit, their usual disregard for walking trips, and their problems in capturing the complex details of non-home based travel, traditional urban travel demand models have limited usefulness in forecasting CBD circulation travel. Only the few modeling efforts specifically oriented toward travel in dense activity centers show significant promise as an aid to the downtown planner. Many of these efforts, however, have dealt exclusively with pedestrian travel, considering the CBD circulation problem to be only a unimodal (walking) problem. Examples of such modeling efforts include the following:

- Diversion procedures to predict the shift of CBD pedestrian travel to walkways or other "new mode" technologies. These procedures have been developed and applied in a number of areas, including Boston (BRA, 1971),1/ London (Cryer, 1971), Chicago (Rutherford, 1974), Detroit (Gannett, 1975), Houston (1976), Cleveland (1976), and Baltimore (1976). Each of the last four applications involved the prediction of demand for a Downtown People Mover (DPM) system. A major deficiency in all of these cases was that the diversion rates or diversion curves used were based on assumptions about traveler behavior which could only be verified by tests of reasonableness and common sense.

- Linear regression equations which estimate the number of pedestrians who will be located on a one-block length of sidewalk at a given instant of time, as a function of the amount of sidewalk space, the amount of building and other activity space bordering the sidewalk, the location of the block with respect to transit stops and stations, and the location of the block with respect to the center of the CBD. Models of this type have been estimated for New York City (Pushkarev, 1971) and Orebro, Sweden (Percivall, 1972). Because these models do not provide a forecast of travel by any vehicular mode, they provide limited information for planning CBD circulator systems.

- Gravity models of the distribution of pedestrian travel, which have been estimated and applied in many areas, including Toronto (Morrall, 1968) and Chicago (Rutherford, 1974). Again, because these models are limited to pedestrian travel, they do not provide estimates of circulator system travel. In some studies, however, the procedures described in the next paragraph have been applied to the trip tables obtained from a gravity model to forecast CBD circulation travel.

1/All references appear in Section 7.6.

- Activity center models (ACM) developed to predict travel in downtown Los Angeles (Barton-Aschman, 1976, and Peat Marwick, 1981). These models, described in Section 7.3, were developed using survey data collected from travelers in the Los Angeles CBD. A downtown minibus was in operation providing circulation and distribution services similar to automated DPM systems. A circulation trip is a trip entirely contained in the CBD study area. A distribution trip is the CBD portion of a regional trip to the CBD. This is the trip to the final destination in the CBD from the CBD parking lot for regional auto users or from the bus stop where the traveler first exits the bus in the CBD for regional transit users.

The component models consider separately four types of CBD travel:

- distribution trips by CBD-workers who reach downtown by auto;
- distribution trips by CBD-workers who reach downtown by transit;
- circulation trips by CBD workers; and
- distribution and circulation trips by people who come to the CBD for purposes other than work.

Of the various modeling approaches, the Los Angeles ACM model most nearly meets the requirements previously discussed. It explicitly deals with both walking and vehicular trips, and with both circulation and distribution travel. The model is properly structured to predict some of the expected changes in the number and length of CBD trips as downtown transportation systems are improved. Finally, the ACM model is based on observed traveler responses to a downtown transit system providing circulation and distribution services. For all of these reasons, refined and generalized versions of the Los Angeles ACM models have been chosen as the basis for the demand estimation procedures presented in this report.

The Los Angeles models were originally calibrated in 1976 on the preferences for travel revealed by trip makers within the Los Angeles CBD (Barton-Aschman, 1976). Extensive surveying was conducted which included:

- CBD employees entering or leaving offices and businesses;
- shoppers entering and leaving stores;
- pedestrians making trips for all types of purposes;

- shuttle bus riders; and

- people parking in CBD parking lots.

Each of the surveys was designed to determine the origin and destination of the trip, the trip purpose, whether the trip maker was a CBD employee, and the choice of mode for the trip (if not predetermined by the survey location). These surveys were supplemented with the following counts:

- pedestrian counts throughout the CBD;

- counts of people entering and leaving stores and other buildings;

- counts of cars and buses entering and leaving the CBD; and

- counts of regional bus and shuttle bus ridership.

Networks were then coded for each mode of travel which could be used to determine, for any particular origin and destination pair, the travel time and cost by each of the modes.

A computer program was used to "calibrate" the ACM models based on the data collected in Los Angeles. Calibration is a process which estimates the statistical relationships between a traveler's decisions on where and how to travel, and the characteristics of both the traveler and the transportation system. The calibration process uses data on observations of individual traveler choices, called disaggregate data. However the models forecast demand using more aggregated data on the average characteristics of travelers in a given study zone.

The models developed in 1977 were refined in 1980 to incorporate additional information collected in two major surveys: a work place employee survey and an on-board transit survey conducted in Los Angeles in May-June of 1980.

The work place survey collected information on the CBD distribution portion of an employee's travel to and from work. It also contained a midday travel diary which collected information on the purpose, frequency, mode choice, and destination choice of a CBD worker's midday circulation trips. The on-board transit survey was distributed in the downtown study area on regional buses and circulator minibuses which provide service to or within the CBD area. It collected information such as regional bus trip origins and destinations, bus boarding and alighting locations, trip purpose, and the time of day. The information in these surveys enabled more accurate coefficients to be developed for the utility expressions for distribution and circulation trips made by CBD workers. The calibration of the refined Los Angeles models is discussed in Appendix A.

7.1.2 Analytical Methods

Two approaches have been developed for applying the activity center models calibrated in Los Angeles: (1) sketch planning which estimates the incremental change in downtown transit patronage associated with revised circulator services, and (2) network analysis which uses a more traditional approach to apply the models to estimate patronage. Sketch planning, as presented here, is a manual technique to produce a quick, inexpensive estimate of the viability of a circulator service given an aggregate representation of the service. The network analysis method requires a computer application of a set of travel demand models, with the level of service information either prepared manually or developed using automated network processing capabilities.

Similar types of data are needed to use the ACM models for sketch planning or for network analysis, although the specific data needed will vary with the level of detail in the study. The data requirements, described in Exhibit 7.1, include (a) information on individual zone characteristics, (b) level of service data for individual zone interchanges, (c) trip tables from external corridors to CBD zones, and (d) modal bias constants for each CBD circulation service to be evaluated. A modal bias constant represents a mode's non-quantifiable characteristics; such as comfort, convenience, and perceived status.

The level of detail in the analysis method will affect the ability of the ACM model to evaluate different types of services or operating policies. However, the nature of the analyses which the ACM model can perform are fairly similar for both sketch planning and network analysis. The variables to which the model is sensitive are divided into three categories:

- the characteristics of the downtown study area;
- the physical characteristics of the proposed circulator system; and
- the operating policies for the proposed circulator system.

Exhibit 7.2 presents a number of system parameters for each of these areas. The first category, the characteristics of the study area, corresponds closely to the data described previously in Exhibit 7.1. The zone data describe the size and activity of

EXHIBIT 7.1

INFORMATION NEEDED TO APPLY ACM MODELS

For Each Downtown Zone

- acreage
- total employment in the analysis year
- floor areas by building type: office, retail, service and institutional, and manufacturing and wholesale
- parking capacity
- parking costs: daily and hourly

For Each Downtown Origin Zone/Destination Zone Pair

- travel times by mode: walk, regional transit, downtown circulator, auto
- fares by mode: regional transit, downtown circulator
- auto distances

For Each External Corridor to Downtown Destination Zone Pair

- regional auto users
- regional transit users
- downtown zone at which regional transit users will leave the regional transit vehicle bringing them into the downtown area

For Each Downtown Circulator Technology to be Tested

- modal bias constant, relative to circulator buses

EXHIBIT 7.2

PARAMETERS TO WHICH THE ACM MODELS ARE SENSITIVE

Characteristics of the Downtown Study Area

- Downtown activity
    - employment
    - floor area
    - parking capacity
    - regional auto and transit users who travel to the area
- Existing transportation system
    - parking capacity and costs
    - travel times
    - fares
    - auto distances
    - regional transit routes and stops

Physical Characteristics of the Proposed Circulator System

- system technology
- route location
- station or stop location
- vehicle type

Operating Policies for the Proposed Circulator System

- speeds
- frequency
- fares
- station stopping strategies
- modal transferring policies
- other policies affecting system speed, cost, or convenience

the study area, and the zone interchange data describe the levels of service in the existing transportation system.

The two remaining parameter categories, the physical characteristics and the operating policies of the proposed circulator system, affect the estimated demand through their impact on the level of service provided between zone pairs by the circulator system. A discussion of four physical system characteristics which affect the level of service follows:

- System Technology - Downtown circulator systems are unique in that they may be automated and they may be operated on exclusive guideways. These features affect patronage predictions in the following ways:
  - The use of exclusive guideways, usually either above or below ground level, has two opposing impacts on door-to-door travel time. The on-vehicle portion of travel on a DPM system is likely to be at high speed, tending to increase demand. The need to use stairs or escalators to access the DPM stations from street level increases the travel time, tending to decrease demand.
  - An automated technology has route and station locations in the downtown area which are fixed and highly visible. The circulator system can be expected to have an enhanced modal image, relative to a circulator bus system, resulting in increased demand.
- Route Location - Changes in the location of the circulator route within the downtown area impact (a) the amount of downtown activity which is accessible to the circulator system, and (b) the ease of transfer to other transit services. Changes in the circuitry of the circulator route will impact travel times on the system. More circuitous routes will have longer travel times, tending to attract fewer trips. These two effects of route location have opposing impacts on demand.
- Station or Stop Location - The number and location of stops will impact system accessibility just as route location will. However, increased numbers of stops will decrease the system speed.
- Vehicle Characteristics - The number and capacity of circulator system vehicles places an upper limit on the travel demand which can be served and affects demand by changing the waiting times.

Operating policies affect the level of service provided by a circulator system and therefore affect the anticipated ridership. Operating policies which affect travel times include system speeds and stopping strategies. Operating policies which affect travel costs include the base fare, transfer charges, and any additional zone charges.

7.1.3 Organization of Section 7

The remainder of Section 7 discusses the procedures for applying the ACM models. Section 7.2 discusses the use of the ACM models for sketch planning. Section 7.3 discusses the use of the ACM models for network analysis, including both manual preparation and computer coding of the network level of service data. Section 7.4 discusses issues involved in transferring and adjusting the ACM models calibrated in Los Angeles for use in other areas. Section 7.5 presents criteria to help the user decide on the appropriate level of detail for his or her needs. Appendices A, B, and C in Volume III of this report provide additional information on the ACM models. Appendix A is a detailed explanation of the calibrated ACM models. Appendix B is a user's manual which describes the work involved in preparing and running the ACM models for a detailed network analysis study, and Appendix C is a case study application of the ACM models to Los Angeles at different levels of detail.

7.2 Sketch Planning

The sketch planning technique for activity center travel estimation permits the manual development of quick, rough estimates of expected ridership. While the technique incorporates the relationships embodied in the full set of Los Angeles ACM models, it only permits estimation of the incremental ridership due to changes in the transportation system, such as the substitution of a downtown people mover for a minibus service. Since only the increment or change in travel is estimated, this approach requires knowledge of the existing ridership. This is different from travel models which estimate total ridership without data on the current demand.

A manual sketch planning process could be designed to estimate the ridership for new services as well as for changes to an existing service, but at a significant increase in the calculations. For simplicity, the sketch planning process in this report is designed only to estimate the impact on ridership of changes in existing services.

For a manual process to be useful, the number of calculations should be kept to a minimum. The planner must remember that the quick results provided by the sketch planning technique reflect a compromise regarding detail, and must make use of the results accordingly.

The technique. as presented in the following discussions, allows the planner to minimize the number of calculations in either of two ways: (1) using very few analysis zones to keep the number of zone interchanges low, or (2) analyzing a small sample of interchanges and expanding the results to represent all travel in the study area. Each of these approaches reflects a compromise on detail, but permits the planner to conduct an inexpensive first cut analysis of the viability of revised downtown transit services.

This section presents a step-by-step description of the manual sketch planning process for estimating travel in the CBD. A number of worksheets are provided to help set up and perform the calculations. These worksheets are also included in Appendix D.

The sketch planning process is presented as six (6) major steps. These steps are listed below and then discussed individually in sections 7.2.1 through 7.2.6.

(1) Choose the analysis parameters

(2) Select zone interchanges

(3) Collect data for the base and alternative systems

(4) Compute travel times

(5) Compute revised patronage forecasts

(6) Expand and summarize the travel forecasts

7.2.1 Choose the Analysis Parameters

The purpose of this step is to make those decisions which affect both the level of effort required in the analysis process and the specific units for which data must be collected. The analyst must define the zone system, the market segments, and the base and alternative services.

Define the Zone System

The following factors must be considered in choosing zone sizes and the number of zones in the study area:

- Data availability - Nearly all of the data items discussed in the following section, Section 7.2.3, are required either for each zone or for each possible pair of zones. The lower limits on zone size are, therefore, determined either by the amount of detail which exists for available data, or by the validity of assumptions required for further subdivision of available data.

- Relationship of zones to proposed circulator systems - Zone sizes can vary with distance from a given proposed circulator system: distant areas can be represented with less detail than closer areas without significantly affecting the accuracy of patronage prediction. Also, for relatively coarse analyses, zones may be defined such that each zone has one circulator station as its centroid. This type of careful tailoring of zones to a proposed system is not possible until the location of the proposed system is relatively fixed.

Define the Market Segments

The analyst may specify the number of market segments to be analyzed, thereby directly controlling the analysis costs. However, at least two market segments must be specified for analysis: distribution travelers and circulation travelers. The basic difference between the forms of the demand models requires this stratification. Additional segments can be formed by subdividing either or both of these basic groups into subgroups, as shown in Exhibit 7.3. The most detailed market segmentation approach would normally be the following four groups:

- distribution trips by CBD-workers who travel to the CBD by auto;
- distribution trips by CBD-workers who travel to the CBD by transit;
- circulation trips by CBD-workers; and
- distribution and circulation trips by others.

Of course, the analyst may choose to concentrate the analysis effort on only one or two of these groups, realizing that the results will not represent total expected downtown travel demand.

Define the Base and Proposed Alternatives

A base alternative must be defined which has each of the following characteristics:

- a circulator system must exist in the downtown area;
- the level of service[1] for trips which use the circulator or regional transit systems must be known;

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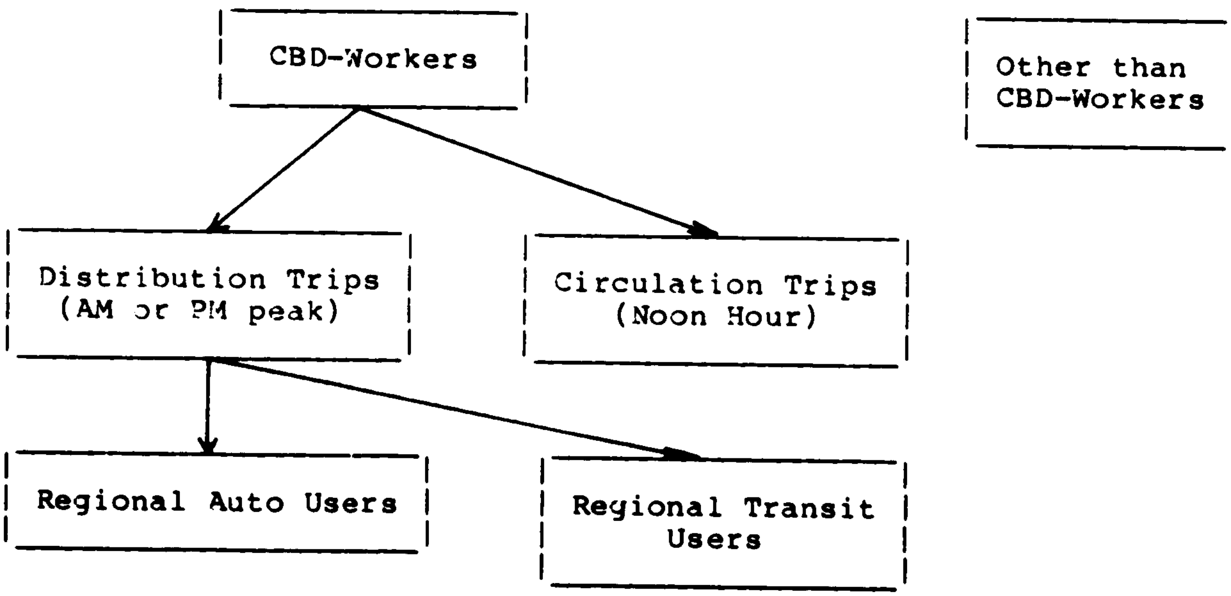
[1] A complete list of the variables required is presented in Section 7.2.3.

EXHIBIT 7.3

RELATIONSHIPS OF ALTERNATIVE MARKET SEGMENTS



- the existing fraction of travel using the circulator and regional transit systems must be known for each market segment and zone pair;
- the existing total number of distribution trips must be known for each zone pair; and
- the existing total number of circulation trips produced in each zone must be known.

The alternative downtown circulator systems can be designed to test a number of changes, including:

- revisions in the routing and scheduling of an existing conventional shuttle bus system;
- replacement of the existing system with an automated downtown people mover (DPM); and
- addition of a circulator system to the existing transit system.

In addition, routing and scheduling changes in the regional transit routes which serve CBD circulation travel can be tested.

Each of the proposed alternatives must be defined to the level of detail necessary to determine the level of service characteristics between zone pairs.

As an alternative to defining market segments in this way, a slightly more approximate approach can be used. Existing travel data can be segmented by time period and the trips made in each period can then be allocated to the travel market segments. The following provides a reasonable solution to market segmentation:

- focus on the AM or PM peak hour trips and on noon hour trips;
- assume 100 percent of the AM or PM peak hour trips are for regional distribution travel; and
- assume 100 percent of the noon hour trips are for circulation travel. These trips may be further allocated between CBD-workers and others, a 60-40 percent split may be reasonable between CBD-workers and others.

7.2.2 Select Zone Interchanges

Manual sketch planning calculations can realistically be performed for all interchanges in study areas with up to ten zones. The number of interchanges increases with the square of the number of zones making it unrealistic to manually calculate the service characteristics for all interchanges in study areas with greater than ten zones. A representative sample of interchanges can be analyzed to apply sketch planning to larger zone systems. The results for the sampled interchanges can then be expanded to estimate the travel demand over all the interchanges in the study area.

A single sampling approach does not exist to select a representative set of interchanges. The sample has to reflect the shape of the study area, the number of zones in the study area affected by the proposed circulator system, and the desired level of precision in the estimated change in ridership on the circulator system. The sampling process is not a statistically complex problem, it is a straightforward application of basic sampling concepts but keyed to the characteristics of the individual study area. Interchanges may be selected by a random or a systematic process as long as the selected interchanges are representative of travel in the study area. The analyst must not intentionally pick major interchanges because the results will be biased to indicate larger than actual travel volumes.

The sample selection can be designed to favor the selection of major interchanges by using probability proportional to size (PPS) sampling. This requires information on the relative travel volumes between each zone pair. The higher probability of selecting busy interchanges must then be compensated for when the results are expanded. A thorough discussion of sampling is provided in Sampling Techniques (Cochran, 1977).

7.2.3 Collect Data for the Base and Alternative Systems

The kinds of data needed to operate the ACM models were presented in Exhibit 7.1.

Zone Data

Several pieces of information are needed to describe the level of service in each analysis zone for both the existing circulator system and for the existing regional transit system:

- walk distance between the zone centroid and the transit system;
- wait time at the transit stop in the AM and/or PM peak periods; and
- wait time in the noon hour peak.

These data should be assembled and recorded on Form II. Form II is included here as Exhibit 7.4 and is also included in Appendix D.

EXHIBIT 7.4

FORM II: ZONE MODE ACCESS CHARACTERISTICS

Check: [ ] Base system

[ ] Option ____________

Origin Zone	Access Walk Distance (feet)				Peak Period Wait Time (minutes)				Off-Peak Wait Time (minutes)			
	Circulator	Regional Bus	Shuttle Bus	Other	Circulator	Regional Bus	Shuttle Bus	Other	Circulator	Regional Bus	Shuttle Bus	Other

Zone Pair Data

For each of the existing transit modes, the following data items are required for each origin-destination zone pair:

- in-vehicle distance between origin and destination zones;
- transit fare between origin and destination zones; and
- measurement of the "station integration" (INTEG) variable for distribution travel.

This variable measures how well the CBD circulation system accommodates transfers to and from the regional travel modes. It is defined as the fraction of distribution trips for an interchange which enter the CBD using transit or park in a facility integrated with the circulation system. For interchanges having an integrated parking facility, the variable would have a value of 1.0 as all trips would either enter the downtown using transit or park in the specified facility, while for interchanges not having a parking facility the variable would be computed as the number of trips making the interchange who access the downtown by transit divided by the total number of distribution trips making the interchange. When using the manual sketch planning approach and assuming that the circulation system has little or no impact on regional transit ridership, the change in the station integration variable should be set to zero.

Form IIIa or IIIb should be used to record these zone pair data items. Form IIIa is used when all interchanges are analyzed. Form IIIb is formatted differently for use when a sample of interchanges is analyzed. Forms IIIa and IIIb are included as Exhibit 7.5.

Trip Table Data

Sketch planning is an incremental process so information is needed on the existing volumes of circulation and distribution trips in the CBD study area. This differs from the data used by the network analysis process which estimates distribution travel and circulation travel from regional trip tables and CBD employment data respectively. The following data items are needed for the existing transit modes and for each zonal interchange selected for the analysis:

- the existing market share for the circulator system;
- the existing market share for regional transit; and
- the existing number of intra-CBD distribution trips made during the AM or PM peak (only needed if distribution trips are being analyzed).

EXHIBIT 7.5

FORM IIIa: ZONE PAIR DATA FOR ALL INTERCHANGES STUDY

Mode: ____________

Check: [ ] Base system

[ ] Option ____________

Check: [ ] In-vehicle travel distance (in miles)

[ ] Fare (in cents)

[ ] Station Integration

In-vehicle travel time (in minutes)

[ ] Peak period

[ ] Off-peak period

Origin Zone	Destination Zone									
	1	2	3	4	5	6	7	8	9	10
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

EXHIBIT 7.5 (Cont.)

FORM IIIb: ZONE PAIR DATA FOR SAMPLE INTERCHANGE STUDY

Check: [ ] Base System (Current or Proposed)

[ ] Option ____________________

Origin Zone	Destination Zone	Variable ____________				Variable ____________			
		Circulator	Regional Bus	Shuttle Bus	Other	Circulator	Regional Bus	Shuttle Bus	Other

These data items can be recorded directly on Form VI (see Exhibit 7.6).

One additional piece of zone data needed for the application of the noon hour forecasting models is the existing number of noon hour trips produced in each zone. This includes the sum of all intra-CBD walk, circulator, regional transit, and automobile travel originating from a zone during the noon hour. These trips should be summed up for each zone and each market segment, and recorded on Form VI.

7.2.4 Compute Travel Times

Form IV is used to compute interzonal travel times, see Exhibit 7.7. Travel times must be computed for each sampled zone pair interchange, each mode, each alternative, and each market segment if the travel times differ, such as the frequency of service for transit during the peak hour versus midday. The following data items are used as inputs:

- from Form II: walk distances and wait times;
- from Form III: in-vehicle distances; and
- from Exhibit 7.8: travel speeds (Note that the speeds in feet/minute must be used in Form IV. The miles/hour values are shown for information only.)

Once these items are recorded on the forms, the distances between zone pairs are converted to travel times.

7.2.5 Compute Revised Patronage Forecasts

Form VI is used to compute revised mode shares for a specified market segment and a specified service alternative, see Exhibit 7.6. One line must be completed for each origin-destination pair. The required data items are available from the following sources:

- the change in travel time (TIME) is the difference between the time values calculated on Form IV for the base and proposed alternative;
- the change in travel cost (COST) is the difference between the cost values on Form III for the base and proposed alternative;
- the change in the station integration variable (INTEG) is the difference between the values on Form III for the base and proposed alternative;

EXHIBIT 7.6

FORM VI: CHANGES IN TRAVEL FROM BASE SYSTEM

MARKET SEGMENT ____________________ OPTION ________________________

(1) Origin Zone	(2) Dest. Zone	Mode C or O.T.	(3) ΔTime	(4) ΔCost	(5) ΔInteg	(6) $\Delta U = [\ ] * \Delta Time + [\ ] * \Delta Cost + [\ ] * \Delta Integ$	(7) Exp (ΔU)	(8) Base Market Share	(9) y=(7)(8)	(10) $\sum y$	(11) Revised Market Share $\frac{y_C}{\sum y}$	(11) Revised Market Share $\frac{y_{O.T.}}{\sum y}$	(12) Total Trip Productions	(13) Revised Trips (11) * (12) C	(13) Revised Trips (11) * (12) O.T.
		C													
		O.T.													
		C													
		O.T.													
		C													
		O.T.													
		C													
		O.T.													
		C													
		O.T.													
		C													
		O.T.													
													TOTAL		

C - circulator system
O.T. - other transit

EXHIBIT 7.7

FORM IV: TRAVEL TIME CALCULATIONS

Mode: ________________ Check: [ ] Base System

[ ] Option ____________

Check: [ ] Peak

[ ] Off-Peak

Origin	Destination	Origin Walk	Wait	On-Vehicle	Dest. Walk	Total Time
		D ____ S ÷ ____ T ____	____ + ____	____ ÷ ____ + ____	____ ÷ ____ + ____ =	
		D ____ S ÷ ____ T ____	____ + ____	____ ÷ ____ + ____	____ ÷ ____ + ____ =	
		D ____ S ÷ ____ T ____	____ + ____	____ ÷ ____ + ____	____ ÷ ____ + ____ =	
		D ____ S ÷ ____ T ____	____ + ____	____ ÷ ____ + ____	____ ÷ ____ + ____ =	
		D ____ S ÷ ____ T ____	____ + ____	____ ÷ ____ + ____	____ ÷ ____ + ____ =	
		D ____ S ÷ ____ T ____	____ + ____	____ ÷ ____ + ____	____ ÷ ____ + ____ =	

D = distance (feet) S = speed (feet/minute) T = time (minutes)

EXHIBIT 7.8

TRAVEL SPEEDS BY MODE

Description	Speed feet/minute	Speed miles/hour	Speed time (minutes)
Walk Mode			
Sidewalk - up-grade	175	2	
- down/level	265	3	
Stairs - up			0.5
- down			0.3
Automated Walkway	350	4	
Escalator (up/down)			0.3
Automobile Mode			
- arterials (core)	880	10	
- arterials (peripheral)	1320	15	
- freeways	3080	35	
- ramps	2200	25	
Bus Circulator			
- mixed traffic	700	8	
- exclusive lane	800	9	
DPM Circulator 1/	max. = 2640	max. = 30	
Regional Bus			
- mixed traffic	700	8	
- exclusive lane	800	9	
Regional Rail Transit 1/	max. = 4400	max. = 50	

1/ Individual station-to-station times should be developed based on network geometry and acceleration/deceleration characteristics.

- the model coefficients for the specific market segments are given in Exhibit 7.9;

- the base modal shares for circulator and other transit modes were entered in Form VI during step 3 on data collection; and

- total productions of circulation or distribution trips were also entered in Form VI during step 3 on data collection.

Following the recording of these data items on each row, the values for columns 6, 7, and 9 can be calculated and recorded for each row of Form VI. These columns contain the values of the utility expression, U; the exponential function of the utility, EXP(U); and an interim calculation of the effect of the changed utilities on the individual interchange mode shares, referred to as a weight.

Utilities are the benefits, or negative costs, to a decision maker of choosing a particular alternative. A utility expression is an equation which estimates the utility of an alternative from a set of its characteristics, such as travel time for a mode choice decision. The utility expressions used in the ACM models are discussed in Appendix A.

The circulator and other transit values in the weight column, column 9, are summed up and the total is entered in column 10. The remaining columns, columns 11 through 13, can now be calculated and recorded for each row in Form VI. Summing column 13 provides the total circulator and other transit trips for all origin destination pairs.

7.2.6 Expand and Summarize the Travel Forecasts

We now have the initial (base) and revised ridership volumes by mode for each of the selected zone interchanges. If all interchanges were included, we would sum up the individual base and revised interchange volumes to get the total ridership by mode for the existing and proposed CBD circulator systems. However if a sample of interchanges were selected in Step 2, the volumes on the sampled interchanges must be expanded or factored up so they can be used to represent travel over all the interchanges in the network.

The expansion process is the reverse of the sampling process. For example, if one-seventh (1/7) of the interchanges were sampled at random, the total volume on the sampled interchanges will represent on average only 1/7 of the total travel in the network. Each interchange volume must therefore be multiplied by a factor of seven (7). If interchanges were not selected

EXHIBIT 7.9

COEFFICIENTS OF THE ACM MODELS FOR CBD CIRCULATION SYSTEM TRAVEL[1]

MARKET SEGMENT

Variable	Regional Auto Distribution Trips	Regional Transit Distribution Trips	CBD-Worker Circulation Trips	Other Circulation Trips
Travel Time (minutes)	-.5137[2]	-.5137[2]	-.1386[3]	-.0878[4]
Travel Cost (1980 cents)	-.0275	-.0275	-.0681[3]	-.0071[4]
Station Integration	+0.995	+0.995	+1.247[3]	+1.121[4]

1/ The coefficients are from the models described in Appendix A.

2/ This is the average value of the walk, in-vehicle, and out of vehicle time coefficients.

3/ These coefficients are the weighted averages of the coefficients for the regional auto and regional transit access models, assuming 2/3 regional auto and 1/3 regional transit mode shares.

4/ These coefficients were obtained from the CSI study (CSI, 1978) with the cost coefficient adjusted to 1980 dollars.

at random and with equal probabilities, the expansion process is more involved. PPS sampling was suggested as a means to emphasize selecting important or heavily traveled interchanges. With PPS sampling, high volume interchanges are selected more frequently than the average interchange so they do not have to be factored up as greatly. For PPS sampling, the resulting travel volumes on each interchange will be expanded by the following factor:

$$F_i = \frac{N}{n} * \frac{\overline{Vol}}{Vol_i}$$

Where: F_i is the expansion factor for interchange i;

N is the total number of interchanges in the network;

n is the number of sampled interchanges;

$\overline{Vol}$ is the average volume of trips on an interchange in the network; and

Vol_i is the volume of trips on the sampled interchange i.

For a full discussion of expanding survey results see Sampling Techniques (Cochran, 1977).

Form VII, included here as Exhibit 7.10, provides a single sheet which can be used to summarize the predicted changes in trips and shares for each mode and market segment, and for all market segments. The required data items are obtained by summing the distribution travel and circulation travel results on Form VI for each origin-destination pair.

7.3 Network Analysis

The network analysis method is a wholly or partially computerized procedure to forecast travel volumes by mode between all zone pairs in the study area. It forecasts total ridership, not the increment or change in ridership due to a change in the transportation services in the study area. This method does not require input data on the existing ridership levels, however, if data on existing ridership levels are available they can be used to calibrate the ACM models to local conditions. This may increase the confidence of the analyst and the decision-makers in the model forecasts.

Network analysis is appropriate to forecast travel for study areas with roughly ten (10) or more zones. It may be easiest to manually prepare the network level of service inputs for study

EXHIBIT 7.10

FORM VII: REVISED TRAVEL SUMMARY USING MANUAL SKETCH PLANNING

DISTRIBUTION TRIPS

Mode	Revised trips, all origins		Total		Total mode share
Circulator		÷		=	
Regional Transit		÷		=	
Other		-		=	
TOTAL					

CBD-WORKER CIRCULATION TRIPS

Mode	Revised trips, all origins		Total		Total mode share
Circulator		÷		=	
Regional Transit		÷		=	
Other		÷		=	
TOTAL					

OTHER CIRCULATION TRIPS

Mode	Revised trips, all origins		Total		Total mode share
Circulator		+		=	
Regional Transit		÷		=	
Other		÷		=	
TOTAL					

TOTAL INTRA-CBD TRIPS

Mode	Revised trips, all origins		Total		Total mode share
Circulator		÷		=	
Regional Transit		÷		=	
Other		÷		=	
TOTAL					

areas with up to fifteen (15) zones, but these inputs may be more efficiently generated using computer coded networks for larger zone systems.

This section presents a step-by-step description of the computerized network analysis process to estimate travel by mode in the CBD. Separate procedures are provided to develop network level of service characteristics by manual preparation or by using computer coded networks. Worksheets are provided to help in the manual preparation of network level of service characteristics. These worksheets are also included in Appendix D.

An overview of the computerized network analysis process is presented in Exhibit 7.11. The process is presented in the text as four (4) major steps. These steps are listed below and then discussed individually in sections 7.3.1 through 7.3.4.

(1) Choose the analysis parameters

(2) Collect data for the base system and each alternative

(3) Compute network levels of service

(4) Execute the computerized mode split models

Appendix A to this report explains the component models used in the network analysis process and Appendix B contains a user's manual which describes how the models are applied.

7.3.1 Choose the Analysis Parameters

The purpose of this step is to make those decisions which affect both the level of effort required in the analysis process and the specific units for which data must be collected.

Define the Zone System

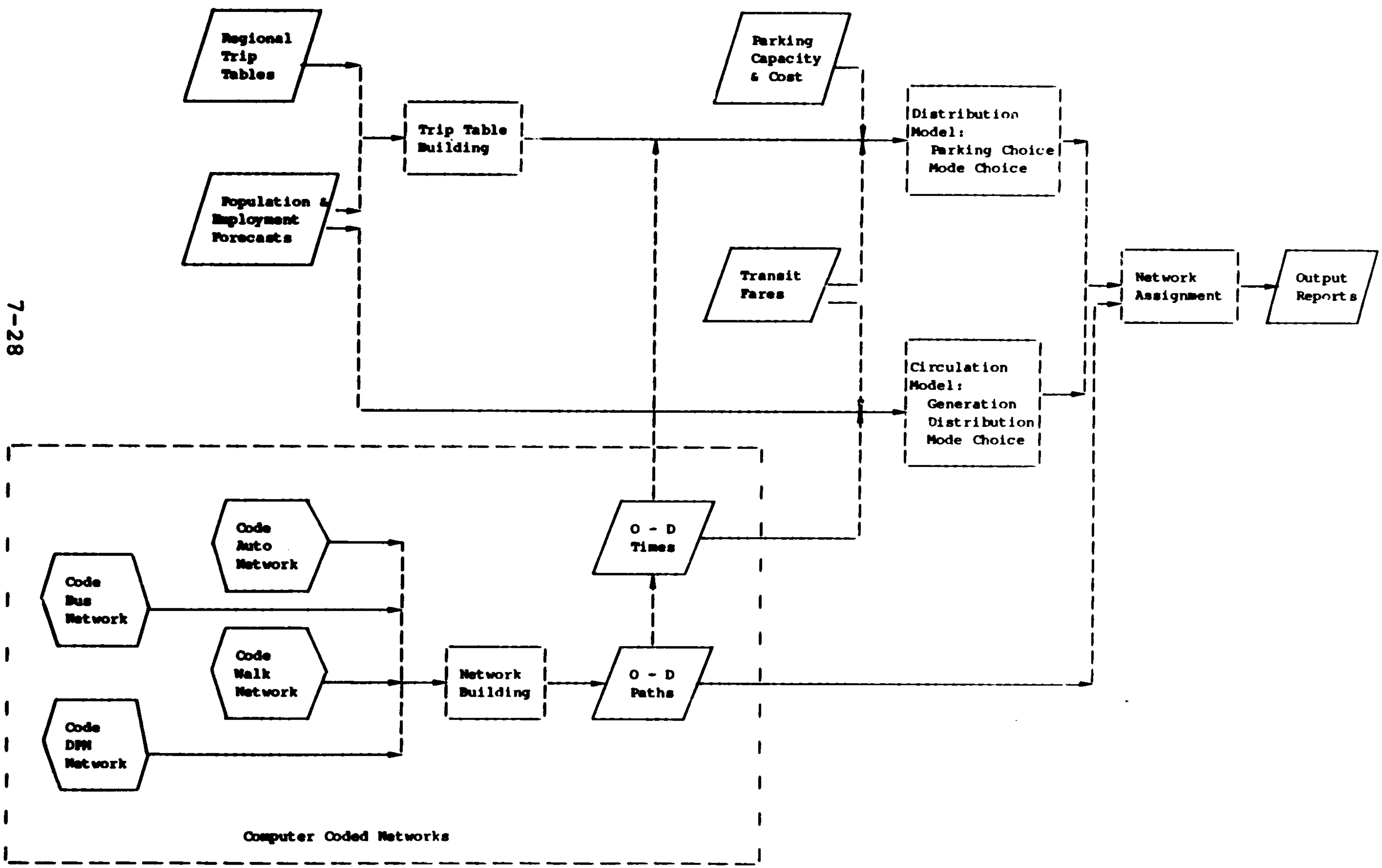
This step is unchanged from the discussion of the manual sketch planning process in Section 7.2.1. The following factors must be considered in choosing the sizes and the number of zones:

- Data availability - Nearly all of the data items discussed in the following section, Section 7.3.2, are required either for each zone or for each possible pair of zones. The lower limits on zone size are, therefore, determined either by the amount of detail which exists for available data or by the validity of assumptions required for further subdivision of available data.

- Relationship of zones to proposed circulator systems - Zone sizes can vary with distance from a proposed circulator system; distant areas can be represented with less

EXHIBIT 7.11

Computerized Network Analysis Process



detail than close areas without significantly affecting the accuracy of patronage prediction. Also, for relatively coarse analyses, zones may be defined such that each zone has one circulator station as its centroid. This type of careful tailoring of zones to a proposed system is not possible until the location of the proposed system is relatively fixed.

Define the Market Segments

The computerized model structure is designed to accommodate up to four travel markets:

- distribution trips by CBD-workers who travel to the CBD by auto;
- distribution trips by CBD-workers who travel to the CBD by transit;
- circulation trips by CBD-workers; and
- distribution and circulation trips by others.

Any of these market segments can be eliminated from the analysis, but the trips made by that market segment will then be lost.

Define the Proposed Alternatives

Each of the proposed downtown circulator systems must be defined to a sufficient level of detail to determine the level of service characteristics between the zone pairs. It is not necessary to specify the existing system unless the model is to be recalibrated to existing conditions.

Each alternative design for the CBD circulator system encompasses all the transit services proposed for operation in the CBD which will provide service for distribution or circulation travel in the CBD study area. These include the portions of regional bus routes which pass through the study area; specialized services, such as demand responsive services for the elderly and handicapped; circulator bus service; and automated downtown people movers.

The following kinds of information are needed for each of the modes in a proposed circulator system:

- route alignment;
- station or bus stop locations;
- vehicle speed between stops;

- frequency of service; and
- fare.

7.3.2 Collect Data for the Base and Alternative Systems

Zone Data

Several items of demographic data are needed to describe the characteristics of the CBD study zones in the forecast years. The following data should be collected and recorded on Form I (see Exhibit 7.12):

- employment;
- land uses;
- non-worker circulation trip productions;
- parking capacity;
- hourly parking cost; and
- zone area.

Most of the data items on Form I are straightforward though considerable time and effort may be required to gather the necessary information. Two data items can be estimated using procedures in Appendix A: non-worker circulation trip productions and circulation trip attraction density. Both of these variables can be determined from specialized CBD travel surveys or they may be estimated as a function of the CBD floor space dedicated to each of several land uses. It is not necessary to input the land use data to the computer programs. It is only collected in order to compute the information on trip productions and attractions.

In addition to the data on Form I, information is needed to describe the level of service in each zone to access the circulator and regional transit systems. The following data should be collected and recorded on Form II (see Exhibit 7.4):

- the walk distances between the zone centroid and the transit systems;
- the wait times at transit stops in the PM peak hour period; and
- the wait times at transit stops in the noon hour period.

EXHIBIT 7.12

FORM I: ZONE DATA INPUTS TO NETWORK ANALYSIS PROCESS

	DATA USED TO CALCULATE INPUTS						← INPUT DATA →					
	LAND USE DATA (1000's ft²)											
Zone	Pvt Off	Gov't Off	Retail	Hotel	Manuf	Zone Area (acres)	Parking Capacity (no. spaces)	Hourly Pk. Cost (1980 cents)	No. Employees	Employee Density (emp/acre)	Non-Worker Circ. Trip Productions1/ (trips)	Circulation Trip Attraction Density2/

1/ See Appendix A, Section A.3.4.1 to compute the value of this variable.

2/ See Appendix A, Section A.3.3.1 to compute the value of this variable.

Zone Pair Data

This step is unchanged from the discussion for the manual sketch planning process in Section 7.2.3. The following data are required for each of the existing transit modes for each origin-destination zone pair:

- the in-vehicle distance between origin and destination zones; and
- the transit fare between origin and destination zones.

Form IIIa, presented in Exhibit 7.5, should be used to record each of these zone-pair data items. One copy of the form is needed for each variable and each alternative.

Trip Table Data

The network analysis models derive the distribution trips from a set of regional trip tables. These regional trip tables contain person trips from regional corridors to CBD zones. Separate tables are provided for the following market segments:

- regional auto work travel (person trips and vehicle trips);
- regional transit work travel; and
- regional transit non-work travel.

7.3.3 Compute the Network Levels of Service

Level of service characteristics can be prepared manually or through the use of computer coded networks. The preferred approach will depend on the size and complexity of the zone system, and on the availability of existing computer files and networks which may have been prepared for other uses. A significant amount of labor is required to develop networks for each mode and then to code and keypunch the networks in a computer readable format. For small networks of roughly fifteen zones or less, it may be faster to compute the level of service characteristics by hand and avoid the development and coding of modal networks. The use of computer coded networks becomes more attractive as the number of zones in the study area increases. The work involved in computer coding of networks increases linearly with the number of zones, while the calculations for manual preparation of level of service data increase with the square of the number of zones.

Manual Preparation of Network Levels of Service

This process is similar to the travel time computation for manual sketch planning presented in Section 7.2.4. The process is expanded here to include all modes, such as auto and walking, rather than simply the existing versus the proposed circulator transit systems.

Forms I, II, and IIIa were filled in during the collection of zone data and zone pair data. Form IV and the travel speeds in Exhibit 7.8 are now used to compute the interzonal travel times by each of the available modes. Also, a copy of Form IIIa should be used to record zone-to-zone walk distances.

The data are prepared for use in the computerized mode split models by computing each of the required zone pair variables and recording them on Form V, see Exhibit 7.13. The variables are obtained from the forms developed above, as calculations based on other data, or from special operations. The distance and the vehicle travel times are taken from Forms IIIa and IV. The auto costs and walk times are calculated from the distance, and the costs for DPM, bus, and shuttle services are represented as the one-way fare in 1980 dollars. Each fare will normally be the same for all zone pairs, but the flexibility is provided to vary the fare as in a zone based system.

If any mode is not available for a given zone pair, then the corresponding costs and or times should be set to a uniformly large value; e.g., 9999. This value serves as an indicator of mode unavailability.

Computer Coding of Network Levels of Service

When more than fifteen zones are defined or a complex circulator systems is to be analyzed, the planner should consider making use of available software to estimate the transportation level of service on each interchange. Such software exists for transit networks in the Urban Transportation Planning System (UTPS) package and for highway networks in both the UTPS and Federal Highway Administration (FHWA) packages. The following steps describe the preparation of transit level of service data using this software:

(1) Prepare a map showing the location of each zone and the transit lines for each mode.

(2) Assign node numbers to each stop and transfer location (the connection between two nodes is a link).

EXHIBIT 7.13

FORM V: ZONE PAIR INPUTS TO NETWORK ANALYSIS PROCESS

Check: [ ] Base System   Check: [ ] Peak period

[ ] Option ____________   [ ] Off-peak period

Origin Zone	Destination Zone	Walk		Auto		Regional Bus		Circulator Bus		Other		Transit Modes
		Time (minutes)	Distance (miles)	Time (minutes)	Cost (cents)	Times (minutes)	Cost (cents)	Time (minutes)	Cost (cents)	Time (minutes)	Cost (cents)	Station Integration

(3) Code and keypunch each link and its characteristics (i.e., nodes, mode, speed, distance) and each line and its characteristics (i.e., number, mode, headway, and node sequence).

(4) Build a computer useable form of the network using UTPS programs UNET or INET. These programs examine the network inputs for coding errors, build files of the information which are useable by other UTPS programs, and output various reports describing the network.

(5) Develop level of service data for each interchange using programs UPATH and UPSUM. These data consist of the in-vehicle time and the out-of-vehicle time by mode for the interchange. Program UPATH finds the shortest path between each pair of zones and outputs a file which is used to assign the circulator trips. Program UPSUM meanwhile "skims" the paths to accumulate the run and wait times for each interchange, outputting a set of matrices in the form required by the mode choice models.

The planner is referred to the various UTPS and FHWA publications for a more detailed discussion of network coding and the capabilities provided by the various software packages. For transit network coding see the UTPS Network Development Manual, UTMA, August, 1974 and Transit Network Analysis - INET, UMTA, July, 1979. Program descriptions can be found in the most recent version of the UTPS program writeups. For highway network coding, see the UTPS program HR writeup, and the FHWA PLANPAC General Information Manual, April, 1977.

7.3.4 Execute the Computerized Choice Models

The execution of the computerized choice models consists of assembling various input data and running the programs containing the application software for each model. As is described in Appendix B, where such a process is presented in more detail, much of the effort is involved in assembling the various model inputs in the proper format.

Preparation of the person trip input tables is a key element. The distribution choice models require that the regional trip tables be modified to reflect only movement which occurs within the CBD study area. This is the movement to the traveler's destination either from their parking lot or from the location where the person exits the transit vehicle used to enter the downtown area. The effort involved in developing these tables will depend on what forms of data are available for the area. If a computerized regional planning process is conducted for the urban area, the trip tables can be extracted from the regional data base. The correspondence between the study area and regional zone systems will determine the amount of factoring or squeezing required to reformat the trip tables.

A process is needed to convert the regional trips which cross the CBD boundary to internal study area trips. In Los Angeles, special software (i.e., the BUSSTOP program[1]) was developed to estimate the internal distribution trips of regional transit users, and a parking lot choice model was used to develop the internal distribution trip tables of regional auto users.

Even when the level of service data are developed manually, they must still be entered into the computer in the format required by the ACM models. These models are usually implemented as user-coded subroutines to the UTPS program UMODEL, so the input format is usually UTPS-format matrices. UTPS program MBUILD creates UTPS matrices from interchange data of the type contained on Form V. The planner has to keypunch the data and prepare the necessary data identification cards to indicate the format followed. At this point, all of the various data should be available for execution of the demand models. Appendix B provides additional information on the actual execution of the ACM computer models.

7.4 Transferability Issues

The ACM models discussed in this section were calibrated with data from the CBD of a single city, Los Angeles, California. The Los Angeles CBD has unique characteristics, as do all CBD's, that are not explicitly accounted for in the models. Characteristics such as the income of CBD employees, climate, and special attractions in the CBD, are important determinants of the volume and nature of intra-CBD travel but are not accounted for in the models. Therefore, the models should be adjusted for local conditions whenever they are transferred from one city to another. This implies that a certain amount of information must be available for any city in which the models are to be applied.

At least three parameters should generally be adjusted when transferring the ACM models to another city:

(1) the value of time of trip makers in the CBD - both CBD employees and non-employees;

(2) the frequency with which CBD employees make intra-CBD trips; and

---

[1] Program BUSSTOP is explained in Appendix B.

(3) the total volume of non-CBD employee trips made to the CBD.

The sketch planning model can be transferred to another city with only a single adjustment, the value of time. The local trip rates and trip volumes are already required as part of the input data to the sketch planning method.

If information on one of the above items is not available it may still be possible to adjust these parameters by matching the outputs of the forecasting process to known data on existing travel, such as the number of walk trips or the patronage on the shuttle bus or regional bus systems.

The adjustments made to reflect local conditions do not affect the predictive powers of the models. They are still valid as predictors of:

- trip distribution;
- mode choice;
- changes in the frequency of trips by CBD employees;
- changes in the trip distribution of all trips; and
- changes in the choice of mode for all trips when the level of service changes or a new mode is introduced.

7.4.1 Value of Time Adjustment

The value of time can be changed if the value implied by the coefficients in Exhibit 7.9 is not felt to be appropriate for local conditions. The following procedure can be used to adjust the model coefficients:

(a) determine the value of time (in 1980 dollars)

There are various ways to estimate the value of time for a trip maker. The following technique is based on the estimated annual income:

$$VOT = INCOME \quad 2080 * Y$$

where:

VOT = value of time (in dollars per hour)
INCOME = estimated annual household income of the average trip maker (in dollars)

2080 = approximate number of working hours per year

Y = ratio of the value of time to the average wage rate

Recent studies of travel behavior[1] offer the following ratios (Y) to determine values of time.

Work trips Y = .97
Non-Work trips Y = .75

If the value of time is estimated for a year other than 1980, the value must be converted to 1980 dollars for use in the model. The Consumer Price Index (CPI) can be used as follows:

$$VOT_{(1980)} = VOT_{(Base)} * \frac{CPI_{(1980)}}{CPI_{(Base)}}$$

Regional consumer price indexes are available from the Bureau of Labor Statistics of the U.S. Department of Commerce, but for general references the following national consumer price index values are provided:

Year		CPI	Year		CPI
1970	-	116.3	1976	-	170.5
1971	-	121.3	1977	-	181.5
1972	-	125.3	1978	-	195.4
1973	-	133.1	1979	-	217.4
1974	-	147.7	1980	-	246.8
1975	-	161.2			

(b) <u>adjust the cost coefficient</u>

The coefficients of time and cost are related to one another by the value of time. If the value of time is adjusted to local conditions, it must then be used to adjust the cost coefficient in the utility expressions in the ACM model. The model coefficients developed for Los Angeles were presented in Exhibit 7.9. An adjusted cost coefficient can be calculated as follows:

1/Ben-Akiva, Moshe and Earl Ruiter, Cambridge Systematics, Inc., "The Development of a Complete System of Disaggregate Travel Demand Models," paper prepared for presentation to the Transportation Research Forum, 1977.

$$COEF_c' = \frac{COEF_t}{VOT} * 60$$

where: $COEF_c'$ = new cost coefficient (cost in dollars)
$COEF_t$ = time coefficient (in minutes)
VOT = value of time (in dollars per hour)
60 = constant to convert VOT to minutes

(c) adjust the modal constant

Changing the coefficient of cost will shift the percentage of travelers choosing each mode for a given situation. To prevent this from occurring, the modal bias constants are adjusted in a way which compensates for the effect of the changed cost coefficient. The following calculation must be performed for each mode:

$$CONST_m' = CONST_m - COST_m * (COEF_c' - COEF_c)$$

where: $CONST_m'$ = new constant for mode m
$CONST_m$ = old constant for mode m
$COST_m$ = average cost of travel by mode m in the original Los Angeles calibration data set in 1980 cents (regional bus = 50¢, shuttle bus = 20¢, auto = 13¢ per mile)
$COEF_c' - COEF_c$ = change in the cost coefficient

7.4.2 CBD-Worker Circulation Trip Making Rate Adjustment

The noon-hour CBD-worker circulation trip model predicts both the frequency of circulation trips by CBD-workers and the distribution over the zones in the study area. Trip frequency, in this case, is the percent of CBD-workers who make a CBD circulation trip on an average day.

Circulation trip frequency is affected by local conditions, such as climate and the number of interesting destinations close to the CBD employment workplaces. Trip frequency in the ACM model can be adjusted to reflect local conditions if information is available for the local city on the percent of CBD-workers making noon-hour circulation trips. The ACM model is adjusted by changing the constant term in the zero or "no" trip alternative in the frequency choice model for midday circulation trips (see Exhibit A.21 in Appendix A):

$$CONST_z' = CONST_z + \Delta CONST_z$$

where: $\Delta CONST_z = \ln \frac{p'(1-P)}{P(1-p')}$

$CONST_Z'$ = adjusted zero frequency constant
$CONST_Z$ = original zero frequency constant
$CONST_Z$ = adjustment to zero frequency constant
P = original percentage of CBD-workers who do not make midday trips
p' = actual percentage of CBD-workers who do not make midday trips
ln = natural logarithm

7.4.3 Non CBD-Worker Circulation Trip Volume Adjustment

The volume of non CBD-worker circulation trip productions is one of the inputs to the ACM model system. These volumes can be estimated for future study years using relationships between trip production rates and the floor area land uses in the CBD zones. The relationships developed for Los Angeles are presented in Appendix A.

The relationships between trip productions and land uses can be adjusted for cities other than Los Angeles if the necessary data are available. This requires data on the land uses in the study zones and on the volume of trip productions during the noon-hour in the study zones for the existing system.

7.4.4 Test Applications of the Network Analysis Process

To demonstrate the validity of the CBD circulator models for application to cities other than Los Angeles, the models were applied in three cities for which ridership data on CBD circulator systems were available: Washington, D.C.; Denver, Colorado; and Milwaukee, Wisconsin. The estimated riderships are reported in Exhibit 7.14 and are compared to the actual ridership measurements that were available. Before producing these forecasts, the models were adjusted according to the discussion in Sections 7.4.1 through 7.4.3. In each case, the noon-hour circulator models (CBD worker and others) were applied using the network analysis process with between 5 and 10 zones. The level of service values for travel between all zone interchanges were estimated manually (no networks were constructed).

As is demonstrated in Exhibit 7.14, the estimated total daily volume for the shuttle buses was within 20% of the actual value in each case. The estimates for the one-hour noon period, however, differ more from the actual volumes. This is most likely due to inaccuracies in measuring the actual peak one-hour volumes and in estimating the assumed distribution of trips by time of day used to expand the noon-hour volumes to total daily volumes.

The CBD circulator mode which best simulates the characteristics of an automated DPM is the initial phase of the Washington, D.C., subway, the Metrorail. The simulated values for this case

EXHIBIT 7.14

TEST APPLICATIONS OF THE ACM MODELS FOR CIRCULATION TRAVEL

Circulator Mode	Time Period	TEST CITY					
		Washington, D.C.		Denver, Colorado		Milwaukee, Wisconsin	
		Estimated	Actual	Estimated	Actual	Estimated	Actual
Shuttle Bus	All Day	2800	3300	2500	2080	2500	2800
	Noon Hour	1800	1200	650	480	415	840
Regional Bus	All Day	5500	5300				
	Noon Hour						
Subway	All Day	11,000	10,000				
	Noon Hour	3300	2500-3000				

were within 10% of both the actual daily volumes and the actual noon hour volume.

Test runs of the ACM models were made with the Washington, D.C., circulation trip data to determine the sensitivity of the models to changes in travel time and travel cost. The results are illustrated in Exhibit 7.15 in the form of demand elasticities, the percentage change in demand which would result from a one percent change in the variable. For example, Exhibit 7.15 indicates that a one percent increase in the subway fare would result in a .32% decrease in subway ridership by CBD-workers. This sensitivity analysis clearly indicates that both CBD-workers and others are more sensitive to travel time changes than to fare changes. Also, CBD-workers are less sensitive to changes in travel cost than are others.

7.5 Selection of an Analysis Approach

All the analysis approaches discussed in Section 7 are based on the ACM models developed in Los Angeles. The difference is primarily the level of detail at which the model is applied.

This section, Section 7.5, discusses the types of applications appropriate for the manual sketch planning procedure and the network analysis procedure. It then presents some simple criteria for use in determining the analysis method which is most appropriate for a given situation.

7.5.1 Sketch Planning Model Capabilities

The parameters to which the ACM sketch planning model is sensitive were discussed in Section 7.1.2. However, because of the roughness of the results, sketch planning is not always appropriate to analyze the service changes to which it is sensitive. Sketch planning is probably an appropriate analysis method for the following types of applications:

- estimate total ridership on each mode;
- estimate areawide air quality, noise, and energy impacts;
- compare broad alignment corridors;
- compare average station spacings;
- compare frequencies of service; and
- compare alternative transit fares and CBD parking prices.

EXHIBIT 7.15

ELASTICITIES OF METRORAIL RIDERS IN WASHINGTON, D.C.

Variable	Circulation Travel Market	Mode Elasticities	
		Shuttle Bus	Subway
Travel Time	CBD-Worker	-1.76	-1.69
	Other	-1.74	-1.71
Travel Cost	CBD-Worker	- .12	- .32
	Other	- .20	- .54

Sketch planning evaluates actions which impact all or a large portion of the downtown circulator system. It cannot detect the impact of subtle changes, such as small shifts in the alignment of a transit service.

7.5.2 Network Analysis Model Capabilities

Exhibit 7.2 listed the system parameters to which the set of ACM models is sensitive. The choice of the network analysis approach depends on the type of application as well as the effected parameters. Network analysis should be chosen when broad descriptions of the performance of the circulator system are not sufficient. Network analysis is intended to estimate volumes of trips for sub-regions of the study area and even for individual interchanges. The following list illustrates the types of applications which network analysis shares with sketch planning and the additional applications for which network analysis is needed:

- applications shared with sketch planning
  - estimate total ridership on each mode;
  - estimate air quality, noise, and energy impacts;
  - compare broad alignment corridors;
  - compare average station spacings;
  - compare frequencies of service; and
  - compare transit fares and parking prices.
- applications requiring network analysis
  - estimate travel volumes for sub-regions of the CBD study area;
  - estimate travel volumes for individual zone interchanges;
  - analyze changes to individual routes;
  - evaluate small changes to station locations and route alignments; and
  - evaluate final system engineering for station capacities and vehicle capacities by link in the system.

7.5.3 Selection Criteria

Three factors influence the choice of an appropriate analysis method:

- type of change to the circulator system - this determines the system parameters to which the models must be sensitive;
- purpose of study - this determines the level of detail and therefore the number of zones in the analysis; and
- resource availability - this determines the cost or difficulty to an agency of manual versus computer analysis.

Three alternatives, or levels of analysis methods, were presented in these sections:

- sketch planning;
- network analysis with manually prepared level of service data; and
- network analysis with computer coded networks.

An elimination process is used to select the best analysis approach based on the three factors mentioned previously:

1. Determine whether the ACM models are sensitive to the type of change planned for the CBD circulator system. If they are not, none of the methods discussed here are applicable. If they are, continue to select the best approach.
2. Determine the level of detail required by the analysis. If fewer than ten zones are needed, select sketch planning. If more than fifteen zones are needed, select network analysis with computer coded networks. If between ten and fifteen zones are needed, continue to step 3 to select the best form of network analysis.
3. Determine the difficulty, in terms of time and cost, of preparing computer coded networks. If networks already exist from other studies performed in the area, the fully computerized network analysis process may be chosen, even for studies involving fewer than fifteen zones.

7.6 References

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8. CIRCULATOR COST ESTIMATION

This section presents a manual method which can be used, with the demand information obtained using the procedures described in Section 7, to obtain an order-of-magnitude estimate of downtown circulator system costs. For illustration, the cost estimation methodology is applied to a DPM system. The section begins with a background discussion of the major DPM cost components, the determinants of these costs, and the most important sources of uncertainty in cost estimation. The second section presents historical capital and operating cost data on existing automated systems which can be used as a basis for estimating DPM costs. The third section describes a set of worksheets which can be used manually to obtain estimates of DPM total capital, annual operating, and total annual costs. Finally, Section 8.4 contains references to the documents which were used in deriving various cost parameters, and Appendix 8-A lists the assumptions used in developing default cost parameter values.

8.1 BACKGROUND ON DPM COST ESTIMATION

8.1.1 Cost Components

As for all transportation systems, two major categories of costs must be considered when DPM systems are evaluated: capital, or fixed, costs and operating, or variable, costs. The major components of each of these costs are the following:

Capital Costs

Eight components can be used to classify the capital costs of DPM systems:

- Guideways - All guideway facilities including foundations, supporting structures, running and guidance surfaces, switching equipment, and special features for melting snow and ice if required.
- Vehicles - The rolling stock, including on-board command and control equipment.
- Stations _ Passenger loading platforms and shelters; access facilities such as ramps, stairways and elevators; graphics and fare collection equipment; vehicle interface equipment such as coordinated doors and other facilities related to the movement of passengers on and off the DPM vehicles.

- Control and communications - Wayside and central office control and communications equipment, including operational software and public address systems.

- Power and utilities - Electric power transformers, feeders, switch gear, power rails and normal power for illumination and housekeeping; also facilities for guideway and power heating if required.

- Maintenance and support facilities - Repair shops and equipment such as emergency vehicles.

- Right-of-way - All land takings and easements required for stations, guideway structures, and air rights.

- Engineering and project management - All costs of architecture and engineering services, design systems integration, acceptance testing, and overall project management.

Each of these cost components is explicitly considered in the cost estimation procedure described in this section.

Operating Costs

- Labor - Both operations and maintenance labor must be considered. Operations labor includes system supervision and central control operators, as well as station attendants and on-vehicle personnel if needed; maintenance labor includes personnel for upkeep repairs and overhaul of equipment and facilities, and for cleaning and custodial tasks.

- Energy - Electrical power for propulsion, on-board equipment, lighting, shop power, etc.; and natural gas or oil for guideway, office, and shop heating.

- Materials and services - Consumable supplies, replacement parts, tires; maintenance and other work performed by contractors or other organizations.

- General and administrative - Overall system management; support services such as accounting, engineering, public relations and advertising; insurance and legal fees.

The cost estimation method presented in sections 8.2 and 8.3 employs several operating cost measures which incorporate each of these components.

8.1.2 Inputs Required for Cost Estimation

Cost estimation for DPM systems requires information on system characteristics, operating policies, and predicted demand levels.

System Characteristics

DPM system costs depend on each of the following system characteristics:

- Guideway length and location
- Number of stations and location
- Vehicle capacity
- Local labor and utility costs

Operating Policies

The following policy descriptors are needed to estimate system costs:

- Round trip vehicle schedule time
- Peak period headway
- Hours of operation

Other aspects of operating policy, such as train length and off-peak headways, are determined within the cost estimation process based on reasonable assumptions concerning the behavior of transit system operators.

Predicted Demand Levels

To simplify cost estimation, only a subset of the demand information developed using the procedures described in the previous section is required. The most important demand descriptor is the one-way peak hour volume at the maximum load point, since this determines the number of vehicles required. The only other demand information used is the variation in maximum load point demand over the day.

8.1.3 Uncertainties in DPM Cost Estimation

The cost estimation methodology presented in sections 8.2 and 8.3 is designed to provide planners with an order-of-magnitude cost estimate for a DPM system under consideration. In addition to the uncertainties introduced by using average costs to estimate DPM costs, the following will also influence the actual DPM cost:

- Right-of-way costs - Right-of-way acquisition costs for existing automated guideway transit (AGT) systems are included under guideway costs. These costs are small due to AGT locations in controlled environments - a university, shopping center, hospital complex, amusement centers, and airports. Because DPM systems are planned for downtown areas where there is a complex land use and ownership pattern, the cost of acquiring the right-of-way for the DPM guideway is expected to be higher than for the AGT systems. Therefore, no attempt is made to provide an average or default value for right-of-way costs.

- Underground construction costs - Relative to the costs of DPM stations and guideway constructed at grade or above grade, costs of below grade guideway and station construction are both much higher and more variable. This is due principally to uncertainty in underground excavation and construction costs, which are functions of such wide-ranging factors as subgrade composition, required station depth, and proximity to adjacent building foundations. For this reason, default unit cost values should be supplemented with additional local experience early in the planning process.

- Station costs - The cost of stations is a function of the station's location, size, and elegance. These features are related not only to the stations' role as part of the transportation system but also to their role in the city's image and development plan. The existing automated systems represent a wide range of these functions, but in general do not represent typical urban achitectural settings. Thus, the planner should have a clear picture of the type of stations envisioned for the local implementation.

- Labor and utility costs - The full costs of labor vary considerably depending not only on the city but on the organizational setting, work rules, benefits, etc. The estimates for all non-labor costs in this report are direct costs. Thus, the labor rates must reflect wage and fringe as well as any indirect non-labor charges such as rents. The methodology used in the following subsections allows adjustments based on full labor rates and worker available hours. Utility costs must be adjusted for vehicle efficiency, local power costs and climate factors, and the type of usage. All but the type of usage, which usually reflects peak load vs. base load pricing of utilities, are accounted for in the methodology.

- Inflation - It is essential to note that all costs are reported in 1980 dollars. Projections for any years other than 1980 should include an appropriate cost inflation factor.

8.2 CAPITAL AND OPERATING COST EXPERIENCE

8.2.1 The Bases for Available Cost Data

Because no DPM systems exist at this time, the experience of their closest substitute (and technological predecessor) - automated guideway transit systems - provides the only available information for use in the DPM cost estimation methodology. This strategy is a reasonable one, based on the similarities of AGT and DPM systems in the areas of guideway construction, vehicle technology, control systems, and maximum frequency of service. Table 8-1 shows the location and operational characteristics and total costs in 1980 dollars of several existing automated guideway transit systems.

Some of the differences between AGT and DPM systems, however, must be kept in mind as the AGT cost information is used. DPM systems can draw upon the experience which has been gained with operating AGT systems. In a sense, therefore, DPM systems will represent "second generation" systems with a greater level of testing and refinement, and with less variation in system costs. The unique location of DPM systems in downtown areas will result in some significant differences in costs and operations compared with the AGT systems, which have generally been built in controlled environments such as airports, universities, and amusement parks. Finally, DPM and AGT systems are likely to differ significantly in their demand levels and in the distribution of demands over the hours of the day and the days of the week.

For all of these reasons, the available cost data for AGT systems must be regarded as indicative of general ranges rather than as complete determinants of DPM system costs. As much use as possible should be made of site-specific data, and of the improved DPM-specific data which will become available as implementation of these systems is begun.

8.2.2 Costs Reported for the Operational AGT Systems

Capital Costs

The infrastructure costs of operational AGT systems are listed in Table 8-2, together with their system dimensions, such as the length of guideway above and below ground, the number of stations above and below ground and certain key characteristics such as percent elevated and station density. To facilitate comparison of the systems which are built in different years, all costs have been adjusted to 1980 dollars using the producer price

TABLE 8-1

GENERAL CHARACTERISTICS OF RECENTLY CONSTRUCTED AUTOMATED SYSTEMS

SYSTEM OR SITE	MANUFACTURER	SITE DESCRIPTION	INITIAL OPERATION	HOURS OF OPERATION	DAYS PER YEAR	MODE OF OPERATION	TOTAL COST $1980 ($M)
AIRTRANS	Vought	Airport	1/74	24 hrs/day	365	Single-lane Multi-loop	83.4
ATLANTA	Westinghouse	Airport	9/80	24 hrs/day	365	Single-lane loop	61.8
BUSCH GARDENS	Westinghouse	Amusement Park	5/75	11 hrs/day	143	Single-lane loop	6.3
DISNEYWORLD	Disney	Amusement Park	7/75	13 hrs/day	365	Single-lane loop	16.6
DUKE	Otis/TTD	Hospital Center	5/80	24 hrs/day	365	Dual-lane and Single-lane shuttle	N/A
FAIRLANE	Ford	Shopping Center	[illegible]/76	81 hrs/wk	365	Single-lane shuttle	8.4
KING'S DOMINION	UMI	Amusement Park	4/75	11 hrs/day	143	Single-lane loop	21.6
MIAMI	Westinghouse	Airport	4/80	24 hrs/day	365	Dual-lane shuttle	13.4
MINNESOTA ZOO	UMI	Amusement Park	8/79	10 hrs/day	365	Single-lane loop	8.6
MORGANTOWN	Boeing	University and City	9/75	76 hrs/wk	341	Dual-lane Multi-loop	141.3
ORLANDO	Westinghouse	Airport	7/81	-	-	4 Dual-lane shuttles	25.5
PEARL RIDGE	Rohr	Shopping Center	11/77	69 hrs/wk	365	Single-lane shuttle	N/A
SEA-TAC	Westinghouse	Airport	2/73	24 hrs/day	365	2 single-lane loops 1 single-lane shuttle	47.3
TAMPA	Westinghouse	Airport	4/71	24 hrs/day	365	4 dual-lane shuttles	19.5

SOURCE: Reference (8).

TABLE 8-2

1980 DOLLAR COSTS OF RECENTLY CONSTRUCTED AUTOMATED GUIDEWAY SYSTEM INFRASTRUCTURE

LOCATIONS	MILES OF TWO[1] TRACK FACILITY AG + EL	UG[2]	% EL	Stations	STATIONS/ MILE AG + EL	STATIONS/ MILE UG	1980 $ TOTAL COST ($ M)	1980 $ COST/TWO TRACK MILE ($ M)
KING'S DOMINION Amusement Park	1.03	0	5	1	1.0		4.5	4.5
BUSCH GARDENS Amusement Park	.67	0	40	1	1.4		5.3	7.9
MINNESOTA ZOO	.70	0	90	1	1.4		6.0	8.6
AIRTRANS DFW Airport	6.40	0	20	28	4.4		66.8	10.4
TAMPA Airport	.70	0	100	8	11.4		15.8	22.5
FAIRLANE Shopping Center	.30	0	100	2	6.7		7.14	24.6
ORLANDO Airport	.74	0	100	8	10.8		20.6	27.8
WALT DISNEY WORLD Amusement Park	.43	0	100	1	2.3		12.3	28.6
MORGANTOWN Urban System	4.30	0	60	5	1.2		123.0	28.8
MIAMI Airport	.3	0	100	2	6.7		11.9	39.6
HOUSTON Airport	0	.7		9	0	12.9	20.5	29.2
ATLANTA Airport	0	1.1		10	0	9.1	49.6	45.0
SEATAC Airport	0	.9		8	0	8.9	40.6	45.0

1. Single track miles/2

2. AG = at grade, EL = elevated, UG = underground.

Source: Reference (8).

index, the consumer price index (CPI) and the ENR construction cost index. The total infrastructure cost per two track mile (a common measure for comparing transit alternatives) for each system is shown in the right hand column. The systems have been ordered by increasing cost. One can see that systems built entirely at grade cost approximately $10 million/mile, systems built entirely elevated cost $25 million/mile and systems built under airports cost $45 million/mile. A simple model for systems built at grade and elevated was estimated (excluding Morgantown) as:

Infrastructure cost per two-track mile = $2.43 + $.23 * % elevated
($M 1980 dollars)

(t-stats) = (.51) (2.88) R^2 = .57

Thus a system built entirely elevated would cost $25.43 million per two track mile. This is a good approximation for systems similar to those currently deployed and can serve as a rough baseline for sketch planning.

Table 8-3 shows the preliminary engineering estimates for three DPM systems. The costs in the referenced reports* have been updated to 1980 dollars. The costs per two-track mile range from $26.4 to $50.3 million per two track mile. The St. Paul figure is near the 100% elevated cost while the cost in Los Angeles is 30% higher and that of Detroit is 100% higher than existing systems. Both Los Angeles and Detroit have relatively high station densities and include right-of-way costs which are not included in Table 8-2.

Table 8-4 shows the fleet size, physical characteristics and unit costs in 1980 dollars of the existing automated vehicle fleet. Costs range from $145,000 to $855,000 per vehicle. The regression equations below the table were developed from the data to aid in cost estimation. Given the vehicle's passenger capacity and the fleet size, the planner can estimate total fleet costs using equations (1) and (2) or equations (1) and (3).

The cost records for the thirteen AGT systems are maintained differently and thus any comparison of costs from system to system must be made carefully. In some cases stations may have been built in conjunction with an airport terminal and the actual station costs must be estimated. Due to accounting methods, it is not always possible to separate the cost of power and utilities or control and communications from the initial cost of guideways. Where costs could be identified as belonging in a particular category, or "missing" data could be estimated, the appropriate adjustments were made so that the listed costs would be comparable.

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*All references appear in Section 8.4.

TABLE 8-3

DPM SYSTEMS - PRELIMINARY ENGINEERING ESTIMATES

ITEM	ST. PAUL[1]	LOS ANGELES[2]	DETROIT[3]
MILES OF 2-LANE GUIDEWAY[4]			
UNDERGROUND	.25	.07	.0
ELEVATED	2.32	3.05	1.48
AT-GRADE	.15	.22	.0
TOTAL	2.72	3.34	1.48
NUMBER OF STATIONS			
UNDERGROUND	1	1	0
ELEVATED	10	18[5]	13
AT-GRADE	1	0	0
TOTAL	12	19	13
NUMBER OF VEHICLES	26	60	26
1980 DOLLAR COST (MILLIONS)[6]			
TOTAL COST LESS VEHICLES	71.9	111.7	74.5
TOTAL COST/MILE	26.4	33.4	50.3
COST/VEHICLE	.39	.35	.54
CONSTRUCTION PERIOD[7]	4/80-10/83	midpt=1982	10/82-9/83
ACTUAL DOLLAR TOTAL COST (MILLIONS)			
EXCLUDE VEHICLES	78.67	110.635	80.732
INCLUDE VEHICLES	89.80	131.988	95.800

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1 City of St. Paul and Metropolitan Transit Commission, Final Report: Preliminary Engineering and Related Studies for St. Paul Downtown People Mover, MTC-TD-79-1, February 1979.

2 Community Redevelopment Agency of the City of Los Angeles, "Basis of Capital cost Estimate," December 1978.

3 Southeastern Michigan Transportation Authority, DPM Preliminary Cost Estimate, September 1979.

4 Calculated as total DPM Single Lane miles/2

5 Six station locations having single side platforms on either side of street counted as 12 stations.

6 Total cost less vehicles includes all facility construction related costs, system hardware, engineering, management, contingency, right of way.

7 Construction period from system supplier selection to system operation.

TABLE 8-4

AUTOMATED VEHICLES

System	FLEET SIZE	VEHICLE DIMENSIONS (FT) Length/Width/Height	VEHICLE WEIGHT (LBS) Empty/Gross	VEHICLE CAPACITY Seated/Standing	VEHICLE SPEED (MPH) Maxiumum/Average	COST PER VEH. (1980 $)
Airtrans	51	21.0/7.0/10.0	14,000/20,700	16/24	17/10	326,000
Atlanta	17	39.0/9.3/11.0	27,500/42,100	8/88	27/13	718,000
Busch Gardens	2	36.3/9.8/11.0	26,500/43,800	8/88	30/11	561,000
Disneyworld	30(5 car trains)	8.0/4.8/3.8	4,800/7,800	20/0 (train)	14/5	145,000*
Duke	4	20.0/10.8/9.8	10,200/16,500	4/18	28/14	-
Fairlane	2	24.7/6.7/8.7	12,500/17,000	10/14	30/10	500,000
Houston	6(3 car trains)	12.0/5.8/8.0	N/A	18/18 (train)	15/6	185,000
King's Dominion	6(9 car trains)	14.0/6.0/7.4	18,700/31,500	96/0 (train)	18/6	511,000
Miami	4	36.3/9.7/11.0	25,800/43,800	2/97	28/17	372,000
Minnesota Zoo	3(6 car trains)	11.7/7.0/7.4	47,800/65,000	94/0 (train)	8/7	855,000
Morgantown	71	15.5/6.7/8,8	8,600/11,800	8/13	30/17	258,000
Orlando	8	39.0/9.0/11.0	25,600/46,000	0/100	28/21	619,000
Pearl Ridge	1(4 car trains)	40.0/6.0/9.0	29,200/40,800	32/32 (train)	8/7	-
Sea-Tac	12	37.0/9.3/11.0	25,000/46,700	12/90	26/9	562,000
Tampa	8	36.3/9.3/11.0	21,500/40,300	0/100	30/9	460,000

* propulsion in guideway

(1) Square Feet/Vehicle = 32 + 3.19 * passenger capacity $R^2 = .96$
(2.47) (16.8) (t-statistics)

(2) Unit Cost = 248 + .68 * Square Feet/Vehicle $R^2 = .32$
($000) (2.32) (2.27) (t-statistics)

(3) Total Cost = -1.41 + 2.07 * Total Fleet Area/1000 $R^2 = .78$
($ M) (-.49) (6.27) (t-statistics)

Square Feet = Length * Width

Total Fleet Area = Number of Vehicles * Square Feet

Source: Reference (8).

Operating costs

The 1980 operating statistics and costs of nine AGT systems are listed in Table 8-5 along with the number of vehicle-miles, place miles, passengers carried, system operating hours and number of employees to which the costs correspond. As with capital costs, the comparison of these costs must be made carefully. Whenever possible, adjustments were made so that costs fall into the categories outlined in Section 8.1, and any costs which were not in 1980 dollars were escalated to 1980 by the appropriate CPI factor. Operations at Tampa are supplemented by a maintenance contract with the supplier. The number of employees at AIRTRANS includes passenger service agents at stations. Table 8-6 shows some common measures of unit cost. The average unit costs for all seven systems are:

$$\frac{\text{Total Annual Cost}}{\text{Total Vehicle Miles}} = \frac{\$8,911,000}{6,166,000} = \$1.44/\text{vm}$$

$$\frac{\text{Total Labor, Service, G\&A Cost}}{\text{Total Employees}} = \frac{\$6,648,000}{294} = \$22,612/\text{emp}$$

Table 8-7 shows the trend in annual operating costs for the five major AGT systems operating during the past 5 years. Costs have remained stable in constant dollars except for AIRTRANS' which have increased due to additional service agent personnel and Morgantown's which have decreased with the addition of more service.

8.2.3 Development of Unit Costs for Urban Applications

The preceding subsection presented aggregate unit cost values for infrastructure, vehicles, and annual operating costs. Because the AGT systems represented in Tables 8-4 through 8-7 have different construction specifications, operating policies, patronage, and cost, and because there are no operating AGT systems which are equivalent to an automated system deployed in a downtown area, the aggregate values should be used only as reasonableness checks.

Table 8-8 presents unit cost values for each category of system development except right-of-way, which is very site specific. Recently constructed rapid rail systems have experienced right-of-way costs in the $3 to $10 million per route mile range, and they are not built in the downtown (Reference 9). Referring to Table 8-8, reported unit costs are shown for guideway and stations as a function of location. The low, average, and high values correspond to actual data (adjusted to 1980 dollars). The default values are taken from the average if the range is narrow and uncertainty low, otherwise preliminary engineering data from proposed DPM's were used. Vehicle cost default values were estimated from the equations developed using the actual data in Table 8-4. Control, power, and maintenance support costs were disaggregated to show the scale of the

TABLE 8-5 1980 OPERATIONS AND MAINTENANCE COST BREAKDOWN (1980 DOLLARS)

	TAMPA	SEA-TAC	AIRTRANS	MORGANTOWN	DISNEYWORLD	MINNESOTA ZOO	PEARL RIDGE	MIAMI	BUSCH GARDENS
Operational Statistics									
Vehicle Miles	365,000	550,724	3,282,959	1,218,780	719,600	7,606	12,500	76,136	44,500
Equivalent Place Miles	30,660,000	47,362,264	121,469,483	31,688,280	34,540,800	935,538	750,000	6,699,968	3,960,500
Passengers Carried	19,223,500	10,941,450	7,013,994	3,009,762	5,328,510	374,280	1,200,000	4,618,296	1,365,086
System Operating Hours	8,784	8,052	8,597	4,121	4,797	3,245	3,750	N/A	1,395
Number of Employees	6.6	17.25	143	81	18	15.4	13	N/A	12
Operations & Maintenance Costs ($)									
LABOR	17,706	602,389	3,064,315	1,086,599	287,779	198,947	252,884	-	-
Operations	5,059	198,789	881,142	244,481	159,659	91,394	68,731	-	48,700
Maintenance	12,647	403,600	1,891,873	576,548	128,120	107,553	168,422	-	-
Other	-	-	291,300	265,570	-	-	15,731	-	-
UTILITIES	86,453	17,941	296,865	367,878	64,345	30,647	7,204	20,397	14,000
MATERIALS & SERVICES	493,615	156,860	940,039	699,028	-	25,828	30,880	-	-
Spare Parts & Materials	74,042	126,860	696,312	439,998	-	23,078	30,880	-	-
Contract Services	419,573	30,000	243,727	259,030	-	2,750	-	-	-
GENERAL & ADMINISTRATIVE	14,487	20,006	81,801	-	31,932	-	35,100	-	-
TOTAL ANNUAL COST	612,261	797,196	4,383,020	2,153,505	384,056	255,422	326,068	N/A	N/A

\- No entry in this category in the accounting records of the operator.
N/A Not Available.

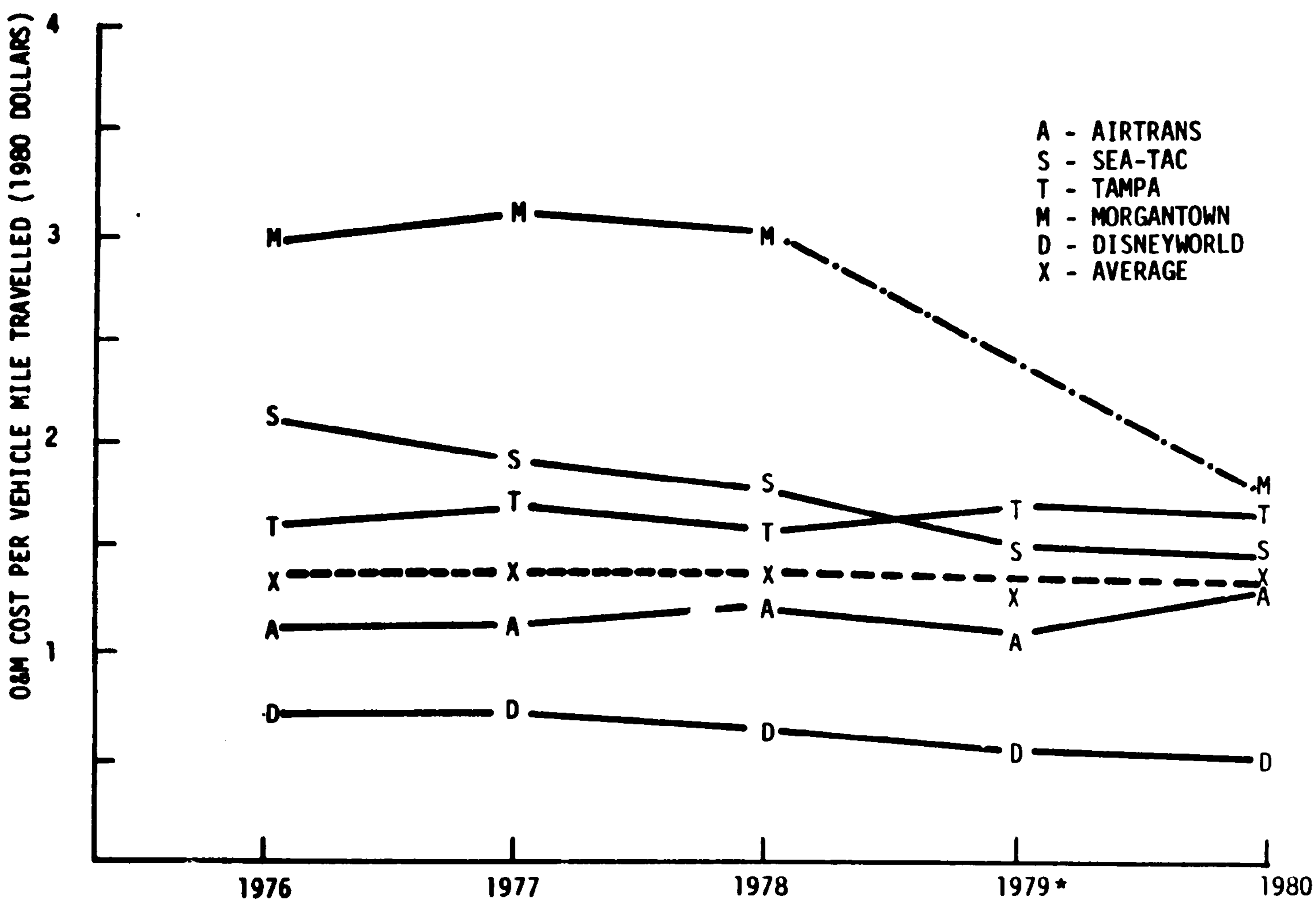
Source: Reference (8).

TABLE 8-6 1980 OPERATIONS AND MAINTENANCE COST MEASURES (1980 DOLLARS)

	TAMPA	SEA-TAC	AIRTRANS	MORGAN-TOWN	DISNEYWORLD	MINNESOTA ZOO	PEARL RIDGE
O&M Cost Per Vehicle Mile	$1.68	$1.45	$1.34	$1.77	$.53	$33.58	$26.09
O&M Cost Per Vehicle (Train)	76,533	66,433	85,942	29,500	12,802	85,141	81,517
O&M Cost Per Equivalent Place Mile	0.020	0.017	0.036	0.068	0.011	0.273	0.435
O&M Cost Per Passenger	0.03	0.07	0.62	0.72	0.07	0.68	0.27
O&M Cost Per Passenger Mile	0.19	0.21	N/A	N/A	0.08	0.50	1.19

Source: Reference (8).

TABLE 8-7 TREND OF O&M COST PER VEHICLE MILE TRAVELLED FOR FIVE AGT SYSTEMS



*1979 does not include Morgantown (the isolated point denoting the four system average is not included in the plot of the average.

Source: Reference (8).

TABLE 8-8

CAPITAL COST FACTORS, REPORTED COSTS AND DEFAULT UNIT COST PARAMETERS FOR ESTIMATION OF CAPITAL COSTS
(all costs in millions of 1980 dollars)

Cost Category	Units of Cost	Reported Costs[1] Low	Ave	High	Default Unit Cost Parameters
Guideway					
o elevated	per lane-mile	2.18	3.43	6.5	3.43*
o at grade	per lane-mile	.708	1.31	1.7	1.31*
o below grade	per lane-mile	5.32	7.94	9.89	11.80*[2]
o extra guideway	per lane-mile	.708	1.31	1.7	1.31*
Station					
o elevated	per station platform	.126	.255	.607	.500[3]
o at grade	per station platform	.044	.166	.177	.320
o below grade	per station platform	.528	.821	.934	1.720[4]
Vehicle	per vehicle	.258	.467	.855	--
	per vehicle, per vehicle capacity unit				(See Table 8-4)
Control	per lane-mile	.023	1.64	5.04	--[5]
	fixed cost				1.95
	per lane-mile				.30
	per station side				.028
	per vehicle				.005
Power Supply	per lane-mile	.211	.836	2,140	--[5]
	per lane-mile				.560
	per station				.280
Maintenance Support	per vehicle	.027	.116	.324	--[5]
	fixed cost				1.18
	per lane-mile				.025
	per vehicle				.058
Project Management	% added to sum of above costs	7.7	25.2	37.8	25.2
Contingency	% added to sum of above costs	For Planning Only			12

*Default unit cost values are for unheated guideway; for heated guideway, add $.84/lane-mile to the default unit costs.

TABLE 8-8 (CONTINUED)

NOTES

1. Actual values have been tabulated using reference (8). The average value for all costs, except vehicles, are the weighted average, i.e., total costs divided by total units.

2. Costs for underground tunneling in urban setting will likely exceed cost of building in an airport during construction of the airport. Costs of recently constructed rail tunnels range between $17 million - $35 million per single track mile. See reference (9).

3. Station default was estimated from DPM design in LA and St. Paul. See Appendix 8-A for detailed design assumptions.

4. Same logic as note 2. Recent underground rail station costs range between $20,000 and $50,000 per foot; an average DPM station may be 80-100 feet, thus $1.6 to $5.0 million per station underground would be consistent with recent rail costs.

5. Actual costs for control, power and maintenance support vary considerably, suggesting a more disaggregate approach to cost estimation is appropriate. Default values were developed from references (4) and (5).

property due to the wide range of the actual data. Project management add-on was taken from the actual data. To update the capital cost data for time and regional factors the following variables are suggested:

> Guideway, stations, power, maintenance support should be updated by a ratio of the local ENR Building Cost Index (BCI) (1913 base) for the base year desired to the 20-city National Average of the ENR BCI for 1980 (1913 base). Vehicle costs should be updated by the ratio of the PPI for machinery and motive products to the PPI in 1980. Control equipment should be updated by the ratio of the PPI for electrical equipment to the PPI for electrical equipment in 1980.

Tables 8-9 and 8-10 were developed using references (1) through (8) and represent an attempt to capture the scale of the deployment and the local wage and efficiency conditions. Table 8-9 shows the default values for labor, energy, parts, services (elevators/escalators) and general administrative (liability) costs as functions of either service supplied or system size. Note the high fixed cost (23 people) which is independent of the size of the organization.

Table 8-10 shows how the default values can be adjusted for time, local wage and fringe rates, local labor availability, power costs, and vehicle energy usage. The wage rate is the fully burdened rate including all wage payments, fringe benefits, and non-labor overhead charges. The 1980 available hours represents direct productive hours. For example, the use of six central controllers assumes two people on duty at all times (see Appendix 8-A assumptions) and operation 16 hours per day 365 days per year. It would require 6.2 controllers if they were on the job 1880 hours per year. If more than 25 paid holidays, sick days, and vacation days were granted or if the controllers were only on duty 7 of 8 hours, then more than 6 people would be required. Actually, in the example, if 6.2 were the answer, 7 controllers would be required. We are assuming a homogeneous distribution of personnel. This is a crude way of predicting the effect of work rules and fringe benefits on labor requirements. The figure 1880 hours represents a ratio of pay hours to platform hours of .90 assuming 40 pay hours per week. The effective wage rate and power costs take inflation into account. The CPI ratios for parts, repairs, and liability take time and, if regional CPI's are used, location into account for operating cost. The cost adjustment procedure and an example (using proposed Los Angeles DPM system figures) are shown in Table 8-10.

8.3 WORKSHEETS FOR ESTIMATING DPM COSTS

Four worksheets, included in Appendix D, can be used to obtain the following DPM system costs:

TABLE 8 - 9

ESTIMATION OF UNIT OPERATING COSTS
(1980 Dollars)

Expense Category	Functional Category				
	Fixed	Per Veh-Mile	Per Lane-Mile	Per Station	Per Vehicle
Labor[1]	$645,000[2]	$.266	$22,100	$ 7,100	$4,000
Energy[3]		.250	800[4]	4,000	
Parts		.161	16,600		
Elev/Escal				6,000[5]	
Liability		.100			
Default Value	$645,000	.777	39,500	17,100	4,000

1. Assumes average wage and fringe of $13.48/hr and productive hours per employee of 1,880/yr.
2. Fixed staff includes: 6 in Central Control, 3 in General Admin., 3 Clerical, 3 in Maintenance Management, 2 Technical Staff, 6 in Customer Service or Security.
3. Assumes unit cost of electricity of $.05/KWHR.
4. Does not include cost to heat guideway. St. Paul preliminary engineering estimate for DPM system was approximately $75,000 per lane-mile of heated guideway.
5. Assumes 1 elevator and 1 escalator per station.

TABLE 8-10

ADJUSTMENT OF DEFAULT UNIT OPERATING COSTS (1980 DOLLARS) FOR LOCAL CONDITIONS AND YEAR

a.) Computation of Adjustment Factors

Expense Category	Local Cost Adjustment		Local Productivity Adjustment		Adjustment Factor
Labor	$\frac{\text{Ave. Wage \& Fringe}}{\$13.48}$	x	$\frac{1880}{\text{Productive Hrs./Yr.}}$	=	LF
Energy	$\frac{\text{Cost/KWHR}}{\$.05}$	x	$\frac{\text{KWHR/Veh.-Mile}}{5.0}$	=	EF1*
Energy	$\frac{\text{Cost/KWHR}}{\$.05}$			=	EF2*
Parts	$\frac{\text{CPI in Yr.}}{246}$			=	PF
Elev/Escal	$\frac{\text{CPI in Yr.}}{246}$			=	SF
Liability	$\frac{\text{CPI in Yr.}}{246}$			=	IF

*EF1 is applied in the per vehicle-mile cost adjustment and EF2 is used to adjust per lane-mile and per station costs.

b.) **Adjustment Procedure:**

Fixed cost = 645,000 x LF ______

Per vehicle mile cost = .266 x LF ______ + .25 x EF1 ____ + .161 x PF ______
+ .100 x IF ______

Per lane-mile cost = 22,100 x LF ____ + 800 x EF2 ____ + 16,000 x PF ____

Per station cost = 7100 x LF ____ + 4000 x EF2 ____ + 6000 x SF ____

Per vehicle cost = 4000 x LF ____

EXAMPLE: Assume 1980 local labor average wage and fringe is $23.90 and productivity is 1726 hours/year in Los Angeles; assume other default assumptions hold true.

a.) Compute Labor Adjustment Factor:

$$LF = \frac{23.90}{13.48} \times \frac{1880}{1726} = 1.93$$

b.) Adjust Default Unit Costs:

Fixed Cost = 645,000 x LF 1.93 = 1,244,850

Per Vehicle-Mile Cost = .266 x LF 1.93 + .25 x EF1 1.0 + .161 x PF 1.0 + .100 x IF 1.0 = 1.024

Per Lane-Mile Cost = 22,100 x LF 1.93 + 800 x EF2 1.0 + 16,600 x PF 1.0 = 60,050

Per Station Cost = 7100 x LF 1.93 + 4000 x EF2 1.0 + 6000 x SF 1.0 = 23,700

Per Vehicle Cost = 4000 x LF 1.93 = 7,720

- Capital costs for each of the eight components listed in Section 8.1, and total capital costs
- Annual operating costs
- Annual capital costs
- Total annual costs

This section contains a step-by-step description of these worksheets. As an example of the use of the cost estimation worksheets, they have been used to estimate the costs of the proposed Los Angeles DPM system.* The completed worksheets are shown in Tables 8-11 to 8-14. The default values presented in Tables 8-8, 8-9, and 8-10 are used for the unit costs on the worksheets. The computed summary cost measures and comparable estimates developed for the Los Angeles system are shown in Table 8-15.

8.3.1 Summary of System Characteristics

Worksheet A (Table 8-11) serves mainly as a place to collect each of the major input variables affecting system costs, and to compute the unique demand variable, daily equivalent peak hours, which is used on subsequent sheets. The following variables appear on this form:

- Lane-miles of elevated, at grade, and below grade guideway (ELM, ALM, BLM) - these variables pertain to the main guideway only. For DPM systems not consisting of uniform guideway sections, the length of each type of section (i.e., elevated, at grade, below grade) must be specified. This is important for estimating guideway costs, since unit costs vary widely for different guideway types. For one-way (i.e, loop) systems, the number of lane-miles is simply equal to the distance along the guideway. For two-way (i.e., linear) systems, the number of lane-miles equals two times the distance along the guideway. For more complex systems consisting of both linear and loop guideway sections (e.g., Los Angeles DPM), the calculation of guideway lane-miles may be somewhat more tedious.
- Extra lane-miles of guideway (EXM) - this variable must include all guideway not accounted for by ELM, ALM and BLM. The lengths of all storage lanes and of all connections to maintenance facilities and off-line stations must be included. If detailed estimates of

*The system specifications used in the example are based on October 1978 data obtained from the Community Redevelopment Agency of the City of Los Angeles, CA.

TABLE 8-11

A. SUMMARY OF SYSTEM CHARACTERISTICS

ELM	=	Lane-Miles of Elevated Guideway	= 5.88	ELM
ALM	=	Lane-Miles of At Grade Guideway	= 0	ALM
BLM	=	Lane-Miles of Below Grade Guideway	= .14	BLM
EXM	=	Extra Lane-Miles of Guideway	= .60	EXM
ELSTA	=	Number of elevated station platforms	= 18	ELSTA
AGSTA	=	Number of at grade station platforms	= 0	AGSTA
BGSTA	=	Number of below grade station platforms	= 1	BGSTA
NSTA	=	Total number of stations	= 13	NSTA
SSTA	=	Number of Station Platform Sides	= 22	SSTA
RTGD	=	Round-Trip Guideway Distance (miles)	= 5.45	RTGD
STIME	=	Round-Trip Schedule Time (minutes)	= 25	STIME
HDWY	=	Peak Period Headway (minutes/train)	= 1.8	HDWY
VCAP	=	Vehicle Capacity (passengers/vehicle)	= 41	VCAP
PVOL	=	One-Way Peak Per. Volume at Maximum Load Point (passengers/hour)	= 1754	PVOL
NDIS	=	Number of Days in Service (days/year)	= 365	NDIS
LPP	=	Length of Peak Period (minutes)	= 20	LPP

TABLE 8-11

A. **SUMMARY OF SYSTEM CHARACTERISTICS** (continued)

Assumed Demand Variation

	Time Period (I) From	To	Total Hours(I) H(I)	Fraction of Peak Period Demand FR(I)	Equivalent Peak Hours EPH(I)=H(I)*FR(I)
AM	6:00 AM	9:00 AM	3	.8	2.40
midmorning	9:00 AM	11:30 AM	2.5	.4	1.00
noon	11:30 AM	1:30 PM	2	.7	1.40
midafternoon	1:30 PM	4:30 PM	3	.4	1.20
PM	4:30 PM	6:30 PM	2	1.0	2.00
night	6:30 PM	9:00 PM	2.5	.3	.75

DEPH = Daily equivalent peak hours = $\sum_I EPH(I)$ = 8.75 DEPH extra lane-miles of guideway are not available (or are unnecessary), a crude approximation can be made by multiplying the lane-miles of main guideway (i.e., ELM+ALM+BLM) by a factor such as 0.10 (as is done in the cost estimation example presented here).

- Number of station platforms elevated, at grade and below grade (ELSTA, AGSTA, BGSTA) - these variables are needed for estimating construction costs associated with DPM stations, which are a function of the number of separate structures (i.e., platforms) which need to be built and the degree of difficulty of the construction (i.e., elevated, at grade, below grade). In the Los Angeles example, there are 12 elevated stations, no at grade stations, and 1 below grade station. Of the 12 elevated stations, 6 have split platforms (i.e., one on each side of the station), 3 have a center platform, and 3 have a single side platform. The total number of elevated platforms is thus:

  ELSTA = 6(2) + 3(1) + 3(1) = <u>18</u>

  The below grade station has a single side platform. Therefore, BGSTA=1.

- Total number of stations (NSTA) - in two-way systems, an individual station is assumed to provide access for travel in both directions along the guideway.

- Number of station platform sides (SSTA) - a station will generally have either one or two platform sides depending on whether trains travel through the station in one direction or in two. The value of this quantity is equivalent to the sum of ELSTA, AGSTA, and BGSTA, except that one additional side for each center platform must be accounted for. Thus, for the Los Angeles example:

  SSTA = 18 +0 + 1 + 3 ctr. plat. = 22 station sides

  This quantitity is a measure of the amount of control apparatus required to start and stop vehicles passing through the stations.

- Round-trip guideway distance (RTGD) - the value of this variable is equal to the distance traversed by a service vehicle in going from its origin station around the guideway and back to its origin station.

- Round-trip schedule time (STIME) - vehicle, rather than passenger, schedule time is required. Vehicle requirements are strongly dependent on the total time, including any turn-arounds and layovers, required for a DPM vehicle to make a complete circuit of the system.

- Peak period headway (HDWY) - this variable is the major operating policy characteristic which must be provided. Other operating policy characteristics, such as maximum train length and headways and train lengths in off-peak periods, are determined on subsequent worksheets based on predicted demand levels and reasonable assumptions about operator behavior.

- Vehicle capacity (VCAP) - this variable represents a combination of vehicle size and of a policy decision on the number of standees and amount of crowding to be allowed. If different candidate DPM systems are being evaluated, then this variable and some of the unit costs variables will be the major ones to vary by system.

- One-way peak period volume at maximum load point (PVOL) - this volume is the major input to the costing methodology from the demand analysis discussed in Section 7. As in all transit systems, DPM costs depend significantly on this variable rather than on total system ridership. The value of this variable should correspond to the chosen length of the peak period (LPP).

- Number of days in service (NDIS) - the value of this variable is equal to the number of days per year of revenue operation. This includes the number of holidays and weekend days as well as the number of weekdays of service.

- Length of peak period (LPP) - the value chosen for this variable should depend upon the nature of the peak period demand distribution. In some cases, peak demand is fairly uniform over the course of a one hour period; hence it may be appropriate to use a one hour peak period for obtaining the peak volume (PVOL). In other cases, an extremely high peak demand concentration may occur over a fifteen to twenty minute time period. For example, in analyzing peak hour volumes for the proposed Los Angeles DPM system it was found that one half of the peak hour volume was concentrated in a twenty minute span. In such cases it may be more appropriate for design purposes to use a peak period smaller than one hour.

- Assumed demand variation (H and FR) - the expected variation in demand levels over the day (FR(I)), expressed as fractions of peak period demand, is required. These variations can be obtained from the demand analysis discussed in Section 7. The number of hours (H(I)) for which each demand level is expected is also required. Six different time periods are suggested on the form, but alternatives may readily be used. For example, if a decision has been made to provide the maximum required train length and peak period headway for all 16 hours of daily operation, then only one period must be defined, with H(1) =16 and FR(1) = 1.0.

- Daily equivalent peak hours (DEPH) - the procedure required to compute this variable are provided on the worksheet. The resulting variable, used to determine vehicle-miles of service, incorporates the assumption that train lengths and/or headways will be adjusted in each of the defined time periods to provide just the required fraction of peak period capacity.

8.3.2 Estimation of Guideway, Vehicle, and Train Requirements

Worksheet B (Table 8-12) facilitates the computation of each of the DPM system variables needed to estimate system costs. Values for the following variables are required:

- Total one-way lane-miles (TLM) - this variable, required to estimate guideway capital costs, is computed from the ELM, ALM, BLM, and EXM variables specified on the first worksheet.

- Vehicles per train at maximum load point (VPT) - the values of PVOL, HDWY, LPP and VCAP specified on Worksheet A are used to compute this variable, which ensures that peak period capacity at the maximum load point will not be exceeded.

- Vehicles required past maximum load point (VPH) - based on the required vehicles per train and specified headway, the total number of vehicles which must pass the maximum load point in the peak hour are determined. Because the planned DPM systems are generally too small to provide for more than a single route, this same number of vehicles will usually be passing any point on the DPM system during the peak period.

- Vehicles required for revenue service (RVEH) - this variable depends directly on vehicles required past a point, and scheduled round-trip travel times (STIME).

- Total vehicles required (TVEH) - the revenue vehicle requirement is increased to account for the spare vehicles required to ensure both full service and required levels of maintenance. This is done using a factor which is the number of spare vehicles required per revenue vehicle. Typically, this factor will range from .1 to 1.0 for systems involving relatively new and untried technology.

- Average speed in revenue service (ASRS) - this average represents the overall nominal speed of DPM vehicles

TABLE 8-12

B. ESTIMATION OF GUIDEWAY, VEHICLE AND TRAIN REQUIREMENTS

Total One-Way Lane-Miles

TLM = ELM 5.88 +ALM 0 +BLM .14 +EXM .60 = **6.62** TLM

Vehicles Per Train at Maximum Load Point

VPT = [1 + PVOL 1754 x HDWY 1.8 /(LPP 20 x VCAP 41)] = **4** VPT

Note: [y] means the integer part of y, i.e., [4.7] = 4

Vehicles Required Past Maximum Load Point

VPH = 60 x VPT 4 /HDWY 1.8 = **133.3** VPH

Vehicles Required for Revenue Service

RVEH = VPH 133.3 x STIME 25 /60 = **55.5** RVEH

Total Vehicles Required

TVEH = (1 + spare vehicles per revenue vehicle .10) x RVEH 55.5 = **61** TVEH

Average Speed in Revenue Service

ASRS = 60 x RTGD 5.45 /STIME 25 = **13.1** ASRS

Annual Vehicle - Miles of Service

AVMS = RVEH 55.5 xDEPH 8.75 x ASRS 13.1 x NDIS 365 = **2,320,000** AVMS over the passenger service portion of the system (RTGD), based on the total round-trip vehicle travel time (STIME).

- Annual vehicle-miles of service (AVMS) - the revenue vehicles required (RVEH), daily equivalent peak hours (DEPH), and average speed (ASRS) variables computed previously along with the number of days per year in service (NDIS) are directly used to compute this variable, which is a major determinant of operating costs.

8.3.3 Estimation of Capital Costs

Each of the eight components of DPM capital costs, and total capital costs, can be computed using Worksheet C (Table 8-13). The component costs are determined as linear combinations of system variables (obtained or computed from the first two worksheets) multiplied by corresponding unit cost parameters. Blanks are provided on the worksheet for the user to input his/her own unit cost parameters if desired. For most of the cost factors, default unit cost parameters have been provided for possible use. These default unit costs are listed explicitly in Table 8-8, and a summary of the assumptions and cost references used to derive these has been included in Appendix 8-A and Section 8.4.

Total capital costs can be obtained from the worksheet by adding each of the eight component costs, plus a contingency fee which is computed as a fixed percentage of capital costs. As can be seen in Table 8-15, the capital costs estimated from the worksheets compare quite favorably with the preliminary engineering estimates for the Los Angeles DPM system. Of course, such a close cost estimate will only be expected to hold true when the assumptions of the default unit costs are in line with the actual engineering assumptions applied. When the assumptions of the default costs are not well matched to the actual DPM system design assumptions, the user should compute his/her own unit cost parameters.

8.3.4 Estimation of Annual Costs

Worksheet D (Table 8-14) provides an estimate of annual operating and capital costs, and total annual costs. Annual operating costs are computed as the sum of several cost factors, each multiplied by a corresponding unit cost parameter. Each of the cost factors (which can be obtained from the first two worksheets) captures the effects of several operating cost determinants; these include labor, energy, materials and services, and general and administrative (see Section 8.1). For example, the unit cost per station represents annual labor costs for supervisory, janitorial, fare collection, and station maintenance personnel; annual costs for station heat and

TABLE 8-13

C. ESTIMATION OF CAPITAL COSTS
(all costs in millions of 1980 dollars)

1) Guideway Costs

GDWY$ = ELM 5.88 x cost/lane-mile, elevated 3.43

+ ALM ____ x cost/lane-mile, at grade ____

+ BLM .14 x cost/lane-mile, below grade 11.80

+ EXM .60 x cost/lane-mile, extra 1.31 = **22.61** GDWY$

2) Station Costs

STA$ = ELSTA 18 x cost/station platform, elevated .500

+ AGSTA ____ x cost/station platform, at grade ____

+ BGSTA 1 x cost/station platform, below grade 1.72 = **10.72** STA$

3) Vehicle Costs

VEH$ = [Fixed cost/veh. .248 + cost/sq. ft. .00068

X (fixed sq. ft./veh. 32 + VCAP 41

X sq. ft./passenger 3.19)] x TVEH 61

OR

VEH$ = cost/veh. .357 x TVEH 61 = **21.72** VEH$

4) Control Costs

CNTL$ = FIXED 1.95 + TLM 6.62 x cost/lane-mile .30

+ SSTA 22 x cost/station side .028

+ TVEH 61 x cost/vehicle .005 = **4.86** CNTL$

TABLE 8-13

C. ESTIMATION OF CAPITAL COSTS (continued)
(all costs in millions of 1980 dollars)

5) Power Supply Costs

PWR$ = TLM 6.62 x cost/lane-mile .560
+ NSTA 13 x cost/station .280 = 7.35 PWR$

6) Maintenance Support Costs

MAINT$ = FIXED 1.18 + TLM 6.62 x cost/lane-mile .025
+ TVEH 61 x cost/vehicle .058 = 4.89 MAINT$

7) Direct Costs

DCOST$ = GDWY$ 22.61 + STA$ 10.72 + VEH$ 21.72
+ CNTL$ 4.86 + PWR$ 7.35 + MAINT$ 4.89 = 72.15 DCOST$

8) Engineering and Project Management Cost

EPM$ = DCOST$ 72.15 x Eng. & Proj. Mgt. rate .252 = 18.18 EPM$

9) Contingency Cost

CONT$ = [DCOST$ 72.15 + EPM$ 18.18] x contingency rate .12 = 10.84 CONT$

10) Right-of-way Costs

ROW$ 17.6 = 17.6 ROW$

11) Total Capital Costs

TCAP$ = DCOST$ 72.15 + EPM$ 18.18
+ CONT$ 10.84 + ROW$ 17.6 = 118.77 TCAP$

TABLE 8-14

D. ESTIMATION OF ANNUAL COSTS
(all costs in millions of 1980 dollars)

1) Annual Operating Costs

AOP$ = AVMS 2,320,000 x cost/vehicle-mile .000001024

+ TVEH 61 x cost/vehicle .007720

+ NSTA 13 x cost/station .023700

+ TLM 6.62 x cost/lane-mile .060050

+ FIXED 1.25 = **4.78** AOP$

2) Annual Capital Costs

ACAP$ = ROW$ 17.6 x CRF (ROW) .08 + (VEH$ 21.72

+ CNTL$ 4.86 + PWR$ 7.35 + MAINT$ 4.89)

x CRF (Vehicles) .149 + (GDWY$ 22.61 + STA$ 10.72)

x CRF (Structures) .089 = **10.16** ACAP$

3) Total Annual Costs

ATOT$ + AOP$ 4.78 + ACAP$ 10.16 = **14.94** ATOT$

TABLE 8-15

COMPARISON OF COST ESTIMATION OUTPUTS WITH LOS ANGELES DPM ESTIMATES
(all costs in millions of 1980 dollars)

COST CATEGORY	FROM WORKSHEETS	CRA ESTIMATES*
Capital Costs		
Guideway	22.6	26.4
Stations	10.7	17.2
Vehicles	21.7	21.2
Control System	4.9	5.4
Power Supply	7.4	8.5
Maintenance Support	4.9	4.7
Eng. & Project Management	18.2	19.2
Contingency	10.8	12.4
Right-of-Way	17.6	17.6
Total Capital	118.8	133.3
Annual Operating Costs	4.8	5.0

*Cost figures obtained from the Community Redevelopment Agency (CRA) of the City of Los Angeles, California, December 1978. Adjusted by the FNR index for infrastructure, the producer price index for vehicles and the CPI for project management, ROW, and annual operating costs. Contingency remains at 12% of all other costs except ROW.

electricity; and annual costs for elevator and escalator operation.

Blanks have been provided on the worksheet for user-specified unit costs. As was done for estimation of capital costs, the default unit cost parameters have been used for illustration for estimating annual operating costs. A listing of the default unit costs for estimating annual operating costs is given in Table 8-9 and the method for adjusting these costs is shown in Table 8-10. A summary of the cost references and assumptions used in deriving these default unit costs is given in Section 8.4 and Appendix 8-A of this section.

As can be seen in Table 8-15, the annual operating cost estimated from the worksheet compares closely with that estimated for the Los Angeles DPM system. The closeness of the cost figures can be attributed principally to the adjustments made for labor assumptions. The Los Angeles assumptions for labor wage (including fringe and overhead) are considerably higher than those used for deriving the default unit costs (about $24./hour average vs. $13.50/hour average). Assumptions for labor availability also differ greatly between the two estimates (approximately 1726 hours/person/year - LA; 1880 hours/person/year - default). Combined, these two differences in assumptions mean that the default unit costs needed to be adjusted for specific local conditions. The adjustments made to the default unit operating costs are shown in the example in Table 8-10.

Annual capital costs can be computed with varying assumptions about the economic life of purchased right-of-way, vehicles and vehicle-related components, and structures. Standard assumptions would be the following:

- Right-of-way - infinite life
- Vehicles - ten years
- Structures - thirty years

These costs also depend on the assumed interest rate. Table 8-16 shows capital recovery factors (CRF's) for a range of economic lives and discount rates.

As a final step, total annual costs are obtained by summing annual capital and operating costs.

TABLE 8-16

CAPITAL RECOVERY FACTORS

Economic Life	Discount Rate			
	6%	8%	10%	12%
5	.237	.250	.264	.277
10	.136	.149	.163	.177
15	.103	.117	.131	.147
20	.087	.102	.117	.134
25	.078	.094	.110	.127
30	.072	.089	.106	.124
35	.069	.086	.104	.122
40	.066	.084	.102	.121
	.060	.080	.100	.120

8.4 REFERENCES

1. U.S. DOT/Transportation Systems Center, Assessment of Operational Automated Guideway Systems - AIRTRANS (Phase II), Chapter 5, March 1979.

2. N.D. Lea and Associates, Inc., Summary of Capital and Operations and Maintenance Cost Experience of Automated Guideway Transit Systems, UMTA-IT-06-0157-78-2, June, 1978.

3. N.D. Lea and Associates, Inc., Supplement I, Summary of Capital and Operations and Maintenance Cost Experience of Automated Guideway Transit Systems Costs and Trends for 1976-1978, UMTA-IT-06-0188-79-1, March 1979.

4. City of St.Paul and Metropolitan Transit Commission, Preliminary Engineering and Related Studies for St. Paul Downtown People Mover, Final Report, MTC-TD-79-1, February, 1979.

5. Community Redevelopment Agency of the City of Los Angeles, California, "Preliminary Cost Estimates for Los Angeles Downtown People Mover," December, 1978.

6. Custom Engineering, Analysis and Correlation of Morgantown Phase II System Costs for Applicability to DPM System Costs, August, 1978.

7. U.S. DOT/Transportation Systems Center, Supplement II, Summary of Capital and Operations and Maintenance Cost Experience of AGT Systems, Costs and Trends 1976 - 1979, UMTA-MA-06-0069-80-1, March 1980.

8. U.S. DOT/Transportation Systems Center, Supplement III, Summary of Capital and Operations and Maintenance Cost Experience of AGT Systems, Costs and Trends 1976 - 1980, UMTA-MA-06-0069-81-2, July 1981.

9. Bhatt, K., "Draft Guidelines for the Estimation of Transit Cost," Urban Institute Report 1266-100, November 1980.

APPENDIX 8-A

Assumptions for Default Capital Cost Parameters

1. **Elevated Guideway**

    a. bottom supported, 50 passenger vehicles
    b. 6-meter columns, drilled caissons
    c. 30% curved, urban construction

2. **At Grade Guideway**

    a. urban construction

3. **Below Grade Guideway**

    a. urban construction
    b. cut/cover

4. **Extra Guideway**

    a. same unit cost as for at grade guideway

5. **Elevated Stations**

    a. platform dimensions: 4 meters wide x 32 meters long
    b. 2 car trains = 14 meters long
    c. 2 doors/car
    d. 1 elevator, 1/2 escalator up
    e. free standing station, 7.3 meters high
    f. 2 ticket machines, cameras, phones, etc.
    g. side platform

6. **At Grade Stations**

    a. platform dimensions: 6 meters wide x 32 meters long
    b. 2 car trains = 14 meters long
    c. 2 doors/car
    d. free standing station
    e. 2 ticket machines, cameras, phones, etc.
    f. center platform

7. **Vehicles**

    a. cost relationships developed using data from Table 8-4.
    b. cost per vehicle is a linear function of the size (i.e., floor area) of each vehicle, and the size is a linear function of the passenger capacity.

8. Control/Communications

   a. fixed control cost equals cost for central command/control computer and central communications.
   b. central computer with full ATO, ATP, ATS (Automatic Train Operation, Protection, Supervision).

9. Power

   a. one power substation per station

10. Maintenance

   a. fixed cost represents costs for maintenance/administrative and storage buildings at unit cost of $570./meter^2.

Assumptions for Default Operating Cost Parameters

1. 2 persons in central control
2. 5¢/KWH for energy
3. Chicago heating/cooling requirements
4. 1880 available man-hours/person/year
5. 2.3 meters/guideway width to heat
6. 5.0 KWH/vehicle-mile vehicle energy requirement
7. hourly wage including fringes and overhead = $13.48/man-hour
8. system operates 16 hours per day, 365 days per year

9. CIRCULATOR REVENUE ESTIMATION

9.1 INTRODUCTION

The process of estimating downtown circulator system revenue is primarily a process of selecting the desirable mechanisms for recovering revenue and then estimating the success of the circulator system in attracting ridership. This section presents a variety of mechanisms for recovery including various user fare structures, various value capture and joint development schemes, and a variety of schemes which involve parking revenues for DPM operations.

The discussions in this section are intended primarily as a synopsis of the issues involved in revenue generation. The implications of each of the alternative schemes are discussed with respect to the likely effects on system usage, usage of other modes of travel, and development impacts in the downtown area.

The actual estimation of DPM revenue is basically an accounting of the chosen revenue mechanisms and an estimation of the likely success of each. Worksheets are provided to aid in this manual accounting and to relate the revenue estimation process to the demand estimation procedure suggested in Section 7. These worksheets are included both in Appendix 9-A of this section and in Appendix D of Volume 3 of the report.

9.2 ALTERNATIVE FARE STRUCTURES

A variety of fare structures currently being employed by transit agencies around the country can be considered for use on a DPM system. Each of the fare structures has different implications and effects on both system ridership and system revenues. The use of a particular fare structure may vary according to local priorities and policies, but should reflect consideration of the issues raised in the following questions:

- What will the relationship be between the DPM fare and the fare on other transit modes; will special fare arrangements be considered to allow and encourage transfer opportunities between the DPM and feeder modes?

- Will a reduced DPM fare structure be adopted temporarily to initially promote the system?

- Will special fare structures be adopted to reflect the distance travelled or the time of day of travel?

- Will special fare structures be adopted for particular population subgroups?

- Will fare arrangements be coordinated with the private sector to reflect special fare discounts for persons using the DPM for particular activities (e.g., restaurants, shopping, etc.)?

These issues will be discussed in the context of the range of fare structures which are currently being used on transit systems in the United States. A brief description of each fare structure and its applicability to a DPM system is presented below.

9.2.1 Flat Fare

The flat fare structure charges the same price for all trips. It does not recognize distance travelled, time of day of travel, special user characteristics, etc. The major advantage of a flat fare structure is that it is easily understood by the rider and easily administered by the transit operator. The major disadvantage of the structure is that it does not capture the differential values that riders place on the transit trip and the differential cost of providing particular trips to the transit user. An example of this is when the same fare is charged for a long suburban trip by a middle-upper class user as for a short trip by a low income user.

This fare structure is most appropriate when the trip characteristics of users are similar. In that the short distances of DPM systems tend to ensure that the trip lengths for users are similar, a flat fare system can be equitable from the perspective of the transit rider and the transit agency.

The flat fare can utilize basic fare collection devices since no special sorting or counting ability is required. In this respect, the costs of fare collection equipment and labor should conform to the costs for flat fare collection on other systems.

9.2.2 No Fare

The free fare has the same characteristics as the flat fare except that instead of a positive out-of-pocket charge to all users, there is no charge. The advantages and disadvantages discussed for the flat fare system also apply to the no fare system but each of the positive and negative aspects become exaggerated when a free fare is applied.

The no fare structure has been implemented on several transit systems (sometimes as part of a Federal demonstration program) in order to encourage increased use of transit, particularly by those persons who are currently making the trip by auto. Decisions must be made as to whether a free fare would apply to all transit trips, at all times and for all riders, or whether the free fare will be applied selectively. One of the more popular applications of no fare has been on downtown circulation systems during offpeak hours.

Obviously, in the short run, a no fare system results in a loss of fare box revenues if a fare had been charged previously. However, if a free fare results in permanent mode shifts from auto to transit, then when a positive fare is re-introduced after a designated time period, fare box revenues may be higher than they were prior to the implementation of the free fare.

The labor costs and the operating costs of the equipment associated with fare collection may be eliminated for the period of time in which the free fare is in use. In addition, if no fare equipment has been purchased previously, a cost savings can be achieved here. However, if a decision is made to impose a fare, collection costs will be introduced (or re-introduced) at this time. The magnitude of the costs will reflect the level of equipment, sophistication, and personnel required for the fare collection process.

A decision on whether to adopt a no fare structure for a DPM system, of course, depends upon the financial feasibility of this alternative. The results obtained from travel demand forecasting models and an analysis of fare elasticities should be included in the analysis of financial feasibility as an indication of potential fare box revenues if the free fare is only to be implemented on a temporary basis.

9.2.3 Differentiated Fares

A differentiated fare structure implies a varying price structure for a transit trip based on any of several factors. These include distance travelled, time of travel, level of service provided, and population group served. The rationale for adopting a differentiated fare structure is that the cost of providing the trip varies for different trips, or the value of making the trip differs for groups of transit riders. Thus, setting fares to reflect the above issues injects equity considerations into the setting of fare structures. For an example, refer to the situation of the suburban commuter versus the inner city rider illustrated in the discussion on flat fares. With a differentiated fare, the suburban commuter could be charged a higher fare than the inner city traveller to reflect the longer distance travelled, possibly a higher level of service, and the higher value of the transit trip to this person.

Several methods may be applied to design a distance-based fare structure. These include grid systems, concentric circles, segmented circles, etc. When a rider crosses a boundary from one zone to another using any of these methods, the fare will increase in a specified manner as established by policy. Because the DPM systems usually are short systems, it would not be appropriate to differentiate fares strictly on the basis of distance travelled on the DPM system.

The labor and equipment costs for collecting differentiated fares are likely to be higher than for collection of flat fares. More sophisticated equipment is required to handle a differentiated fare structure if the fare collection process is automated. Labor requirements can vary although it may be expected that higher labor needs are associated with manual collection of differentiated fares.

Time-differentiated fares usually distinguish between the peak versus the offpeak traveller. Experience dictates that the heaviest ridership occurs during the peak periods. Very often, rolling stock that is acquired to serve peak hour travel sits idle during the rest of the day. Conventional microeconomic theory indicates that to reflect this situation and to reflect the increased level of congestion and thus discomfort that each additional peak transit rider is imposing on the other transit riders, the fare charged during peak hours should be higher than in the offpeak. This argument, however, does not take into account externalities and does not consider the situation from the perspective of the entire transportation network. In this light, the peak-hour transit rider is providing a benefit to the motorist by reducing the level of congestion on the highway. Viewed in this way, one could argue that the motorist should be willing to subsidize the transit rider and low transit fares should be applied to encourage peak hour transit ridership.

Different fare structures can also be arranged for particular population subgroups. School children and the elderly and handicapped population are two such groups that have in recent years enjoyed special fare privileges on transit systems. Of particular importance are Federal regulations requiring all transit systems to charge a maximum of one half of the basic fare to elderly and handicapped riders during offpeak periods. The DPM system would similarly be subject to these regulations, but other fare arrangements for particular population groups could also be established as long as they meet the Federal regulations.

9.2.4 Value-Based Fares

A value-based fare structure uses the criterion for pricing as the highest price a person would be willing to pay for the transit service. This type of fare structure may be used in two kinds of situations. The first case is where a decision has already been made to provide a certain kind and level of service. In this situation a value-based fare will reflect the highest fare that can be charged and still utilize the service to capacity. In the second case, a value-based fare is applied in determining whether or not to provide special transit services. Once again, using the tenets of microeconomic theory, the special service should be provided only if the revenue generated exceeds the incremental cost of supplying the service. Examples of special services would include providing transit to airports, ballparks, etc. Generally, used in this latter application, the value-based fare is not appropriate for a DPM system since the DPM service is a fixed guideway service and is therefore not flexible with regard to its route. A value-based fare may be appropriate, however, if a special event would necessitate operating the DPM system outside the normal operating hours.

9.2.5 Other Fare Structures

Three other fare structures will be briefly discussed here: promotional fares, package fares (for using a combination of transit modes), and special multiple use fare passes.

9.2.5.1 The promotional fare was introduced previously in the discussion on free fares. The basic characteristics of a promotional fare are that it is a reduced or free fare and it is implemented for a temporary time period. The objective of this kind of fare is to attract new riders to the system and, hopefully, to achieve a permanent mode shift from auto to transit even after the promotional low fare has been replaced by the basic fare. This kind of fare can be used on a DPM system.

9.2.5.2 A package fare is structured to enable a person who is riding a combination of transit modes to pay less than the full price that would be required for each of the separate transit modes. This fare policy encourages transfers between modes and can be specifically structured to encourage the use of one type of transit mode. In the case of a DPM system, a package fare could be designed for those persons using bus or rail to get to the CBD and then transferring to the DPM system for the final distribution part of their trip. Another variation of the package fare would be one designed for auto drivers who park at DPM intercept points, paying a combined parking charge and round-trip DPM fare. Arrangements for this type of fare package are simplified when the same agency administers all transit and parking operations. However, joint power agreements can be pursued when responsibilities among agencies are fragmented.

9.2.5.3 Finally, multiple use fare passes, like the package fares, provide a cost savings to the user of a particular transit service. Special reduced monthly passes, weekly passes, etc., can be offered to encourage people to use the services more frequently. As an example, special multiple use reduced fare passes can be offered for DPM riders to encourage noon hour shopping trips, restaurant trips, etc.

9.2.6 Implications of Fare Changes on Revenue

Much research has been directed toward the impacts of fare changes on system ridership and system revenues. While this research will not be reiterated here, some of the conclusions that may relate to DPM fare considerations are mentioned below:

- The demand for transit service by the elderly population is highly insensitive to fare level. Reduced fares for the elderly have consistently led to losses in revenue.

- The demand for transit service is more responsive to fare changes in the offpeak hours than during peak hours. Thus, the effect of fare increases during peak hours will result in less ridership loss and greater revenues than in the offpeak. Fare reduction during peak hours will result in fewer additional riders than would a fare reduction in the offpeak. Therefore, the loss of revenues due to the reduced fare is greater during peak travel than offpeak travel.

- For any given percentage fare change, the percentage change in ridership is less. Therefore, although the absolute effect on revenue depends on several factors, in general, a fare increase will result in some loss of ridership but with increased fare box revenues, while a fare reduction will result in increased ridership but with a loss of revenue.

9.3 VALUE CAPTURE AND JOINT DEVELOPMENT

The concept of value capture/joint development has been identified throughout this manual as a mechanism by which local public agencies and transit districts can potentially increase their revenues using more innovative revenue generating techniques. This discussion provides a summary of the concept and various value capture techniques and includes examples of recent value capture or joint development applications. It is hoped that this background information can be of assistance to local planners and decision makers who may consider further study or utilization of this concept.

9.3.1 Value Capture: Definition, Premise and Objective

Value capture is a procedure whereby the land adjacent to transportation facilities is purchased, managed or controlled in a way that will enable the public to share in potential financial and community design benefits that may result from the facilities which would not otherwise be possible.

The idea of value capture embodies the theory that privately owned land near transit stations and stops may increase in value as a result of the commercial, industrial, and residential development potential created by improved access to these areas. The concept of value capture and joint development explores the potential for public and private participants to work cooperatively to generate these increased financial benefits and, in turn, "capture" these benefits for their mutual interests. Different value capture and joint development techniques result in a different share of the benefits going to public versus private participants. In general, however, the use of value capture is seen as a way in which local agencies may reduce some of the public costs associated with the system, by applying the financial benefits realized through value capture to the cost of the system's operations and possibly system construction.

9.3.2 Alternative Value Capture and Joint Development Techniques*

There are two broad categories of value capture and joint development techniques. The first category can be labelled real property development techniques, and the second, taxation techniques. Real property development involves the acquisition of real estate by the transit authority alone or jointly with public agencies and/or private interests, for purposes broader than may be warranted by the transit facilities alone. The taxation techniques involve special taxing arrangements by public agencies in order to capture some of the financial benefits within a defined area that may be attributed to the transit system.**

Specific techniques within each of these categories are summarized below:

9.3.2.1 Real Property Development Techniques

Develop/Hold - The entity constructs transit-related facilities around a rapid transit station and leases or rents these facilities. Public participation in the development of facilities can enhance the potential for community design inputs while generating revenues through lease and rental agreements.

Develop/Sell - The entity acquires land and develops transit-related improvements and facilities on it. At the completion of the construction of the transit system, the land and facilities are sold. As in the develop/hold technique, the public here participates in the community development process.

Hold/Sell - Fee, simple interest, and other development rights (air or subsurface) of transit-related land parcels are acquired by the entity. Then at a future date when the development of these parcels meets appropriate public purposes, the land or rights are sold subject to specific use conditions.

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*Many of the value capture and joint development techniques discussed in this section are adapted from the work on value capture prepared for the U.S. Department of Transportation by the Rice Center for Community Design and Research, Houston, Texas.

**It is important to note that the use of any particular technique is conditioned upon the legal and institutional setting in which it is to be applied. Some states and localities have legal or institutional restraints which would preclude the use of certain techniques unless steps were taken to amend existing legislation or to introduce new legislation and institutional arrangements.

Lease - After acquiring land related to the transit facility, the entity enters into long term ground or air/subsurface rights, lease of the land, or related development rights subject to specific development programs in terms of community design and public finance benefits.

Participation - Interest in transit-related land parcels or development rights is ceded to other private or public parties for development at rapid transit station locales. Under some circumstances the transit or development entity may participate in a portion of the income stream produced by the new development, possibly through equity participation or through the utilization of leases which involve the payment of a percentage of the gross sales or income to the transit agency by the private developer.

Incentive Zoning - Special zoning is applied to encourage certain types of development by private interests on land within a defined area of transit stations. This zoning may be targeted to achieve specific community design and/or public finance benefits.

9.3.2.2 Taxation Techniques

Ad Valorem - The transit or development entity would levy a tax on the assessed market value of land and improvements within the entity's taxing jurisdiction or the particular political subdivision served by the transit system.

Special District - An ad valorem tax would be levied by the entity on a district basis to include the property in the transit station locale which receives special benefits from the transit facility. The entity would, through the separate tax on the assessed valuation of the market value of the land and its improvements, receive some of the financial benefits that result, specifically attributable to the transit facilities.

Tax Increment - This instrument also uses a district; however, no new taxes are introduced. The entity receives, per agreement, all or part of the ad valorem tax revenues on the increment or net difference between the assessed valuation on the market value of the land and its improvements at some future date and the assessed valuation "frozen" at a point prior to the construction of the transit improvements. (This technique is also known as marginal value taxation.)

9.3.3 Issues Related to the Use of Value Capture and Joint Development

Some problems may arise in the use of value capture techniques. First is the interpretation of "public use and public purpose". In many cases, these terms require a liberal interpretation in order for the public agencies to be able to exercise the power of eminent domain, supplemental condemnation and subsurface rights in conjunction with the transit facilities.

the financial benefits which will result from the implementation of the transit system around stations. In particular, how does one determine precisely the impact areas and the magnitude of the impact at different distances from the transit station. This is particularly important when considering the use of value capture taxation techniques.

Related to the above is whether revenues from value capture and joint development techniques may be available for system construction. Because the value capture revenues generally accrue after initiation of system operations and after public or private investments in surrounding real estate have been made, and because the resulting financial benefits are difficult to predict with certainty before they occur, the use of value capture revenues for system construction is not likely.

It should be noted that a systematic application of several value capture and joint development techniques may be most productive in order to take account of the specific local conditions in the vicinity of each of the stations.

9.3.4 Selected Examples of Value Capture and Joint Development Applications

The interest in and use of value capture and joint development techniques has substantially increased within the past few years, encouraged by recent Federal policies which have urged consideration of these techniques. Some recent examples are mentioned below:

- Market Street, San Francisco - Market Street in downtown San Francisco is an example of joint development along the BART system. A special Mayor's office, the Transit Task Force, was created to foster this effort. The use of incentive zoning which gave bonuses for the construction of transit related improvements, and the use of increment financing to pay for the Embarcadero Station, are major elements of this program.

- Metro System, Montreal - Extensive joint development has been incorporated into the Metro system in Montreal. The system is viewed as an integral part of a comprehensive pedestrian movement system which provides four miles of shopping promenades and is separated from automobiles. Bus stations are connected with concourse levels of major shopping plazas. Department stores are often connected into subway mezzanines. The Hotel Bonaventure is directly connected to Metro by a subway station beneath the hotel.

- Current DPM Cities - Several of the selected first round DPM cities are incorporating value capture and joint development strategies into their system planning. In particular, Houston has done extensive study of the potential of value capture and has determined that the techniques of most interest involve development participation and air rights leasing options.

9.4 PARKING REVENUES

Parking facilities planned in conjunction with selected DPM stations can be an important contributing factor to increased DPM ridership. The objective of having major auto intercept areas at fringe areas of the CBD, conveniently located to DPM stations, is to encourage motorists to transfer to the DPM system for trip destinations within the CBD. The existence of major parking facilities at intercept points is required to make this concept operational.

In addition to fare box revenues from riders who transfer to the DPM at the intercept areas, a program may be designed to channel some of the parking revenues collected at these fringe parking areas to the DPM operations. The extent of net revenues that may be available depends upon the following factors:

- Revenue Factors
  - parking user charge per space
  - number of parking users
  - number of parking spaces
- Cost Factors
  - number of parking spaces
  - amortization and operation of parking area

Obviously, the parking user charge required to cover amortization and operating costs of the fringe parking facilities must compete favorably (taking into account the combined cost of peripheral parking and the DPM fare) with close-in or on-site parking. Only then will there exist the potential for encouraging mode shifts to the DPM, and the possibility of having net parking revenues available for DPM operation. An exception to this condition is if the criterion for parking at a fringe area lot is not one of choice, but is mandated either by auto restrictions in the CBD, employer policies, or unavailability of close-in or on-site parking.

Variations of the basic peripheral parking concept can be structured to provide additional revenues for DPM system operations. The advantage of additional revenues is that it allows a greater flexibility in setting peripheral parking rates. A low price may be set that is competitive with close-in and on-site parking, yet which covers the parking area amortization and operation costs and still provides revenues for DPM system operations. An example of such a program is the Peripheral Parking Substitution Program which is an integral component of the Los Angeles DPM Financing Plan. The rationale for this program,, as well as the primary features of this program are described below.

The basic concept of the Los Angeles peripheral parking substitution program is to allow private developers to substitute low-cost peripheral parking for high cost on-site structure parking if the developers provide some of their "saved" costs to support the DPM system.

Currently, municipal building codes require developers of new office buildings in the Los Angeles CBD to provide one parking space per 1,000 square feet of net floor area. However, since there is a parking demand for between two to three spaces per 1,000 square feet of office area, many developers provide parking in excess of the code requirements in order to successfully market the private office space. Low-cost surface parking also exists within walking distance of office complexes, thereby allowing the number of on-site parking spaces constructed to be less than total demand.

As downtown development growth in Los Angeles makes space more valuable, the lower cost surface parking will be replaced by development. To maintain a competitive market position, developers will be required to provide a higher ratio of parking spaces within the office structures.

The approximate 1976 cost for providing parking within office buildings is $8,000 - $10,000 per space for below surface parking, and between $4,000 - $5,000 per space for above-grade parking. In comparison, the estimated cost of peripheral parking is between $2,000 - $2,500 per space. In most cases, the revenue generated from privately owned parking within developments does not cover amortization of the spaces and is less than the net revenue that could be generated by converting an equivalent amount of area to office space use.

Thus, it was felt by the agency planning the Los Angeles DPM that, for the future, developers, and property owners would be interested in an arrangement in which they could reduce their costs by decreasing the amount of on-site parking they had to provide if they could still maintain a competitive position in the downtown market.

Since the cost of parking spaces on the periphery of the CBD is significantly less than on-site structure parking, the parking substitution program would allow the developer to substitute a certain percentage of peripheral parking for on-site structure parking, and the DPM system would provide the connection between the parking area and the office complex. The developer in turn would be assessed a certain fee for each on-site space not built which would be applied to DPM operations.

Four variables were identified which could be expected to influence the developers' attitude towards this program. They are:

- Cost of constructing on-site parking
- Perceived need for providing on-site parking on specific sites
- Market and investment acceptability of using peripheral parking as a substitute for on-site parking
- Effectiveness of the DPM connection between the office structure and the parking garage

A condition which must exist, however, is that the cost to the developer of the peripheral parking space plus the assessment for the on-site space not built is less than the equivalent cost for an on-site space.

The revenue projection in 1976 dollars for private sector contributions to the Los Angeles DPM system from the parking substitution program is $1,243,200 per year assuming 3,700 privately supported spaces. This projection is derived as follows: (1) user charges at peripheral lots would be set at $20 - $25 per month to cover the $2,000 - $2,500 cost of the space, (2) developers' savings from reduced annual operating costs for parking would be between $25 and $30 per month per space, and (3) developers would be assessed $20 per month for each on-site space not built which would be applied to DPM operations.

Legally, the municipal zoning and building codes would have to be modified to allow for a reduction of parking spaces required per square feet and an increase in the allowable distance of parking spaces from a building if the owner participates in the DPM program. The DPM planners in Los Angeles do not expect this to be a major problem.

Another situation which could occur as a result of DPM implementation is reduced parking revenues for individual parking area operations within the CBD. Travel demand models should be used to provide information on changed trip patterns into and within the downtown and the resulting impact on parking revenues in various CBD locations. While this situation will be important to the particular parking area owners affected, it will not necessarily affect the financing for the DPM system. The DPM funding will, however, be affected if changed trip patterns result in reduced revenues at municipally-owned parking areas and it was intended that these revenues either directly (through earmarking) or indirectly (as a source of local general revenues) were to be used as local support for the DPM operations.

The revenue calculation worksheets contained in Appendix 9-A of this section and in Appendix D of Volume 3 display how the above described situations should be included in the financial analysis of the DPM system.

APPENDIX 9-A

REVENUE CALCULATION WORKSHEETS

I. REVENUE COMPONENTS AND CALCULATION VARIABLES

REVENUE COMPONENT	CALCULATION VARIABLES		VARIABLE NAME
Fares	• Projected number of daily trips (from demand models) by:		
	population group	$TRIPS_P$ =	
	origin/destination	$TRIPS_{O/D}$ =	
	• Fare level (base)	$FARE_R$ =	
	• Adjustment factor to reflect trips made using discounted fares (1)	ADJ =	
	or		
	Calculation of trips with discounted fares using rider profile (from demand models) and applying fare discounts	$TRIPS_{DISC}$ =	
		$FARE_{DISC}$ =	
	• Equivalent revenue days per year	EDAYS =	
Parking			
a. Parking facilities at DPM intercept points	• Parking charge:		
	- hourly for short term use	$PRICE(DPM)_H$ =	
	- daily for long term use	$PRICE(DPM)_D$ =	
	• Number of daily parking users (from parking lot choice models):		
	- short term	$USERS(DPM)_S$ =	
	- long term	$USERS(DPM)_L$ =	
	• Average number of hours/short term user	HOURS(DPM) =	
b. Municipal parking facilities not directly served by DPM	• Parking charge:		
	- hourly for short term use	$PRICE(M)_H$ =	
	- daily for long term use	$PRICE(M)_D$ =	
	• Number of daily parking users (from parking lot choice models):		
	- short term	$USERS(M)_S$ =	
	- long term	$USERS(M)_L$ =	
	• Average number of hours/short term user	HOURS(M) =	
	• % parking revenues earmarked for the DPM or applied to the DPM from local general revenues	$\%DPM_{PKG}$ =	

I. REVENUE COMPONENTS AND CALCULATION VARIABLES, continued

REVENUE COMPONENT	CALCULATION VARIABLES	VARIABLE NAME	
Advertising	• Projected advertising revenues per year	ADREV =	
Local general revenues which may be applied towards DPM(2)			
a. Sales Tax	• Sales tax rate	$RATE_S$ =	
	• Amount of annual sales in downtown	SALES =	
	• % Sales tax applied towards DPM	$\%DPM_S$ =	
b. Payroll Tax	• Number of employees in downtown	EMP =	
	• Average annual income of downtown employees	INCOME =	
	• Payroll tax rate	$RATE_E$ =	
	• % payroll tax applied towards DPM	$\%DPM_P$ =	
c. Property Tax	• Assessed value of property in downtown	VALUE =	
	• Property tax rate	$RATE_P$ =	
	• % property tax applied towards DPM	$\%DPM_{PT}$ =	
Value Capture/ Joint Development(3)			
a. Parking substitution	• Number of peripheral spaces substituted for on-site spaces	SUBST =	
	• Yearly assessment to developer per substituted space	$PRICE_{SUBST}$ =	
b. Private development in conjunction with DPM stations(4)	• Present value of property/business	$VALUE_T$ =	
	• Expected new value of property/business from the DPM	$VALUE_{T+1}$ =	
	• Improvement costs incurred	$COST_{DEV}$ =	
	• Yearly assessment to developer per dollar of increased value	$PRICE_{DEV}$ =	

c. Real property development techniques
d. Taxation techniques
} Refer to discussion in Section 9 on Value Capture(5).

REVENUE CALCULATION WORKSHEETS

II. CALCULATION OF INDIVIDUAL REVENUE COMPONENTS

1. Fare Revenue

$TRIPS_P$ or $TRIPS_{O/D}$ x $FARE_R$ x (1-ADJ) x EDAYS = [Fare Revenues/Year]

or $TRIPS_P$ or [$TRIPS_{O/D}$ x $FARE_R$ - $TRIPS_{DISC}$ x $FARE_{DISC}$] x EDAYS = [Fare Revenues/Year]

2. Parking Revenue

[$PRICE(DPM)_H$ x HOURS(DPM) x $USERS(DPM)_S$ + $PRICE(DPM)_D$ x $USERS(DPM)_L$] EDAYS = [DPM Parking Revenues/Year]

+

[$PRICE(M)_H$ x HOURS(M) x $USERS(M)_S$ + $PRICE(M)_D$ x $USERS(M)_L$ x $\%DPM_{PKG}$] EDAYS = [Municipal Parking Revenues for DPM/Year]

Total Parking Revenues = [ ]

3. Local Tax Revenue

SALES x $RATE_S$ x $\%DPM_S$ = [Sales Tax Revenues/Year]

+

EMP x INCOME x $RATE_E$ x $\%DPM_P$ = [Payroll Tax Revenue/Year]

+

VALUE x $RATE_P$ x $\%DPM_{PT}$ = [Property Tax Revenue/Year]

+

= [Revenues from other local taxes to be applied to DPM/Year]

Total Local Tax Revenues = [ ]

4. Value Capture/Joint Development Revenue

($VALUE_{T+1}$ - $VALUE_T$ - COST) ÷ $VALUE_T$ = % Increased Value

SUBST x $PRICE_{SUBST}$ = [Parking Substitution Revenue/Year]

+

% Increased Value x $VALUE_T$ x $PRICE_{DEV}$ = [Private Sector Contribution for DPM Station related developments/Year]

+

= [Revenues from Value Capture Taxation Techniques/Year]

+

= [Revenues from Value Capture Real Property Development Techniques/Year]

Total Value Capture Revenues = [ ]

REVENUE CALCULATION WORKSHEETS

II. CALCULATION OF INDIVIDUAL REVENUE COMPONENTS, Continued

5. Advertising Revenues

= [Advertising Revenues/Year]

III. CALCULATION OF REVENUE FROM INDIVIDUAL COMPONENTS

FARE REVENUES [ ]

\+

PARKING REVENUES [ ]

\+

LOCAL REVENUES [ ]

\+

VALUE CAPTURE/
JOINT DEVELOPMENT REVENUES [ ]

\+

ADVERTISING REVENUES [ ]

TOTAL ANNUAL DPM REVENUES = [ ]

NOTES

(1) For instance, Los Angeles adjusted total fare revenues by assuming that gross fares would be reduced by 20 percent after fare discounts so that for a basic $.10 fare, net fare revenues would be $.08.

(2) This differs from value capture in that it does not distinguish between pre-DPM and post-DPM revenues and attempt to "capture" the difference in revenues specifically for the DPM system.

(3) The programs cited here are representative examples and not all inclusive.

(4) Realizable profits will vary by DPM station location.

(5) Revenues utilizing these techniques are difficult to determine prior to DPM implementation. If these value capture techniques are used, revenue estimates should be left open and it should not be intended that these revenues will be available for system construction.

10. CIRCULATOR IMPACT ESTIMATION

10.1 INTRODUCTION

DPM's, and other types of downtown circulator systems, have been proposed by numerous cities as a mechanism for attaining a wide variety of objectives ranging from promotion of regional transit and reducing reliance on the automobile to strengthening of the CBD as an economic activity center. Opponents to the proposed DPM systems suggest an equally diverse set of potential adverse impacts which might result from DPM construction. The purpose of this section is to provide a planning aid which will assist the DPM planner in the identification of the important impacts and in the evaluation of the likely magnitude of each of the impacts.

The impacts have been organized in five major categories for the purpose of presentation in this section. The areas are:

- Travel Impacts
- Economic Impacts
- Social Impacts
- Environmental Impacts
- Urban Design Impacts

In reality, however, the impacts are not so easily separated. As a result, there is frequent overlap and repetition in the discussion of individual impact area.

Although the stated objectives for providing a DPM system have varied greatly from city to city, the primary mechanisms for attaining those objectives remains virtually the same -- changing travel patterns. Because of the importance of the travel impacts of a DPM system, special attention has been devoted to this area in this section. In addition to the detailed discussion of the individual travel impacts, many of the "other" or "non-travel" impacts are related directly to the travel impacts.

10.1.1 <u>Travel Impacts</u>

The discussion of travel impacts provided in this section extends the DPM demand estimation methods presented in Section 7 by relating the predictions of short-range changes in intra-CBD mode choice and destination choice to the secondary impacts on the frequency and mode choice of travel to the CBD, on the frequency of travel within the CBD, and on the choice of parking location. Wherever possible, worksheets are provided to assist in predicting these impacts and in summarizing them in a way which will facilitate DPM system evaluation. The worksheets are included both in Appendix 10-A of this section (along with example worksheets) and in Appendix D of Volume 3 of the report (blank worksheets only).

Medium and long-range travel impacts are also discussed, and their relationships to the economic and urban design impacts presented in subsequent sections are pointed out. The relationships of these impacts to the magnitudes of the short-range impacts are also pointed out.

The specific areas covered in the Travel Impact section are:

- Frequency of travel to the CBD
- Mode of travel to the CBD
- Parking locations for auto trips to the CBD
- Mode of distribution in the CBD
- Frequency of intra-CBD trips
- Net short-range impacts on CBD travel
- Long-range travel impacts

10.1.2 Economic Impacts

The economic impacts considered in this section of the report include the DPM effects which result directly in either an increase or a decrease in the level of business activity in the downtown area. The anticipated economic impacts can generally be classified as either:

- Revitalization of the CBD through improved transportation service to deteriorated or declining areas, or

- Increased economic vitality of the CBD (increased sales) through generation of new trips.

Revitalization, changes in employment density, and DPM generated development are long run land use changes that have yet to be successfully modelled in an analytical form. Available demand estimation techniques do, however, relate trip attraction to retail employment and to the level of transportation service provided, and if a consistent relationship is assumed between retail employment and the volume of trips for non-work purposes, an iterative process can be developed to give very rough indications of changes in employment generated by changes in the level of service of internal circulation. Specific techniques are presented in the section for evaluating the potential for economic improvement in a downtown area, and the likely impact of a DPM system on the economic vitality of the CBD.

The specific areas covered in the Economic Impact Section are:

- Retail activities

- Employment

- Tourism

10.1.3 Social Impacts

The discussion of social impacts provided in this section focuses on the direct costs and benefits of the DPM system that are experienced by the users of the system and the users of the downtown area. The major area of focus is on the changes in accessibility and mobility afforded by the system. Particular attention is given to socio-economic characteristics of the population that are likely to be affected most by the system. The patronage forecasting procedures presented in Section 7 and the Travel Impacts section of this section provide some of the tools necessary for evaluating the changes in accessiblity and moblity for various market segments. This section presents additional techniques to assist in making subjective judgement about improvements in these same areas of social impacts.

The specific areas covered in the Social Impacts section are:

- Accessibility
- Mobility
- Residential Location
- Crime and Vandalism
- System Safety

10.1.4 Environmental Impacts

The extent to which a DPM system can positively affect the environmental quality within a CBD is dependent on the function for which the system is designed. A system designed to facilitate circulation within the CBD is not likely to produce significant environmental improvements. The primary source of circulation trips is travel presently made on foot. Diversion of large numbers of these trips to the DPM will have little or no effect on environmental quality. If anything, the DPM operation itself will result in greater fuel consumption and increase noise and visual intrusion. Only if the DPM system is designed to intercept trips bound for the service area, can the system be successful in improving the environmental quality. When the system is designed to intercept either automobile or transit trips or both, the environmental quality within the service area may be improved by reductions in:

- Pollutant emissions
- Traffic congestion
- Traffic noise
- Traffic exhaust odors
- Visual intrusion from parking and other automobile associated uses

The major improvements will be due to the reduction in the amount of automobiles and buses in the service area. However, the limitation of automobiles is difficult because of the significant investment in parking garages and other automobile related infrastructure. Therefore, it is likely that in the short run the positive environmental impacts will be small.

The specific areas discussed in the environmental impact section are:

- Air Quality
- Noise
- Energy Consumption

10.1.5 Urban Design Impacts

The urban design impacts considered in this section go beyond concerns over the appearance of the DPM in the cityscape. The impacts include:

- Short term changes in the quality of physical environment as perceived by its various users (attraction, comfort, and convenience as well as attractiveness)

- Short term changes in activity patterns and the relationship of these to the physical and social environment and to economic effects

- Longer term structural changes in the physical and activity patterns of downtown that are likely to occur over time as a result of interaction of the DPM with existing conditions, policies, and future actions.

Thus, the urban design considerations tend to bridge the transportation, economic, environmental, and social concerns and examine the way in which these separate impact categories contribute to the overall improvement or detriment of the downtown environment.

Administration and management actions tend to produce impacts in combination. The nature and extent of these impacts is likely to vary greatly with the conditions already existing in the downtown. For example, the DPM can catalyze new development under conditions of vigorous regional economic growth, availability of suitable sites, and well coordinated governmental programs for managing and encouraging development. By contrast, the same DPM scheme may have very little impact on development in the absence of any or all of these conditions. Even in the case of the cited negative impacts, the existing conditions, and the prevailing public and private management of these conditions will probably be more influential than the variations in the design and configuration of the DPM itself.

Thus, the urban design impacts of the DPM must always be examined in juxtaposition to a comprehensive descriptive and analytical model of the existing urban environment, the activities it contains and the trends that are occurring in time. Such comprehensive modelling is a difficult task limited by the measurability of the phenomena and the time, money, and skill available for the analysis.

The techniques cited in this section focus on the essentials. They take into account the fact that some of the data required are already assembled for most downtowns and that much of the new data collected for this analysis will be useful for other future transportation and development planning programs as well.

The specific areas discussed in the urban design impact section are:

- Induced Activities
- Induced Development
- Displaced Activities
- Streetscape
- Construction

10.2 PRESENTATION FORMAT

The discussion of each of the impact areas is presented in a common format which facilitates the use of the section as a planning aid that can be referred to frequently throughout the planning process. Each impact area is divided into six sections.

- Potential or Problem
- Contributing Factors
- Predictive Measures
- Procedures for Testing
- Actions to Maximize Potential or to Minimize Negative Impacts
- References

10.2.1 Potential or Problem

For each of the impact areas, a subjective assessment has been made as to whether the likely impact will be positive or negative. For those potentially positive impacts, the likely degree and nature of the potential is introduced. If the impact is likely to be negative, a brief description of the nature and degree of the problem is provided.

10.2.2 Contributing Factors

At a sketch planning level of detail, each of the impacts can be expressed as a function of either the characteristics of the downtown area, the characteristics of the DPM system or a combination of the two. Within each of these two areas, "Downtown Characteristics" and "DPM Characteristics", the important factors contributing to the impact area under discussion are enumerated.

10.2.3 Predictive Measures

For each of the contributing factors that is identified, a predictive measure or technique is suggested to assist the planner in evaluating the magnitude and influence of the contributing factors. The discussion is presented in a format which enables the reader to easily see the one-to-one correlation between "Contributing Factor" and "Predictive Measure."

10.2.4 Procedures for Testing

The "Procedures for Testing" section suggests techniques for using the "Contributing Factors" and the "Predictive Measures" to determine the likely magnitude and nature of the impact under discussion. In most cases, this section has been used to describe an overall methodology for an evaluation of the impact area, and the discussion points to sources of more detailed information on the subject. In some cases, simple sketch planning techniques are suggested to assist the planner in the early stages of DPM feasibility assessment.

10.2.5 Actions to Maximize Potential or to Minimize Negative Impacts

This section included with each impact area suggests ways in which the most can be made of DPM opportunities, either by maximizing the potential benefits or by minimizing the negative impacts.

10.2.6 References

Although this manual is designed to provide assistance at a sketch planning level of detail, references are made throughout this section to more detailed research efforts which have dealt with the specific impact area. Each reference is followed by a brief description of the specific nature of the material referenced.

10.3 DISCUSSIONS OF SPECIFIC DPM IMPACT AREAS

The following subsections are devoted to presenting material concerning each of the five DPM impact areas outlined in Section 10.1, according to the format described above in Section 10.2.

10.3.1. DPM IMPACTS: TRAVEL

DPM IMPACT: TRAVEL

• **FREQUENCY OF TRAVEL TO THE CBD**

Potential: By providing greater mobility in the downtown area, increased travel to and from the CBD may occur; whether or not new employment, shopping, and social/recreational attractions are located there. Since work trips will only increase in the longer run as CBD employment increases, additional travel to and from the CBD in the short run will be due to additional shopping, social/recreational, and personal business trips.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. An existing viable base of shopping and social/recreational opportunities must exist downtown. When this is the case, their patronage by area residents can increase.	1. Determine the magnitude of existing travel, the number of CBD employees, and/or the square footage of downtown floor area devoted to each of the following activities: • retail sales • recreational activities: restaurants, theatres/entertainment, historical sites, sports facilities, etc. • personal services: medical, legal, financial, etc. This information may be available from the city planning and/or the regional transportation planning agencies. Choose two or three blocks having major concentrations of each of these types of activities for further analysis.
2. Difficulties in both auto and transit travel into and within the CBD may presently inhibit the popularity of the CBD for non-work travel.	2. Determine existing travel speeds in the downtown area, as measured by planning or traffic agencies, and by the local transit operator. Determine typical transit frequencies of service from each of the major corridors of access to the CBD, both in the peak and off-peak periods.
3. Limited availability and high costs of parking may presently limit the CBD's attractiveness for non-work travel.	3. Map the availability of short-term parking in the downtown area, and its cost per hour. Measure the distances between available parking and the attractors identified in 1, above.

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Contributing Factors	Predictive Measures
DPM Characteristics	
4. Station locations.	4. Measure distances from DPM stations to the typical major attractors identified in 1, above. Also, measure distances from DPM stations to fringe parking facilities which will provide short-term parking.
5. Interfaces with regional transit.	5. For each major access corridor, determine the fraction of transit lines which provide direct connections to DPM stations.
6. System coverage.	6. Examine the connectivity provided by the DPM system between alternative non-work attraction areas in the CBD. Ease of travel between these areas will increase the likelihood of travel to the CBD for non-work trips to multiple destinations and/or purposes.
7. Hours of operation.	7. Examine the compatibility of the hours of DPM operation with the hours of operation of CBD restaurants, entertainment centers, etc.

Procedures for Testing

Models which predict regional non-work travel provide estimates of the impacts which the greater accessibility provided by a DPM system can have on the frequency of travel to and from downtown. Worksheet 10-1 can be used to apply these models. It is provided in Appendix 10-A following this chapter, along with an example of its use. The worksheet may be used to evaluate, separately, trips by two generalized non-work purposes: shopping/personal business and social/recreational. The following procedure can be applied to use this worksheet to estimate changes in the number of non-work trips which will be attracted to the CBD:

1. Choose market segments: depending upon the desired level of effort, a single market segment can be chosen, or a number of segments based on corridor of approach to the CBD, distance from the CBD, and destination within the CBD. If a single market segment is chosen, it should be defined as having the average auto and transit travel times and costs for non-work trips to the CBD by each trip purpose.

-continued-

<u>Procedures for Testing</u> (continued)

2. For each market segment, specify each of the following characteristics, and insert this information in the proper spaces on the worksheet for each trip purpose:

   - Predicted new average travel time to the CBD by auto, with a transfer to the proposed DPM system (in minutes)
   - Predicted new average travel time to the CBD by transit, with a transfer to the proposed DPM system (in minutes)
   - Existing average travel time to the CBD by auto (in minutes)
   - Existing average travel time to the CBD by transit (in minutes)
   - Change in auto costs (with DPM minus existing) due to changes in the following:
     - one-way auto distance multiplied by average out-of-pocket operating costs of 6 cents per mile
     - one-half of total parking costs for a two-hour stay in the CBD

     Both of these costs may be assumed to change if the use of fringe parking facilities (at lower cost than CBD lots and closer to some trip origins) is facilitiated by the DPM system (in cents)
   - Change in transit costs, due to changes in fare on the regional system (if any), plus the fare for DPM users transferring from regional transit (in cents)
   - For the non-work purpose and market segment being analyzed, existing trips to CBD attractions by each of two modes; auto and transit
   - For both auto and transit users, the expected fraction who will also use the DPM system; this fraction can be estimated using the mode split model for distribution trips described in Section 7 and Appendix A.

   It should be noted that some of these costs and times may increase for some market segments, and that these increases must be analyzed as well as the decreases for other market segments, to avoid the introduction of an analysis bias in the prediction of the total change in the frequency of non-work travel to the CBD.

3. Insert the appropriate demand model coefficients, from Table 10-1, into the worksheets for each market segment/trip purpose combination.

4. Proceed through the calculations indicated on the worksheet.

It is important to recognize the limitations of the results of predicting changes in trip frequencies using these worksheets. Only the impacts of changes in travel times and costs for the trip between home and the CBD are considered. The impacts of greater intra-CBD mobility (for travel between multiple CBD-destinations) on the number of non-workers who will come downtown are not represented. Although these impacts are expected to be small compared with the net effect of changes in non-work trip frequency to the CBD (as predicted in this section), they may be significant. Unfortunately, no travel models or empirical information provide reliable estimates of these impacts.

TABLE 10-1

COEFFICIENTS FOR PREDICTING CHANGES IN CBD NON-WORK TRIPS*

Trip Purpose	Coefficient of		
	ΔLN (Travel Time) Auto & Transit Modes	ΔTravel Cost	
		Auto	Transit
Shopping/ Personal Business	-1.829	-.02447	-0.08598
Social/Recreational	-0.993	-.02560	-0.04039

*SOURCE: Home-based shop and home-based social/recreational destination/mode choice models developed for San Francisco's Metropolitan Transportation Commission. (Reference 1).

Procedures for Testing (continued)

A second limitation arises because the worksheet has been simplified to ignore all secondary impacts on all non-work trips made to non-CBD locations. This can be done without introducing any significant error as long as the total base trips affected, as computed in Section III of the Worksheet, is less than 2 percent of the total trips made by the market segment (to all attractions in the metropolitan region) for the non-work purpose being analyzed. If this limit is exceeded, then the revised trips for each mode obtained in Section IV of the Worksheet should be normalized by multiplying by the following ratio:

$$\frac{\text{Total Existing Trips (to all attractions)}}{\text{Total Existing Trips (to all non-CBD attractions)} + \text{Total Revised Trips (Worksheet Section IV)}}$$

An example use of the worksheets is included following the worksheets themselves. In the example, the following hypothetical case is used:

1. The single market segment is all social/recreational trips in an urban area.
2. For this market segment, the following data items have been estimated:
   - new travel time by auto = 13 minutes
   - existing travel time by auto = 14 minutes
   - new travel time by transit = 14.8 minutes
   - existing travel time by transit = 16.8 minutes
   - change in auto cost: parking costs decrease by 25 cents due to use of fringe parking, operating costs remain unchanged, and a DPM fare of 10 cents must be paid, resulting in a net change of -15 cents.
   - change in transit cost: transit fares increase by 10 cents due to transfer from slower buses to the DPM at the fringes of the CBD
   - existing trips to CBD attractions:
     - auto users = 108,960
     - transit users = 24,220
   - predicted fractions using DPM:
     - auto users = .085
     - transit users = .120
3. As shown in the completed worksheet, the resulting estimate of new social/recreational trips to the CBD is 4750 which is a 3.6 percent increase compared with the existing total of 133,180 CBD trips. This example represents a very approximate analysis of the changes in trip frequency to downtown due to a DPM system. The analysis of additional market segments would provide more realistic estimates of changes in travel times and costs, and therefore, in the percentages of both auto and transit trips which will use the DPM system.

-continued-

Actions to Maximize Potential

- Plan station locations within easy walk access of concentrations of retail, entertainment, and personal service activities. Look for joint development opportunities at stations which will emphasize these activities.
- Provide fringe parking facilities at DPM stations which can significantly reduce travel times and costs for auto users, and include a significant number of short-term spaces in these facilities.
- Encourage downtown merchants to participate in programs involving validation of fringe parking costs and DPM fares for their clientele.
- Provide direct connections between midday and night regional transit services and DPM stations.
- Coordinate DPM evening operating hours with downtown evening activities which can be served by the DPM.

References

(1) Cambridge Systematics, Inc., "MTC Travel Model Development Project: Final Report", Volume I, Cambridge, Massachusetts, December 1977.

DPM IMPACT: TRAVEL

• MODE OF TRAVEL TO THE CBD

Potential: By changing the time and cost characteristics of travel to the CBD by both auto and transit, the DPM system can cause shifts between these regional travel modes for both existing and newly-generated trips. All trips, both for work and non-work purposes, will be affected.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Trips can only be shifted to transit if a viable level of transit service is provided between residential areas and the CBD	1. Obtain, from cordon crossing information and/or regional travel survey summaries, the existing share of CBD trips which use transit for each of the following purposes: • work • shopping/personal business • social/recreational
2. Limited availability and high costs of parking may presently discourage auto travel to the CBD	2. Map the availability of both daily and short-term parking in the downtown area, and its cost per day and per hour. Measure the distances between available parking and the CBD areas which attract the largest number of both work and non-work trips.
3. Street congestion in the downtown area will impact both auto and bus transit usage similarly, but an existing rail transit system may lose its relative advantage over auto, if auto travel can avoid congestion by transferring to the DPM system.	3. If a rail transit system serves the CBD, evaluate the level of service it provides by determining its station spacing in the downtown area, and the distances of its stations from the major trip attraction areas.
DPM Characteristics	
4. Interfaces with regional transit.	4. For each major access corridor, determine the fraction of both peak period and off-peak transit lines which provide direct connection to DPM stations.
5. Interfaces with fringe parking facilities	5. Measure the walk times between fringe parking facilities and DPM stations. Determine the costs of these facilities, for both work and non-work travel, compared with the costs of facilities closer to the major CBD attraction areas.

Contributing Factors	Predictive Measures
DPM Characteristics	
6. Station locations	6. Measure distances from DPM stations to the CBD areas which are the attractors of work and non-work travel.
7. Hours of operation	7. Examine the compatibility of the hours of DPM operation and the hours of operation of regional transit services in the downtown area.

Procedures for Testing

Many models exist which predict the mode choice in regional travel for both work and non-work purposes. Worksheet 10-1 discussed in the previous section can be used to predict shifts between auto and transit for non-work travel. These shifts can be made explicit using Worksheet 10-2, which represents a continuation of Worksheet 10-1. No additional data items are needed. The new worksheet can be used to compute pre- and post-DPM mode shares in percentage terms and facilitates their comparison. The previous example of its use is continued, following the worksheet form itself in Appendix 10-A. In the example, 1 percent of total travel to the CBD shifts from transit to auto. Changes in the modal shares for work trips attracted to the CBD can be calculated using Worksheet 10-3 which is a modification of the manual mode choice prediction methodology presented in Reference 1. The procedure for using this worksheet is the following:

1. Choose market segments using the same criteria described in the previous section.
2. For each market segment, specify each of the following characteristics, and insert this information in the proper spaces on the worksheet:

   - change in one-way in-vehicle travel time in minutes for each of three modes:
     - auto users who drive alone ($\Delta IVTT_{da}$)
     - auto users who share a vehicle with others for the work trip ($\Delta IVTT_{sr}$)
     - transit users ($\Delta IVTT_t$)
   - change in one-way out-of-vehicle travel time--walking, waiting, and transferring--in minutes for each of the three modes ($\Delta OVTT_{da}$, $\Delta OVTT_{sr}$, $\Delta OVTT_t$)
   - change in one-way out-of-pocket travel cost in cents for the drive alone and transit modes ($\Delta OPTC_{da}$, $\Delta OPTC_t$)
   - change in the portion of one-way out-of-pocket travel costs for shared-ride users which are shared by occupants of the vehicle ($\Delta SOPTC_{sr}$); normally these costs will include all vehicle operating and parking costs.
   - change in the portion of one-way out-of-pocket travel costs for shared ride users which are not shared by occupants of the vehicle ($\Delta IOPTC_{sr}$); normally these individual costs will include any costs for transit usage for the access and distribution portions of the shared ride trip, such as usage of the DPM system.

- average one-way trip length in miles for the market segment
- average value for number of people per shared ride vehicle for the market segment
- existing trips made by the market segment which are attracted to the CBD by each of the three modes
- fractions of auto and transit trips which are predicted to use the DPM system by the distribution trip mode choice model presented in ' Section 7 and Appendix A.

3. Proceed through the calculations shown on the worksheet.

An example of their use is included following the worksheets themselves. In the example, the hypothetical case begun in the previous section is continued:

- the single market segment consists of all work trips to the CBD in an urban area
- for this market segment, the data items shown in Table 10-2 have been estimated. The changes in costs represent decreases in parking costs for auto users of 25 cents per one-way trip (half of the daily decrease), and an increase to all travellers of 10 cents for the DPM fare
- As shown in the completed worksheet, these changes would be expected to result in a shift from transit to the drive alone mode, and a slight decrease in shared ride travel to the CBD. None of these shifts are large, in comparison with the total work travel into the CBD.

Although this example shows auto usage increasing at the expense of transit usage, this will by no means be expected in each case. Much depends on the relative changes in times and costs for each of the modes, and these in turn depend on the interface facilities provided for regional auto and transit users.

Actions to Maximize Potential

- Shifts to more energy-efficient work travel can be encouraged by emphasizing the DPM-regional transit interface in the design of stations at which these interfaces will occur, and in specialized transfer fare arrangements. Also, the usage of parking facilities by shared-ride vehicles can be promoted by reserving sections for them, and by providing reduced parking rates. Similarly, reserved sections and reduced rates can be provided for smaller, more energy-efficient vehicles.

- Encourage downtown employers to provide free DPM transit passes together with either regional transit passes or free parking privileges to encourage the desired changes in work trip mode shares.

References

1. Cambridge Systematics, Inc., "Guidelines for Travel Demand Analyses of Program Measures to Promote Carpools, Vanpools, and Public Transportation," Cambridge, Massachusetts. November 1976.

TABLE 10-2

DATA ITEMS FOR EXAMPLE USE OF WORKSHEET 10-3

Data Item	Drive Alone	Shared Ride	Transit
ΔIVTT (minutes)	-2	-2	-4
ΔOVTT (minutes)	+1	+1	+2
ΔOPTC (cents)	-15		+10
ΔSOPTC (cents)		-25	
ΔIOPTC (cents)		+10	
Trip Length (miles)	9	9	9
Average Occupancy (persons/vehicle)		2.4	
Existing Trips	107,380	69,510	108,990
Fraction using DPM	.085	.085	.120

DPM IMPACT: TRAVEL

• **PARKING LOCATIONS FOR AUTO TRIPS TO THE CBD**

Potential: By providing improved access to both existing and new parking facilities near DPM stations, the DPM system can cause a shift in parking locations for auto trips to the CBD. These shifts are likely to be toward higher usage of cheaper fringe facilities near DPM stations and reduced usage of expensive facilities more centrally located. New parking facilities integrated into DPM stations will have an added attractiveness because they ease the auto to DPM transfer.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Existing constraints on parking availability, and high parking costs, in some areas of the CBD must exist, if significant shifts to fringe facilities are to occur.	1. Map the availability of parking in the downtown area, and its cost on a daily and per-hour basis. Also, map employment levels and non-work trip attractions by area. This information may be available from city planning, traffic and regional transportation planning agencies.
2. Difficulties of auto travel into the CBD areas of constrained parking availability will enhance the attractiveness of new and existing fringe facilities.	2. Determine existing auto travel speeds in the downtown area, as measured by planning or traffic agencies.
3. If existing fringe facilities are poorly served by circulation/distribution and/or regional transit lines, their usage may be unduly restricted.	3. Map existing CBD transit lines and their frequencies obtained from the local transit operator.
DPM Characteristics	
4. Station locations	4. Measure distances from DPM stations to presently under-utilized fringe parking areas.
5. Interceptor parking facilities	5. Measure the average walk distances and times from interceptor parking facilities to DPM station platforms. Compare with distances and times from other fringe parking to DPM stations.

6. System coverage	6. Examine the connectivity provided by the DPM system between the areas of constrained parking availability and new and existing fringe facilities
7. DPM and Parking Costs	7. Compare the combination of DPM fares and interceptor parking costs with parking costs near the major activity centers. Compare interceptor parking costs with those of existing fringe facilities.

Procedures for Testing

- Use maps of parking demand and availability to identify areas of constrained and excess parking capacity.

- Compare the map of parking capacity constraints and excesses with a map of travel speeds to determine if low speeds correspond to capacity constraints.

- Compare the existing transit and planned DPM system service provided between fringe parking and areas of parking capacity constraints.

- The parking facility choice model presented in Appendix A can be used to measure the net impacts on parking locations due to all the factors discussed in this section. Unfortunately, this model is not amenable to manual analyses using worksheets. The model can be applied using the computerized methods introduced in Section 7 however. Also, the model provides elasticities, which indicate the relative importance of a number of factors discussed above. The elasticities, in Table 10-3, each represent the percentage change in usage of any parking facility as the indicated variable changes by one percent. Because a change in any of these variables for a given facility will generally be accompanied by changes in other variables shown the analyst is cautioned against using any single elasticity to predict changes in CBD parking location.

  These elasticities clearly show that distance from parking facility to downtown destination is the most important determinant of parking location, and that parking cost and capacity are also relatively important. The time and cost variables for the portions of the trip between cordon line and parking facility, and between parking facility and CBD destination are relatively unimportant.

Actions to Maximize Potential

- Agreements can be made with CBD developers which will allow them to fund (via purchase or lease, for example) interceptor parking capacity, as an alternative to providing the capacity on the sites they develop, otherwise required by zoning laws. Such agreements can help to ensure usage of the interceptor parking facilities and the DPM system, and also reduce the growth of parking capacity in the more congested CBD areas.

- Downtown employers, retail stores, and entertainment facilities can be encouraged to offer reduced or free interceptor parking cost/DPM fare plans for their employees and clientele.

- Actively market combined interceptor parking/DPM services to those who drive to the CBD.

TABLE 10-3

ELASTICITIES OF CBD PARKING LOCATION

Elasticity with Respect To:	Elasticity: Percent change in parkers at a location for a one percent change in the variable listed
Distance[1]	-2.06
Walk Time[1]	- .0174
Regional Bus Time[1]	- .0026
DPM and Circulator Time[1]	- .0091
Regional Bus Fare[1]	Negligible
DPM and Circulator Fare[1]	Negligible
Auto Cost[2]	- .032
Parking Cost	-1.10
Parking Capacity	+ .915

[1]From parking facilitiy to downtown destination
[2]From CBD cordon to parking facility

DPM IMPACT: TRAVEL

• **MODE OF DISTRIBUTION IN THE CBD**

Potential: By serving a significant portion of intra-CBD trips, and the intra-CBD access portion of regional trips into the CBD; a DPM system can assist in reducing CBD auto, pedestrian, and transit congestion; and increase the mobility of intra-CBD trip makers.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Downtown size	1. Determine the distribution of the lengths of existing intra-CBD trips as measured in available travel surveys conducted by the city planning agency, city traffic department, local transit operator or regional transportation planning agency. Alternatively, conduct a new survey of downtown tripmakers to obtain this information.
2. Difficulty of the use of the auto for long intra-CBD trips	2. Measure average auto speeds in the CBD, and use parking capacity constraint information developed in the previous section to evaluate the problems in using an auto in the CBD.
3. Interaction of pedestrian and vehicular traffic.	3. Compare attainable walking speeds in various CBD areas as reduced by sidewalk congestion and traffic signal delay with "free flow" walking speeds.
4. Undesirability of walk trips due to topography and weather conditions.	4. Locate areas with significant grades. Determine, from local weather information, the likelihood of unpleasant weather: excessive heat or cold, rain and snow, high winds.
DPM Characteristics	
5. Ability to reduce generalized travel costs for significant numbers of intra-CBD trips	5, Determine total origin-to-destination travel times by DPM and the alternatives: walk, regional bus, downtown circulator bus, and auto. Also, compare out-of-pocket costs (fares, auto operating costs, parking costs). Compare these alternatives for trips of various lengths.

Procedures for Testing

The ability of the DPM system to attract intra-CBD trips from other modes can be predicted to the desired level of detail using the models and methods presented in Section 7 and Appendix A. The predictive measures described above can be used to provide general indications of the potential of a DPM system in the CBD area, and to indicate whether additional factors, not represented in the models (such as weather) will enhance the DPM system's attraction or decrease it.

Actions to Maximize Potential

- Plan route alignment, station locations, and frequency of service to serve a maximum number of existing intra-CBD movements.

- Coordinate DPM interfaces with regional transit services and provide fringe parking facilities at DPM stations to maximize the system's potential as a distribution service.

- **FREQUENCY OF INTRA-CBD TRIPS**

Potential: By providing increased mobility, the DPM system can generate new travel by all intra-CBD trip-makers, as well as longer trips which can only be made by transit or auto.

Contributing Factors and Predictive Measures

See previous section. The same factors and measures which apply to mode of distribution in the CBD also apply to frequency of intra-CBD trips.

Procedures for Testing

- The model of travel by downtown workers in the noon period, presented in Section 7 and Appendix A, explicitly predicts changes in trip frequency as intra-CBD mobility changes, when it is applied using either the computerized sketch planning or the detailed network analysis process described in Section 7. In the absence of a similar feature in the non-worker model, it is reasonable to assume that the fraction of DPM users who are making trips they would not otherwise make is similar for non-workers and workers.

- The worker model presented in Appendix A has an elasticity of trip frequency, evaluated for the average conditions of the Los Angeles data for which is was estimated, of .023 with respect to the average speed of DPM travel, and of -.0016 with respect to DPM fare. These elasticities can be used to estimate changes in trip frequency using Worksheet 10-4. The following data items are required:

  - Existing intra-CBD (circulation) worker trips, which can be obtained from Form VI* when the manual sketch planning methods are used.
  - Existing intra-CBD non-worker trips, also available from Form VI.
  - Base values of average speeds and fares on the circulator system presently existing in the CBD.
  - Changes in average speeds and fares: the values for the DPM system, less those for the existing circulator system.

  The worksheet is followed by an example showing its use to predict the change in intra-CBD travel expected when a DPM system which is 5 mph faster and 5 cents per ride more costly than the present circulator system. The circulator system has an average speed of 10 mph and a fare of 10 cents.

  The resulting increase in trips is 3700, 1.1 percent of the existing trip total, 345,900. It is reasonable to assume that the mode choice of these additional trip makers will be the same as that predicted for existing trips using the noon hour models presented in Appendix A.

- Data on existing downtown circulation systems - both bus and rail - is presented in Section 3. Surveys in Washington, D.C., Milwaukee, and Los Angeles indicated that the fraction of circulation system users making new trips ranged from 8 to 16 percent.

*A description of this and other sketch planning forms is given in Section 7.

-continued-

- The results obtained by applying the models presented in Appendix A can be summarized by calculating average trip lengths in miles for both the base data and for the proposed DPM system. These averages can be obtained for the circulator and regional transit modes both separately and combined. Comparison of base and proposed system values will provide an indicator of the extent to which the DPM system is causing longer intra-CBD trips to be made.

<u>Actions to Maximize Potential</u>

- Plan route alignment, station locations, and frequency of service to serve a maximum number of potential intra-CBD trips which are presently inhibited by distance, parking costs, vehicular and pedestrian congestion, topography, and weather.

- **NET SHORT-RANGE IMPACTS ON CBD TRAVEL**

Discussion: Each of the preceding sections on Travel Impacts deals with short-range changes in travel into and within the CBD. It is important to summarize the net effect of all these changes as an aid in DPM system evaluation. Worksheet 10-5 provides a method to obtain this summary which is consistent with the other worksheets in this chapter, as well as with those in Section 7. This worksheet, and an example of its use to summarize each of the previous worksheet examples, follows.

The worksheet provides final short-range estimates of intra-CBD trip totals by three modes: circulator and/or DPM, regional transit, and other (walk, auto, taxi, etc.). Totals are provided for distribution travel, circulation travel, and for the sum of these two. Finally, space is provided to record average trip lengths by mode and trip type. These averages must be computed by summing the products of the trips predicted on Form VI and their distances, which can be obtained from Form IV.

DPM IMPACT: TRAVEL

- **MEDIUM-RANGE TRAVEL IMPACTS**

Potential: By providing greater accessibility in the areas surrounding DPM stations, the DPM system will tend to increase non-work distribution travel from outside the CBD, and also circulation travel from other CBD locations. These short-range impacts will be reinforced by a greater intensity of use of the existing shops and offices in the medium range: the period from approximately three months to two years after the DPM system begins service. During this period, existing and potential CBD businesses may relocate to existing buildings, but there will be no time for new construction, with its location influenced by the DPM system, to be completed. The travel impacts of these expansions and higher intensities of CBD business will be an additional growth in trip-making in the areas surrounding DPM stations and, since trips to and from these areas are most likely to use the DPM, a higher modal share for DPM trips. This additional growth will probably be accompanied by some decline in travel and business activity in other CBD areas, but also by an increase in total CBD travel and activity, as new trip-makers and businesses are attracted to the downtown area.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. The atmosphere of business activity in the CBD must be one of optimism and growth rather than decline, if new activity levels are to follow soon after the opening of the DPM system.	1. Obtain, from retail trade boards, chambers of commerce, and/or city taxation departments, measures of CBD business activity such as sales tax receipts, inventories, and employment levels for the past 3-5 years. Look for trends over time. Sample the opinions of CBD businessmen to determine the prevailing local moods with respect to downtown viability and growth.
2. If the atmosphere of business activity is presently pessimistic, the changes brought about by the DPM system may cause this atmosphere to change for the better and for CBD business growth to begin.	2. If the trends observed in #1 above indicate little change or slow rates of decline, new growth will be more likely.
DPM Characteristics	
3. The DPM system's success in attracting existing travel will serve as an indicator of its ability to attract increased levels of business activity in the medium range, and its success in capturing travel to and from these new activities.	3. Use the short-range predictions discussed in previous sections, especially the predicted DPM modal shares for the areas surrounding stations, as relative indicators of the likelihood of increased levels of business activity. Project increases in DPM patronage by assuming these modal shares will hold also for trips attracted to the new activities.

-continued-

Actions to Maximize Potential

As part of the agency and/or functions set up to operate the DPM system, include the task of publicizing increases in pedestrian volumes, trip-making, and business activity to business people who operate or are potential operators of businesses in the DPM station areas.

References

See the discussion in this Chapter of Economic Impacts (Employment and Retail Activities) and Urban Design Impacts (Induced Activities, Induced Development and Displaced Activities), for further detail on the medium range changes in downtown activities which will also result in medium range changes in travel patterns.

DPM IMPACT: TRAVEL

- **LONG-RANGE TRAVEL IMPACTS**

Potential: In the long range (more than two years), increases in accessibility provided in the areas of DPM stations will tend to encourage faster growth, in the form of new construction, in these CBD areas. Some of this increased growth will be at the expense of growth in other CRD areas; some will be due to an increased rate of growth in the entire CBD area. All types of CBD activity - employment, retail stores, entertainment, and personal services - are likely to experience these changes. The travel impacts of these changes will be additional growth in travel in the areas surrounding DPM stations and a higher modal share for DPM trips.

Contributing Factors and Predictive Measures

The factors and measures discussed in the previous section will also affect long-range CBD development. However, due to the time lags required for significant amounts of new con-truction, it will be difficult to predict accurately the long-range changes very far into the future. Given such predictions, however, changes in trip-making and DPM patronage can be predicted assuming the modal shares predicted in the short range will hold also for trips to and from newly developed facilities.

Procedures for Testing

Land use and/or business activity models which are integrated with travel demand models can be used to predict changes in the equilibrium between trip-making and activity levels. Such models are explored in Reference 1.

Actions to Maximize Potential

See the previous section. The publicity should also be directed to potential developers, to encourage their consideration of sites near DPM stations.

References

1. C.R. Kern and S.R. Lerman, "Models for Predicting the Impact of Transportation Policies on Retail Activity," presented at the Transportation Research Board, Washington, D.C., January 1978.

2. See the disucssion in this Chapter of Economic Impacts (Employment and Retail Activities) and Urban Design Impacts (induced Activities, Induced Development and Displaced Activities), for further detail on the long range changes in downtown activities which will also results in long range changes in travel patterns.

10.3.2. DPM IMPACTS: ECONOMIC

DPM IMPACT: ECONOMIC

• RETAIL ACTIVITIES

Potential: A DPM system can expand the retail opportunities and choices to existing users of downtown (e.g. employees, shoppers and residents) and thus generate increased business to existing retail sites. The system can also increase the attractiveness of the downtown for new retail activity.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Retail sites are disconnected from major downtown activity centers.	1. Measure distances between retail sites and other activity areas to determine feasibility of walk trips; survey current level of pedestrian activity between major areas; obtain from transit schedules information on transit routes and service levels between retail sites and major activity areas.(1)
2. Moderate to high level of surface transportation congestion in the vicinity of major retail centers.	2. Obtain traffic counts by route and time of day and compare to street capacity levels.
3. Impaired physical accessibility to major retail centers for pedestrians and for trips made by automobile.	3. Identify street restrictions; one-way streets; transit only streets; reserved transit lanes; etc. (Information may be obtained from city and county traffic and public works departments and from transit district); existence of natural and man-made barriers (from topographical maps and aerial surveys).
4. Inadequate or inconvenient parking in the vicinity of major retail centers.	4. Survey parking lot locations to identify retail areas not within average walking distances of parking areas (Information on parking lot locations may be available from city departments of planning). Obtain information from survey of parking lot owners and managers, about occupancy rates, turnover rates and parking charges for parking areas within walking distance to major retail sites. (2)

-continued-

Contributing Factors	Predictive Measures
Downtown Characteristics	
5. Market potential among current downtown users; retail sales in the CBD relative to sales in the SMSA.	5. Obtain data on trips to retail areas by time of day through surveys of consumers (3); information on day and evening hours of retail establishments; obtain data on CBD market share from the U.S. Bureau of Labor Statistics, Handbook of Labor Statistics and U.S. Bureau of the Census, Census of Retail Trade, Major Retail Centers.
6. Market potential among non-downtown users.	6. Determine the substitutability between CBD retail choices and suburban retail choices, as determined by uniqueness of CBD products, from a survey of merchants and retail association (4)(5). Consider with parking factors (refer to 4 above).
DPM Characteristics	
7. Station [illegible]ations.	7. Measure distances between DPM Stations and retail areas to determine walk trip lengths and compare with average walk trip distances. (6)
8. Hours of operation.	8. Compare DPM hours of operation with hours of business of retail establishments.
9. Comfort and convenience of DPM for shopping activities.	9. Review vehicle design features (i.e. seat spacing and special baggage areas); allow for convenient transport of bundles; check service frequency particularly during off peak hours from DPM time schedules.

Procedures for Testing

- **Map:**
  - major retail areas relative to downtown employment centers
  - existing transit routes serving major retail centers
  - DPM stations relative to major retail centers and existing and planned parking areas.

- **Superimpose on map:**
  - traffic volumes in vicinity of DPM stations and major activity centers.
  - traffic restrictions. (see 3 above)
  - physical barriers in the vicinity of DPM stations and major activity centers. (see 3 above)
  - pedestrian flows to determine origin and destination patterns.
  - station volumes obtained from travel demand models (assess pedestrian, auto and transit trips diverted to DPM).

- Chart recent retail development trends of CBD and suburban areas; use statistics on regional retail sales disaggregated by location obtained from the U.S. Bureau of Labor Statistics, Handbook of Labor Statistics, and U.S. Bureau of the Census, Census of Retail Trade, Major Retail Centers.

- Interview sample of downtown merchants and retail associations to determine their expectation of increased sales and plans to modify range of market choices and hours.

- Monitor requests for building permits or zoning changes near proposed DPM stations; combine this information with information obtained through interviews with merchants.

Actions to Maximize Potential

- Plan route alignment and station locations to connect major CBD activity centers with retail sites.

- Consider designs for direct access from DPM stations to retail complex using joint development techniques.

- Adjust service frequency to accommodate demand during noon hour and other peak travel times and coordinate service with the hours of operation of major retail establishments.

- Coordinate transit operations into downtown with DPM schedules and station locations, (particularly important during midday heavy retail activity times of 10AM-3PM); establish policies to encourage transfers between transit into downtown and the DPM.

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Actions to Maximize Potential

- Plan for parking to be available near major DPM intercept points for persons driving into the downtown area.
- Conduct marketing campaign to promote downtown retail activites and the accessibility to these activities offered by the DPM.

References and Footnotes

(1) Analysis of Pedestrian Travel Characteristics, G. Scott Rutherford, De Leuw, Cather and Co., and Joseph L.Schofer, Northwestern University, presented at TRB Meeting, January, 1976.

(2) See Implementation and Administration of Air Quality Transportation Controls: An Analysis of Denver, Colorado - Draft Report, pp. 14-15 to 14-17, Cambridge Systematics, Inc., August, 1977. (Attitudes of downtown merchants in Denver, Colorado, about parking lot locations and parking charges for shopping trips).

(3) Op.cit., pp. 14-8 to 14-14, (Importance of noon-hour shopping trips in Denver, Colorado, CBD).

(4) Op.cit., pp. 14-8 to 14-14. (Recent trends of retail sales in downtown Denver).

(5) Models for Predicting the Impact of Transportation Policies on Retail Activity, Clifford Kern, SUNY at Binghamton and Cambridge Systematics, Inc., and Steven Lerman, MIT and Cambridge Systematics, Inc., August, 1977.

(6) See (1) above. (Recent trends of retail sales in downtown Denver).

DPM IMPACT: ECONOMIC

• EMPLOYMENT

Potential: A DPM system can improve accessibility to existing employment areas and allow commuters to leave their automobiles at fringe area parking facilities. The improved accessibility provided by the DPM may cause current downtown employers to expand their activities and may attract new employers to the downtown area, in both cases generating increased employment opportunities. The construction and operation of the DPM system will also provide both short-term and long-term employment opportunities.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. A low level of accessibility to existing employment sites by public transportation.	1. Obtain information on transit routes and frequency of service from transit schedules; system capacities. (Be particularly sensitive to service frequency and system capacities during AM and PM peak hours of travel).
2. Inadequate or inconvenient parking in the vicinity of major employment sites.	2. Survey parking lot locations to identify employment areas not within average walking distances to parking areas. (Information on parking lot locations may be available from city planning departments); survey parking lot owners and operators for information on occupancy rates, turnover rates, and parking charges for parking areas within walking distance to employment areas.
3. High auto mode split for persons commuting into the downtown for work.	3. Obtain information from home interview surveys; cordon counts, etc.
4. Potential for increased employment opportunities within the downtown.	4. Obtain information on existing space potential for new employment from building owners and management associations; obtain data on vacant land and zoning to determine where new development by interested employers can occur. (Information available from city planning department, zoning office, economic development office, etc.)
5. Potential demand for downtown employment.	5. Obtain statistics on SMSA unemployment rates; available from the Bureau of Labor Statistics, U.S. Department of Labor and the State Employment Department.

Contributing Factors	Predictive Measures
DPM Characteristics	
6. System coverage.	6. Examine connectivity provided by system between tourist attractions, hotels, convention facilities and other major business activity centers.
7. Hours of operation.	7. Evaluate compatability of system operations with hours of operation for entertainment, restaurant and tourist sites during day and evening hours.

Procedures for Testing

- Map

  - location of DPM stations relative to major employment sites; use travel demand projections to distribute employees among stations
  - distances between existing transit stops and major employment sites
  - existing and planned parking areas relative to DPM stations.

- Overlay total number of parking spaces available downtown in the vicinity of major employment sites; current occupancy rates and projected number of spaces planned; determine from demand models projected utilization of parking spaces and resulting occupancy rates.

- Review or conduct home interview surveys, surveys of downtown employees through on-board transit surveys, auto user surveys and employment site surveys to determine current mode of travel to work and potential for using DPM.

- Interview sample of business associations and labor unions to assess the interest of employees to expand current activities or to (re)locate business activities downtown due to enhanced attractiveness of downtown, and induced retail activity. Similarly, contact developers to determine their expectations of location decisions by employers in the downtown area.

Actions to Maximize Potential

- Coordinate location of DPM stations, parking areas and major employment sites.

- Conduct major marketing program to inform present and potential downtown employers and employees of DPM services.

- Consider public agency and private sector actions to encourage use of DPM through:

  - low parking prices at DPM peripheral lots
  - transit vouchers by employers
  - parking management strategies which encourage DPM use.

- Increase potential of DPM to enhance business growth downtown by close coordination with downtown chamber of commerce, city economic development department, etc.

References and Footnotes

(1) Analysis of Pedestrian Travel Characteristics, G. Scott Rutherford, DeLeuw, Cather and Co. and Joseph L. Schofer, Northwestern University, presented at TRB Meeting, January, 1976.
(2) Ibid.

DPM IMPACT: ECONOMIC

• TOURISM

Potential: A DPM system can provide improved access to historical and cultural sites for individuals within the region and can also increase the attractiveness of these sites for tourists from outside of the area. The DPM can make the downtown a more attractive place to stay for persons visiting the city on business or pleasure.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Business convention activity in downtown; non-convention business trips to downtown.	1. Determine the number of conventions held in downtown over the past 5 years in either convention facilities or hotels (information from convention and hotel associations, and chamber of commerce organizations); estimate, from the same sources, the approximate percent of hotel guests on business trips.
2. Popularity of recreational, cultural and historical attractions within the downtown.	2. Examine tourist volumes at major attractions. (Obtain information from visitor counts or admission receipts where available.)
3. Poor non-auto access to tourist attractions from hotels.	3. Obtain information on commercial sightseeing tours and public transit service (routes and times) from hotel to (and between) tourist activities.
4. Vitality of downtown during evening hours.	4. Examine the hours of operation for entertainment and restaurant establishments.
DPM Characteristics	
5. Station locations.	5. Measure distances between DPM stations and tourist attractions.

-continued-

Contributing Factors	Predictive Measures
DPM Characteristics	
6. Station locations.	6. Measure distances between DPM stations and major employment areas to determine walk trip lengths and compare with average walk trip distances.(1)
7. Service compatibility with peak hour AM, PM and midday employee trips.(2)	7. Examine frequency of service, hours of operation and service reliability, of the DPM system.
8. Connectivity provided among major employment areas.	8. Examine station locations (see 6 above).

Procedures for Testing

- Map location of historical, cultural, recreation sites, hotels, convention facilities on map containing major activity centers.
- Overlay existing public and private transit routes serving these areas and planned DPM guideway and station locations to determine connectivity among sites and distances between stations and attractions.
- Survey hotel associations and convention center managers to determine expectations of DPM induced business.

Actions to Maximize Potential

- Plan station locations to be within easy walk access of hotels, tourist attractions and other major activity centers; consider joint development opportunities with private developers to provide direct access from DPM stations to hotels, etc. (for example, the Montreal rail system has a subway station which can be accessed directly through the lower level of the Bonaventure Hotel (1); examples of joint development to provide direct access between DPM's and hotels can be found in Seventh Place, St. Paul (2), Bunker Hill, Los Angeles (2), and Allen Center Terminal, Houston (2)). (See also Section 7 for discussion of Value Capture Opportunities.)
- Plan route alignment to provide connections between major attractions.
- Coordinate marketing effort with the Chamber of Commerce to attract conventions to the city; through marketing effort, promote major attractions along DPM route.
- Coordinate DPM evening operating hours with downtown evening activities that can be served by the DPM.

References and Footnotes

(1) Transit Station Area Joint Development: Strategies for Implementation, Final Report, Administration and Management Research Association of New York City, Inc., 1976. (Discussion of Bonaventure Hotel joint development project).

(2) The Downtown People Mover Progam and Associated Joint Development Opportunities and the National Urban Policy, Charles River Associates, Inc., Report No. 419.03.0.99, January 11, 1979.

10.3.3. DPM IMPACTS: SOCIAL

DPM IMPACT: SOCIAL

- **ACCESSIBILITY**

Potential: A DPM system can make employment, shopping and other activities more accessible by means of public transportation.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Low level of existing transportation services to employment, retail and other major activity centers.	1. Examine information on transit routes, frequency, hours of operation and fares, obtained from transit schedule.
2. Moderate to high level of surface transportation congestion in the vicinity of major activity centers.	2. Examine traffic volume counts by route and time of day; road and street capacity; pedestrian activity levels based on origin/destination patterns.
3. Impaired physical accessibility to major activity centers for autos and pedestrians.	3. Identify street restrictions: one-way streets; transit only streets; reserved transit lanes; etc. (Information may be obtained from city and county traffic and public works departments and from transit district); existence of natural and man-made barriers (from topographical maps and aerial surveys).
4. Inadequate or inconvenient parking in the vicinity of major activity centers.	4. Survey parking lot owners and managers for occupancy rates and turnover rates for parking areas within walking distance to major activity centers; survey parking lot locations to identify major activity centers not within reasonable walking distances to parking areas (information on parking lot locations may be available in city departments of planning).(1)
DPM Characteristics	
5. Fare level	5. Evaluate alternative fare policies, using fare elasticities obtained from travel demand models as a guide. (Examine options including distance based fare, zone fare, flat fare, peak/off peak, etc.(2) (See Chapter 9 for discussion of different fare structures.)

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Contributing Factors	Predictive Measures
DPM Characteristics	
6. Accessibility of the system to the elderly and handicapped.	6. Examine vehicle and station design features including loading platform heights; access/egress options other than stairs; vehicle space for wheelchairs; features to secure wheelchairs, priority seats for the infirm; handrails and other devices to assist movement. (3)(4)(5)(6)(7)
7. Information conveyed through the system's public information and communication program.	7. Information conveyed on DPM signs (e.g. route maps, time schedule, transfer points, present location of rider, fare, major points of interest in downtown relative to DPM); organization, visual clarity and comprehensiveness of information; availability of brochures and posted information; vehicle identification on exterior and interior; ability to read from front, read and side of vehicle, from a distance and at night.(8)
8. Available parking for DPM riders at major intercept points.	8. Locate existing parking areas that can serve DPM riders as determined by identification of parking lot locations (see 4 above); locate planned parking areas and capacities as identified in DPM planning documents.
9. Interface between DPM system and other public transit systems.	9. Determine distances between DPM stops and those of other downtown transit systems; examine transit schedules to plan for compatability with DPM operations and for joint fare structure arrangements. Explore potential for enhancing transfer opportunities considering the above factors in discussions with other transit operators and officials.
10. Guideway alignment.	10. Examine engineering plans to locate areas of obstructed pedestrian or auto movement due to physical guideway supports.
11. Incorporate joint development and value capture mechanisms into system plans.	11. Identify strategies to arrange direct access from DPM stations to major activity areas; develop land use plans to be compatible with the transit system.

Procedures for Testing

- On maps of downtown show:
  - existing transit routes serving major activity centers.
  - connections between DPM stations and transit stops of other downtown transit systems.
  - connections between DPM stations and existing parking areas that could serve DPM riders.
  - connections between DPM stations and major activity centers and route of alignment.

- Superimpose on the above maps:
  - traffic volumes in vicinity of DPM stations and major activity centers.
  - traffic restrictions. (see 3 above)
  - physical barriers in the vicinity of DPM stations and major activity centers.
  - street activity along the path of the guideway.

- Using travel demand models and/or above maps, indicate areas of heavy induced traffic around DPM stations, parking needs at DPM intercept points, streets most conducive to the location of the guideway considering physical characteristics of street and retail activities along proposed guideway route.

- Determine current levels of accessibility using information obtained from mapping, road capacities and parking facility capacities; estimate change in level of accessibility due to DPM from travel demand models.

- Compile a list and description of special features currently available on transit systems for the elderly and handicapped from system manufacturers and other transit properties; conduct public meetings with elderly and handicapped organizations to solicit comments and suggestions on equipment, system design and location; assess the likelihood of riding the DPM. (Also conduct meeting with general public for same purposes).

- Engage marketing specialist or if feasible use in house staff to compile information on communication techniques used by transit systems nationwide; select those techniques which appear to have the highest potential for DPM system; develop alternative packages of communication aids and test for comprehensiveness and comprehendibility on sample of public.

Actions to Maximize Potential

- Plan DPM station locations to:
  - maximize pedestrian access.
  - coordinate with parking facilities for auto trip transfers.
  - coordinate with transfer points of other transit systems.
  - locate stations within easy walking distance of major activity centers.

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Actions to Maximize Potential

- Use input obtained from public meetings and from meetings with elderly and handicapped groups to revise design specifications, equipment and location plans as appropriate; incorporate final plans into engineering specifications.
- Incorporate most effective communication aid package into system public information and marketing program.
- Coordinate fare structures and transfer arrangements with other public transit systems.

References and Footnotes

(1) Implementation and Administration of Air Quality Transportation Controls: An Analysis of Denver, Colorado, Draft Report, Cambridge Systematics, Inc., August, 1977, pp.14-15 to 14-17. (Attitudes of downtown merchants in Denver, Colorado, about parking lot locations).

(2) BART Interstation Fare Schedule Report, Office of Research, Bay Area Rapid Transit District, May 18, 1971.

(3) "Specifications for Making Buildings and Facilities Accessible to and Useable by the Physically Handicapped," American National Standards Institute, ANSI A117.1-1961 (Reaffirmed 1971). (Specifications for elderly and handicapped accessibility).

(4) Transportation for Elderly and Handicapped Persons, Department of Transportation, UMTA and FHWA, Federal Register, April 30, 1976. (Specifications for elderly and handicapped accessibility).

(5) "Accessibility of the Metropolitan Washington, D.C., Public Transportation System to the Elderly and Handicapped," Abt Associates, Inc., 1974. (Experience of new rail systems regarding elderly and handicapped accessibility).

(6) BART and the Handicapped, Robert Levine, BART Impact Program Document Number 17-1-75, 1974. (Experience of new rail systems regarding elderly and handicapped accessibility).

(7) The Impact of BART on the Physically Disabled, Jefferson Associates, Inc. and the Center for Independent Living, May, 1975. (Experience of new rail systems regarding elderly and handicapped accessibility).

(8) Getting In Gear - A Transportation Action Kit, Carolyn Fratessa of Public Policy Research Associates and Robert Grether of the KLS Design Group. (Photographic and graphic examples of important communication aids).

DPM IMPACT: SOCIAL

● **MOBILITY**

Potential: A DPM system can provide enhanced circulation and distribution within the downtown with decreased reliance on automobiles, by supplementing and complementing other forms of downtown transportation.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Low level of public transportation service to major activity centers within the downtown .	1. Obtain information on transit routes and service frequency from transit schedules; system capacities.
2. Moderate to high level of automobile and taxi congestion within downtown.	2. Examine auto/taxi volume counts by route and time of day.
3. Current use of public and private transportation forms in downtown for different population groups.	3. Review transit on-board rider surveys; auto driver survey; taxi passenger survey; information from home interview survey.
4. Existing downtown public transportation not accessible to the elderly and handicapped.	4. Review equipment on vehicles and at stations for elderly and handicapped including loading platform heights; wheelchair lifts; handrails and other devices to assist movement; kneeling features; priority seating for the infirm, features to secure wheelchairs. (1)(2)(3)(4)(5)
DPM Characteristics	
5. Interface with other public transit systems.	5. Determine distances between DPM stops and stops of other transit system downtown stations; examine transit schedules to plan for compatability with DPM operations and possible joint fare structure arrangements; explore the potential for enhancing transfer opportunities by considering the above factors in discussions with other transit operator officials.

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Contributing Factors	Predictive Measures
DPM Characteristics	
6. Available parking at major intercept points.	6. Locate parking areas that can serve DPM riders as determined by parking lot locations (information on parking lot locations may be available in city departments of planning); new parking areas planned, and capacities thereof as identified in DPM planning documents.
7. Stations and vehicles are accessible to elderly and handicapped.	7. Review equipment at stations and on vehicles for elderly and handicapped persons (see 4 above).
8. System operations during inclement weather.	8. Review equipment to clear tracks of snow and ice; vehicle protection from moisture. (6)(7)

Procedures for Testing

- Map routes of existing transit services within downtown to determine transit mobility <u>added</u> by DPM; indicate major activity centers poorly served by existing public transportation for high priority DPM location consideration.

- Chart auto volumes within downtown during peak travel hours to determine levels of congestion and potential of DPM to relieve congestion (use information on auto traffic obtained from traffic counts and travel demand models).

- Conduct on-board transit rider surveys, downtown auto and taxi surveys to determine whether transportation mode choice differs by population subgroup (e.g. commuter, shopper, by median family income, auto ownership, etc.); include in survey, question regarding potential mode shift to the DPM.

- Use information obtained from travel demand models to determine demand for parking at DPM intercept points and whether existing and planned DPM parking areas will satisfy this demand.

- Evaluate results of travel demand forecasting models looking at socioeconomic characteristics of potential DPM riders; compare to characteristics of existing downtown users as ascertained by transit on-board surveys, taxi and auto surveys; estimate mode shifts.

- Compile a list and description of special features currently available on transit systems for the elderly and handicapped from system manufactures and other transit properties; conduct meetings with elderly and handicapped organizations to solicit comments on and suggestions for equipment, system design and location; assess likelihood of riding DPM (also conduct meeting with general public for same purposes).

Actions to Maximize Potential

- Coordinate the stops of the DPM system with stops of other transit systems.

- Provide adequate parking at DPM intercept points for persons driving into the downtown area.

- Use input obtained from public meetings and meetings with elderly and handicapped groups to revise design, equipment and location plans as appropriate; incorporate final plans into system engineering specifications.

- Conduct large scale marketing campaign by mail and media to inform citizens of DPM service and special features for the elderly and handicapped.

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References and Footnotes

(1) "Specifications for Making Buildings and Facilities Accessible to and Usable by the Physically Handicapped," American National Standards Institute, ANSI, A117.1-1961 (Reaffirmed 1971). (Specifications for elderly and handicapped accessibility).

(2) Transportation for Elderly and Handicapped Persons, Department of Transportation, UMTA and FHWA, Federal Register, April 30, 1976. (Specifications for elderly and handicapped accessibility).

(3) "Accessibility of the Metropolitan Washington, D.C., Public Transportation System to the Elderly and Handicapped," Abt Associates, Inc., 1974. (Experience of new rail systems regarding elderly and handicapped accessibility).

(4) BART and the Handicapped, Robert Levine, BART Impact Program Document Number 17-1-75, 1974. (Experience of new rail systems regarding elderly and handicapped accessibility).

(5) The Impact of BART on the Physically Disabled, Jefferson Associates, Inc. and the Center for Independent Living, May, 1975. (Experience of new rail systems regarding elderly and handicapped accessibility).

(6) Morgantown Assessment, Charles P. Elms, N.D. Lea & Associates, Inc., and Howard Evoy, Department of Transportation, UMTA, page 4. (Chemical mixtures to prevent track freezing).

(7) "Technology Assessment of Personal Rapid Transit," J.L. Pfeffer and Tom McGean, The MITRE Corporation, MTR-6664, January, 1975. (Chemical mixtures to prevent track freezing).

DPM IMPACT: SOCIAL

● **RESIDENTIAL LOCATION**

Potential: A DPM system can contribute to a comfortable living environment within the downtown area by providing convenient access for residents to employment, shopping, and recreational areas with decreased dependence upon the automobile. The DPM can also be important in the decision to construct new residential development and/or to renovate older residential areas.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Existing downtown residential areas are physically or geographically seperated from major CBD activity centers.	1. Measure distances between existing residential areas and activity centers to determine feasibility of walk trips; survey current level of pedestrian activity between areas. Obtain from transit schedules, information on transit routes and service levels between residential areas and activity centers.
2. Socioeconomic characteristics of persons/families residing within specific areas of downtown.	2. Obtain information from census on median family income, auto ownership and median rental and home rental values for downtown census tracts; records on assessed housing values from county assessors office for downtown residences.(1)
3. Availability of residential units within the downtown area.	3. Obtain information from realtors on general housing market conditions and units available for rental and sale within the downtown area.
DPM Characteristics	
4. Station locations: accessibility to residential areas.	4. Measure distances between DPM stations and residential areas (determine walk trip lengths and compare with average walk trip lengths).
5. Auto volumes around DPM stations.	5. Obtain projections of induced auto traffic at each DPM station from travel demand models to determine noise, emissions and activity levels which can adversely impact close by residences.

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Contributing Characteristics	Predictive Measures
DPM Characteristics	
6. Noise and vibration characteristics of vehicles and guideway.	6. Examine weight and size of guideway and vehicles; speed of vehicles at various segments of route; decibel and reverberation levels at sidewalk and second story levels adjacent to guideway(2)(3)(4).
7. Visual intrusion of guideway and vehicles.	7. Height of guideway; distance of guideway from residences; visual access from vehicles into residences (5)(6).
8. System Coverage.	8. Examine station locations and route of guideway connecting residential areas and major activity centers.
9. DPM schedule particularly during non-peak hours and on weekends.	9. Obtain information on service frequency and hours of operation from DPM schedule.

Procedures for Testing

- Map
  - existing residential areas and planned residential developments in relation to major activity centers to show distances between sites; overlay pedestrian, auto and public transit trip volumes for those trips whose origins and destinations are between target areas. Indicate on map existing transit routes between residential areas and activity centers to determine existing transit coverage (this is particularly significant when walk distances are too far and auto travel between sites is difficult either due to heavy traffic, parking problems, or the presence of physical barriers).
  - station locations and guideway route indicating distances to existing residential areas; potential for adverse noise, vibration and usual impacts can then be determined when distances are established.
  - current and predicted auto volumes around stations obtained from auto counts and travel demand models; overlay this information on map of station location distances to residential areas to determine potential for resulting auto noise, emissions and activity levels to disturb nearby residents. (This applies to existing residences and planned residential developments.)
- Interview
  - realtors to determine their expectation of downtown residential patterns and effect on property values/rents due to the DPM.
  - citizens in the housing market to determine their perceptions about the effect of DPM on attractiveness of housing in the downtown vicinity.
- Review impact studies of the effect of aerial structures on residential environments in other areas of the country (obtain photographs where possible); prepare a report synthesizing the experiences of other systems and highlight impacts of noise, vibration, visual intrusion, and general aesthetics. Assess the extent to which the experiences of other systems may be likely to occur for the proposed DPM.

Actions to Maximize Potential

- Plan route configuration and station locations to connect residential areas and activity centers so that residents can satisfy their demand for goods, services and employment, minimizing the need for an automobile. In planning station locations and guideway route, balance the need for accessibility with consideration of the adverse impacts of having the stations and guideway too close to residences (use results of the case study impact reviews of aerial structures in other areas of the country as a guide).

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Actions to Maximize Potential

- Plan the guideway route so that the height and alignment does not provide riders direct visual access into residences; alternatively, or in combination, provide visual buffers between residential units and DPM.
- Conduct a public information program to inform residents and prospective residents about the DPM services.

References and Footnotes

(1) Implementation and Administration of Air Quality Transportation Controls: An Analysis of Denver, Colorado, Draft Report, Cambridge Systematics, Inc., August, 1977, pp. 14-8 to 14-14.

(2) BART Interstation Fare Schedule Report, Office of Research, Bay Area Rapid Transit District, May 18, 1971.

(3) "Specifications for Making Buildings and Facilities Accessible to and Useable by the Physically Handicapped," American National Standards Institute, ANSI A117.1-1961 (Reaffirmed 1971). (Discussion of noise and vibration issues relative to AGT).

(4) Acoustic Impacts of BART: Interim Service Findings, Bolt, Beranek and Newman, Inc., 1976.

(5) Visual and Environmental Effects of Minitram Guideways, Technical Papers, 1975 Conference on Personal Rapid Transit, Paper 30, Vol. II, Denver, Colorado, September 16-19, 1975.

(6) "Comparison of People Mover Alternatives in Downtown Minneapolis," Personal Rapid Transit II, proceedings of the 1973 International Conference on Personal Rapid Transit, University of Minnesota, February, 1974, pp. 155-172. (Discussion of visual impacts).

DPM IMPACTS: SOCIAL

• **CRIME AND VANDALISM**

Problem: In the social climate existing in many city centers, considerable crime directed against DPM riders (muggings, rape, purse snatching, pickpocketing) and vandalism directed against vehicles and station structures may occur. These incidents can create fear and lead to severe loss of ridership particularly at off peak hours.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. High level of social problems and racial tension in downtown.	1. Observation, recorded incidents, sample interviews with different types of downtown users. Rate in comparison to other parts of region and to other cities.
2. High incidence of crime and vandalism downtown.	2. Police records of crime and observation of vandalism of public facilities mapped - generalized for downtown and specific around each station (300' radius or 4 block area). Rate in comparison to other cities.
3. Lack of after hours activity.	3. Map residential, entertainment and institutional use that regularly animates streets in the evening within one block of station. Identify the specific stations and the times of day and week that are without such activity.
4. Difficulty in providing sufficient public space maintenance and police surveillance.	4. Observe length of time it now takes to remove trash or signs of vandalism. Construct sample interviews to check public perception. Rate in comparison to other cities.
DPM Characteristics	
5. Unattended vehicles and stations without direct surveillance or access to help.	5. Review designs of stations and vehicles and operating plan for ability to respond under various possible scenario of vandalism or violent crime attempts - ascertain likely scenarios from police records and sample interviews.

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Contributing Factors	Predictive Measures
DPM Characteristics	
6. Visual and/or auditory isolation of stations from other public activity.	6. Diagram on plans and sections visibility, blind spots and hearing range and overlay diagram of afterhours public activities.
7. Very low usage at certain stations at off hours.	7. Ridership projections showing likelihood of less than 3 people waiting for more than 30 seconds at a given time.
8. Extreme crowding at peak hours (contributes to purse snatching and pickpocketing, not to violent crime or vandalism).	8. Check ridership projections and nature of contributing activities at each station for potential crush loads.
9. Insufficient maintenance and replacement budget and personnel for surveillance of DPM system.	9. Check operational budgets - compare to other cities with similar incidents of crime and vandalism. Check resources of operating agency for potential increased effort if needed.

Procedures for Testing

- Regular users of downtown generally have a strong idea of the level of crime and vandalism problems. Even if such perceptions are exaggerated or inaccurate, they play a very important role in defining people's reactions to the DPM. Thus sample interviews should be used to gain information on the critical factors 1-4 as well as a measure of the prevailing public attitudes.
- Worse than average scores on factors 1 and 2 for either the area as a whole or for the vicinity of any station will in combination with any one or more of the other factors create a high risk for crime and vandalism. Each such station location should be identified.
- Measures proposed to ameliorate the impacts of crime and vandalism should be described in detail and analyzed for their expected cost and effectiveness. Commitments to these measures must correspond to the life of the DPM or the duration of the problem whichever is shorter.

Actions to Minimize Negative Impacts

- Factors 1 and 2 usually require a broader response than could be provided by the DPM project. Even a concerted effort of downtown interests is only likely to effect slow and gradual changes. Thus in generally crime and vandalism prone areas, more specific and localized measures will be required for the DPM that are listed below.
- Factor 3: Encourage the development of after hours residential and commercial uses near stations. Until such uses are regularly operating either provide attendants at high risk stations or temporarily exclude such stations from after hours operation.
- Factor 4: Set aside special funds and personnel for maintenance and surveillance of streets and other public spaces in DPM station areas.
- Factor 5: The lack of attendants and resulting labor saving is central to the economy of the DPM concept. Nevertheless it may become imperative to have attendants at some of the high risk stations or in the vehicles in the evening hours. Closed circuit T.V. monitoring or 2-way speaker phones may have some benefit but they are limited because a) they cannot bring immediate intervention and b) these devices are likely to be the first targets of vandalism.
- Factor 6: Adjust station designs to provide most direct physical and visual access to and from adjacent activity areas.
- Factor 7: Do not operate these stations in evening hours until travel demand reaches minimum requirement to animate station (see Measures).
- Factor 8: Eliminate overcrowding. Put up warning signs.
- Factor 9: Increase operational budgets if needed.

DPM IMPACT: SOCIAL

• SYSTEM SAFETY

Discussion: DPM ridership can be affected by perceptions and actual experiences of system safety. Efforts to inform the public of safety features by documenting and, if possible, demonstrating safety features will be important in minimizing the public's reservations about the DPM system.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Composition and stability of ground where guideway will be placed.	1. Obtain information on soil strength and bearing capacities through standard penetration resistance tests; (Standards on structural requirements are contained in local building codes), obtain information on earthquake risk from U.S. Geological Survey.
DPM Characteristics	
2. Vehicle entrance and exit features.	2. Review door width; duration of time doors remain open; procedures for checking clearance before closing of doors; vehicle alignment with boarding platform. (1)
3. Vehicle operations along guideway.	3. Review platform switching requirements and methods; sophistication of automatic control equipment and demonstrated experience (2); person(s) on duty to monitor operations and supersede automatic operations as necessary.
4. Ability to determine track clearance.	4. Review failure/obstacle detection devices.
5. Passenger safety during vehicle movement.	5. Review seat angle and direction; seat fabric; poles, handrails, etc., for standees; acceleration/deceleration rate; jerk levels. (3)
6. Passenger emergency evacuation procedures.	6. Review number of vehicle and station attendants; on-vehicle public broadcast system; manual of procedures for emergency evacuations.

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Contributing Factors	Predictive Measures
DPM Characteristics	
7. Vehicle and guideway stability and durability.	7. Review construction materials; weight, dimensions; design specifications.
8. Ability to operate safely during inclement weather.	8. Review track sensors; procedures to clear tracks of ice and snow; chemical solutions used in track to prevent freezing; wind sensitivity. (4)

Procedures for Testing

- Conduct test and borings at representative areas along proposed guideway alignment to determine allowable bearing capacity.

- Compile a composite list of design features, equipment used and experience record of other systems. (5)(6)(7)(8)(9)(10) Identify problem areas, causes and corrective procedures for these systems and relate to current status of their operations; consult with experts to assess feasibility of existing features and equipment and to identify potential new or improved design features and equipment.

- Perform test runs of system prior to opening for revenue service to observe performance of equipment under differing operating conditions. (11)

- Compile information on local state and federal fire and safety codes; test DPM design and operations against prescribed standards.

- Conduct experiments with human subjects in conditions simulating vehicle acceleration/deceleration and jerk levels to determine acceptable levels and system design requirements.

Actions to Maximize Potential

- Document results of test runs and other simulation and present them to the public; if possible allow representatives of the public to observe pre-service operations in order to develop confidence and create advocates through information and observation.

- Sponsor an exhibition of new equipment and, in particular, equipment in operation elsewhere in order to increase public understanding and confidence.

- Conduct a training course for station and vehicle attendants in the procedures to be followed in the necessity of emergency evacuations.

References and Footnotes

(1) Criteria for Evaluating Alternative Transit Station Designs, Lester A. Hoel, Michael J. Demetsky, Mark R. Virkles, School of Engineering and Applied Science, University of Virginia, Charlottesville, February, 1976, pp.4-7. (Criteria for boarding and disembarking vehicles).

(2) Transportation and Travel Impacts of BART: Interim Service Findings, April, 1976, p. 29. (Discussion of problems encountered with the BART control system).

(3) Systems Safety and Passenger Security: A System Level Study Project, Richard Deplar, Dunlap and Associates. (Describes test design for establishing acceptable acceleration/deceleration and jerk levels and seat design requirements).

(4) Morgantown Assessment, Charles P. Elms, N.D. Lea & Associates, Inc., and Howard Evoy, Department of Transportation, UMTA, page 4. (Chemical solutions to prevent track freezing).

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(5) Assessment of Operational Automated Guideway Systems - Airtrans (Phase I), U.S. Department of Transportation, UMTA, July, 1976. (Description of features incorporated into existing automated guideway transit systems).

(6) Assessment of the Automatically Controlled Transportation (AGT) System at Fairlane Town Center, U.S. Department of Transportation, UMTA, December, 1977. (Description of features incorporated into existing automated guideway transit systems).

(7) Assessment of the Passenger System Shuttle (PSS) at Tampa International Airport, U.S. DOT/UMTA, December, 1977. (Description of features incorporated into existing automated guideway transit systems).

(8) Assessment of the Satellite Transit System (STS) at the Seattle-Tacoma International Airport, December, 1977. (Description of features incorporated into existing automated guideway transit systems).

(9) Assessment of the Tunnel Train System at the Houston International Airport, U.S. Department of Transportation, UMTA, December, 1977. (Description of features incorporated into existing automated guideway transit systems).

(10) Assessment of the Midway People Mover System at Walt Disney World, U.S. Department of Transportation, UMTA, December, 1977. (Description of features incorporated into existing automated guideway transit systems).

(11) Safety in Urban Mass Transportation: Guidelines Manual, U.S. Department of Transportation, UMTA, May, 1975. (Federal safety guidelines for urban mass transportation).

10.3.4. DPM IMPACTS: ENVIRONMENTAL

DPM IMPACTS: ENVIRONMENTAL

- **AIR QUALITY**

Potential: A DPM system may improve air quality in the downtown area by providing opportunities to limit automobile and bus traffic on the downtown streets.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Traffic Congestion.	1. Both the high volumes and low speeds often associated with downtown traffic result in high vehicular emissions and therefore, significant impacts on air quality. Maps showing volumes and speeds by street segment are useful in measuring traffic congestion.
2. Level of Bus Transit Service.	2. A high density of bus transit service in the downtown area will result in significant air quality impacts due to the large emissions produced by these vehicles. Maps showing bus volumes by street segment can be developed using published transit schedules.
3. Parking Availability.	3. Large amounts of available parking in the CBD will result in significant impacts on air quality due to the "hot soak" phenomenon in which parked vehicles continue to generate emissions as they cool off after being driven downtown, due to the "cold start" phenomenon as they are used to leave the CBD, and due to the distance travelled by each parked vehicle within the CBD. A measure of these impacts can be obtained by mapping parking availability and use on a block by block basis. Severe limitations in parking availability, when compared with demand, can cause travellers to drive longer distances in the CBD, searching for a place to park. The relative importance of this factor can best be judged by interviewing CBD parkers, asking how many facilities were checked as possible parking locations but rejected due to price or lack of available space, and how many blocks of excess travel took place.

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Downtown Characteristics

4. Existing and projected air quality levels.	4. Only if existing or projected levels present problems is it important to consider the air quality impacts of the DPM system. Data from existing air quality monitoring systems and projections made for the future in the CBD area will indicate the importance of this impact.

DPM Characteristics

5. Interface with regional transit	5. Reductions in bus transit in the CBD area which become possible as intercept facilities are provided at DPM stations will allow the bus-miles of CBD travel and their accompanying emissions to be reduced.
6. Interface with peripheral parking supply.	6. Attraction of parkers to the DPM intercept points, away from more centrally-located parking facilities, will reduce passenger vehicle-miles of CBD travel, and may also reduce congestion, thereby reducing emissions.
7. Level of Service.	7. Reduced usage of private automobile and bus transit for intra-CBD travel will occur if the DPM system provides a high level of service.

Procedures for Testing

Using the travel demand procedures described in Section 7, estimate change in travel patterns and resulting change in vehicle mixture by time of day. Use a rollback model (1) or some more sophisticated procedure for estimating change in air quality.

Actions to Maximize Potential

- Provide the highest levels of DPM service in the CBD areas which have the most severe air quality problems.
- Encourage shifts to fringe parking facilities as a substitute for centrally-located parking, thereby also providing additional developable land.
- Coordinate CBD bus service and the DPM system at intercept facilities, and reduce existing bus transit service through the CBD.

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References

(1) **The Relationship of Emissions to Ambient Air Quality**, U.S. Senate Committee on Public Works, Volume 3 of a Report by the Coordinating Committee on Air Quality Studies, National Academy of Sciences, Washington, D.C., 1974, pages 28-37 and pages 91-130. (Description of auto emission rates and rollback model.)

DPM IMPACTS: ENVIRONMENTAL

- NOISE

Problem: A DPM system, as an at-grade or elevated system, can result in an increase in the noise level along city streets. Only in cases in which the DPM system would result in a significant reduction in bus and auto traffic would there be a potential for a significant decrease in noise levels.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Ambient noise levels.	1. City traffic and/or planning departments may be able to provide measures of existing noise levels and to indicate the extent to which problems are perceived.
2. Building arrangement.	2. Tall buildings presenting a solid barrier on both sides of CBD streets cause high noise levels. Maps of the CBD showing the locations of these conditions can be developed based on land use data and/or observation.
3. Traffic volumes and vehicle mix.	3. Maps of volume levels and percent trucks and buses will aid in identifying potential problem areas.
4. Land use.	4. Residential and hotel land uses will be most severely impacted by high noise levels. The locations of these land uses can be mapped and compared with maps of existing noise levels.
DPM Characteristics	
5. Guideway location.	5. The guideway's location should be compared with the potential problem areas identified using the predictive measures discussed above to determine whether or not it will increase noise problems at the critical sites.

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DPM Characteristics

6. System specification.	6. The noise characteristics of each potential DPM manufacturer's system will vary. Tests of these characteristics should be evaluated for each system being considered. Especially important will be the system's noise characteristics while starting, stopping, and negotiating curves with small radii.

Procedures for Testing

Noise tests have been made for automated guideway transit systems in reference (1). These results can be useful when compared to ambient street noise levels and the noise produced by alternative modes of circulation.

Actions to Minimize Negative Impacts

- Avoid placing the DPM guideway in locations which presently have high noise levels.
- Avoid curves with small radii.
- Avoid placing the DPM guideway in locations which are particularly sensitive to noise such as residential areas, hospital zones, etc.

References

(1) Environmental Impact Issues for Automated Guideway Transit Systems, E. Nussbaum and B. Zumwalt, MITRE Corporation, prepared for the Urban Mass Transportation Administration, Washington, D.C., 1976, pages 73-107. (Discussion of noise measurement criteria and experience with noise levels of existing automated guideway transit systems.)

DPM IMPACTS: ENVIRONMENTAL

- **ENERGY CONSUMPTION**

Problem: The primary source of DPM trips will be trips presently made on foot. Diversion of large numbers of trips to the DPM will have little or no effect on fuel consumption. If there is a significant effect, it will very likely be an increase in energy consumption.

Contributing Factors

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Current level of regional transit service within the CBD.	1. Total bus miles of travel can be estimated from transit schedules. The volume of bus miles eliminated through DPM service will depend upon the specific "intercept" plans.
2. Current regional transit productivity by time of day.	2. For transit services in the CBD area, compare capacities and patronage levels by time of day.
DPM Characteristics	
3. Level of service and system productivity.	3. As level of service measures such as DPM seats per passenger increase, DPM productivity and, therefore, fuel efficiency, will decrease.

Procedures for Testing

The net impacts of a DPM system on fuel consumption can be determined by summing the product of all changes in vehicle flows - by DPM vehicles, regional transit buses, and private automobiles - and their respective fuel consumption rates.

Actions to Minimize Negative Impacts

- Interfacing with both the regional transit system and peripheral parking areas can reduce the amount of travel by cars and buses within the CBD. Transfers from the regional bus system must be fast and convenient. Peripheral parking lots must be easily accessible from major freeway exits. The price of parking and of transfer fares must be low enough to be competitive with alternative parking locations or bus routes.

-continued-

References

(1) Environmental Impact Issues for Automated Guideway Transit Systems, E. Nussbaum and B. Zumwalt, MITRE Corporation, prepared for the Urban Mass Transportation Administration, Washington, D.C., 1976, pages 124-128. (Energy consumption rates for existing automated guideway transit systems.)

(2) Lave, C.A., "Downtown People Movers and Energy," Paper presented at the Annual Meeting of the Transportation Research Board, Washington, D.C., January 1978.

10.3.5. DPM IMPACTS: URBAN DESIGN

• **INDUCED ACTIVITIES**

Potential: A DPM system can promote circulation among downtown activity areas which are now too remote for pedestrian access. Such induced trips can create new markets for retail and office activity, new street life and a greater attraction of downtown as a whole. This potential is one of the key motives for local interest in a DPM. It is essential to specifically define the extent of such potential and the extent to which the DPM will contribute to its realization in a particular city.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Major activity areas disconnected from complimentary activities (i.e. employment from retail, residential, from recreation, etc.	1. Map major activity areas such as financial district, retail district, major university or medical complex, residential neighborhood (1). Indicate number of employees, residents, amount of retail space. Overlay walking distances, present walk trips (based on circulation travel model output), barriers to walking. Compare to similar relationships without access barriers and estimate potential untapped market (in numbers of people and trips).
2. Market potential among current downtown users (employees, tourists, residents).	2. Add to the above a more detailed analysis of disposable income, disposable time and unmet needs of present downtown users. Distribute this potential among DPM stations according to the travel projections. Identify effect in each station area (i.e. reinforcing existing shops, creating markets for new businesses, exceeding sidewalk capacities, etc.) and represent on activity map (2)
3. Overall trends in the attraction of downtown from its regional market.	3. Determine recent trends in market share (3)-assess attraction of downtown developments concurrent with DPM versus their suburban competitors. Rate the attraction of downtown in each activity type (office workers, shopping, living, entertainment, other services) as growing, steady or declining and project annual percentage changes.

Contributing Factors	Predictive Measures
DPM Characteristics	
4. Location of stations.	4. Superimpose DPM plans showing stations and their entrance points over scale 1 and scale 2 activity maps - indicate area within 300 foot walking distance from each station and summarize facilities within this area (retail type and square footage, amount of office space, housing units, recreation, institutions and other facilities) - map these on detailed activity map of each station area (4).
5. Expected new induced trips to each station.	5. Compute and map from travel demand projection new induced trips as well as displaced pedestrian, auto and bus trips by time of day and trip purpose to each station.
6. Evening operation - dependability, coordination with activities.	6. Check coordination of scheduled operations with evening shopping, restaurant and entertainment schedules at each station. Check intent of major stores, restaurants, and hotel operators to extend hours with DPM.

Procedures for Testing

- May require several cycles of distributing present market demand, assessing travel demand on DPM, assessing induced activity potential and distributing among DPM stations and reassessing travel demand based on adjustment in attractions.

- After mapping expected increased activities at each station ion project likely response in each area - i.e. more intensive use of existing facilities - likely demand for expansion - likely demand for new types of facilities.

- Interview a sample of businesses at each station location. Ascertain the amount of increased business they expect with the projected increase of trips to the area - use the interviews to determine potential for filling now vacant space - map results of interviews and test against analytical studies of market and distribution.

Actions to Maximize Potential

- Use activity potential maps from above points(1) and(2) in planning DPM route and stations to fit maximum potential.

- Plan DPM for maximum connections among complimentary activity centers: office to office or government, office to retail, hotel to entertainment or business area, medical center to restaurant district, etc.

- Tailor operating schedules to compliment lunch time and after work shopping , meals and entertainment options for downtown workers.

- Use DPM stations and news media to display information and promote downtown activities - provide information kiosk with directory and daily calendar of downtown events.

- Provide direct access form stations to pedestrian malls, plazas, shopping arcades, preferably with continuous weather protection.

References and Footnotes

(1)see scale 1 mapping. Appendix 4-D - Urban Ecological Analysis Techniques
(2)see scale 2 mapping. Appendix 4-D
(3)apply standard market study techniques
(4)see scale 3 mapping. Appendix 4-D

• INDUCED DEVELOPMENT

Potential: A DPM system will create new accessibility and attraction that can serve as a catalyst for real estate development. This may occur in the form of new projects, expansion or acceleration of projects already planned or the reuse of vacant older buildings and declining districts.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Downtown wide economic growth (or decline) and market potential.	1. Current CBD growth rate and trends - regional economic indicators. Market analysis identifying particular market sectors with growth potential downtown.
2. Specific markets generated by activity centers now isolated but to be linked by DPM (such as a medical center with high employment and no commercial facilities a mile away from the retail center).	2. Analysis of number of users, specific unmet needs, disposable time and disposable income concentrated at each activity center (1).
3. Available and suitable downtown development sites.	3. Inventory and map of major available downtown development sites indicating current planning, zoning, and development intentions(2).
4. Development programs already announced or committed.	4. Inventory and map all such development projects with size, use program, parking provisions, expected start and completion dates and level of current committment(3).
5. Public incentives and joint development programs.	5. Analysis and mapping of funds committed to such programs (4). Analysis of the last five years in development of downtown public spaces and facilities.

Contributing Factors	Predictive Measures
DPM Characteristics	
6. Route and station patterns in relation to developable sites and potential markets from now remote activity centers.	6. Overlay DPM plan on maps, from 2,3,4 and 5 above(5) and analyze development potential of sites within 300 feet of stations.
7. Projected induced trips to potential developable sites.	7. Allocate new DPM trips (discounting mode shift trips) from travel demand projection to stations with developable sites. Breakdown for disposable income and time. Use this as starting potential for new development in feasibility analysis.
8. Physical design of DPM guideway, stations and vehicles - attractiveness and integration into streetscape.	8. See "STREETSCAPE" section. Use drawings, models and photo montage illustrations to test reactions of developers and prospective tenants.
9. Construction phasing.	9. Review schedule coordination of DPM phases with projected opening of developments. Estimate range of likely slippage for each.
10. Joint marketing of DPM and development sites/projects.	10. Review marketing strategy for both DPM and developments. Test frequency of use of one to help the other. (See Section 9 on Value Capture/Joint Development.)

Procedures for Testing

- The most critical and difficult question is to determine the actual feasibility and likelihood of proposed development projects. All of the DPM proposals stress the great potential for complimentary joint development. At the same time most downtowns in the country have several major development sites that have been "about to go forward" for at least five or ten years and are still uncertain. Such developments ar difficult ventures and in the effort to promote them,both city governments and the developers tend to overstate their immediate feasibility. If the occurrence and timing of such developments is essential for DPM success an objective and critical analysis must be applied to determine their realistic probabilities.

- In addition to the above described market analysis, travel projections and site studies, a survey of the local real estate development community should be conducted to use their local experience and intuitive insights as a check. A list and description of proposed projects should be shown to a dozen or more developers and realtors (not the proponents of the projects) and they should be asked to rate the likelihood and probable completion dates of the projects.

- Development potential studies should be conducted site by site for the vicinity of each DPM station. These may well yield varying results proving some areas to be very feasible and others as unlikely. The total market potential in each market segment can be applied as the constraint on total downtown development (DPM related and other). If the sum of individual projections exceeds this constraint, they must either be all scaled down or some must be judged unfeasible.

Actions to Maximize Potential

- Design DPM route and station locations to maximize travel opportunities between potential markets and developable sites.

- Design and market DPM and joint development as a single system of complimentary opportunities, locating within easy access, places to work, live and shop; hotel and entertainment facilities; governmental facilities and other services. Identify combined use scenarios (e.g. parking, shopping, government business, lunch; parking, daily employment, lunch, shopping; convention, hotel, business visit, entertainment, etc). Design for them and promote them as the unique advantage of the downtown.

- Insure schedule coordination to complete key development projects and related DPM segments simultaneously.

References and Footnotes

(1)shown on scale 1 activity maps
(2)scale 2 maps
(3)scale 2 maps
(4)scale 2 maps
(5)scale 1 and scale 2 maps

• DISPLACED ACTIVITIES

Problem: A DPM system may attract people away from present pedestrian paths causing loss of street activity and of retail trade along these paths. A DPM or new development related to it may also attract tenants away from older buildings in parts of the downtown not directly served. The result could be the erosion of the economic base for older parts of the downtown and an accelerating pattern of decline in these areas.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Concentration of existing street level pedestrian routes where large proportion of trips may be shifted to DPM.	1. Pedestrian map(1) (origin, destination and volume) overlay of displaced pedestrian trips map from travel forecasts. (see TRAVEL IMPACTS.)
2. Amount and type of retail along routes with major pedestrian displacement.	2. Overlay map of retail establishments (2) indicating type, reliance on walk-in-trade, and sensitivity to loss of such trade (from interviews, observation and general retail industry standards) - identify high, moderate, and low risk establishments.
3. Older office buildings and other commercial space including hotels and light manufacturing not served directly by DPM.	3. Map downtown office buildings, show rents per square foot above the first floor and occupancy rate(3). Map other commercial structures with occupancy problems.
4. Major retail and office development projected to occur along DPM within 5 years (see INDUCED DEVELOPMENT).	4. Map projects considered firm or highly probable - based on market studies compute share of occupancy that must be drawn from existing facilities downtown - distribute this deficit among existing downtown facilities and map on overlay.
5. Still viable activity areas near DPM stations that are likely to be displaced by new more intensive development.	5. Map buildings and their uses within 500 feet of DPM stations (4). Analyze to determine where redevelopment potential is strong. Determine effect of displacement - i.e. disappearance of historic structures and traditional activities relocation and its costs, etc.

Contributing Factors	Predictive Measures
DPM Characteristics	
6. Lack of stations in older activity centers.	6. Overlay DPM route and station map on maps from 1-4 above. Consider all vulnerable facilities outside of a 300 foot radius from stations and analyse in detail for specific likely displacement and effects(5).
7. Node to node service with no pedestrian access between stops.	7. A given for DPM systems.
8. Elevated stations removed from current sidewalk activity.	8. Review station designs for escalators, connections to most active sidewalks in area. Overlay station plan on Scale 3 station area activity plan.

Procedures for Testing

- The most critical question is the extent to which DPM related growth can increase the attraction of downtown as a whole and how much it has to displace activities already downtown. For any market activity the total increment of that activity in DPM related development, is equal to the portion of that activity attracted from outside of downtown plus the activity relocated within the downtown. A market analysis can project the general potential for restaurant, entertainment, etc.(6). In any segment where the total increment in activity exceeds the potential for activity attracted from outside of downtown, it must be concluded that either the new development will not be feasible or it must draw its clientele from the existing facilities
- No general model exists for predicting the distribution of displacement. The areas most vulnerable are those of marginal businesses that could fail with even a modest loss of trade and those of businesses that are most likely to be attracted to new (more expensive but more convenient or luxurious) facilities. Once these facilities are mapped, the precentage of probable displacement must be manually distributed based on concrete local factors.
- The impact of displaced activities should be further examined to determine whether they are likely to create or accelerate the decline of whole areas, lead to loss of taxes and urban character or to change in use (such as residential conversion) or to larger scale redevelopment. The best tool again is comparative case study analysis of other downtown areas with similar shifts of attraction.

Actions to Minimize Negative Impacts

- Include existing activity centers among DPM stations and design stations for maximum access to and from sidewalk. This may be difficult since severe physical impacts of elevated structure are likely in these areas (see STREETSCAPE).
- An opposite alternative: avoid areas with closely knit pedestrian patterns and related small scale street activity fabric and focus DPM on middle-length trips to more remote activity locations such as universities, government complexes or medical centers. This approach carries a risk of creating a competing attraction around the DPM system which will not replace present pedestrian trips but may drain away tenants and users from the older district.
- Limit new retail office and hotel development to new growth sectors. Focus on complimentary uses that generate new markets for existing downtown facilities: residential, hotel, entertainment and special attractions.

References and Footnotes

(1)see scale 2 maps
(2)see scale 2 maps
(3)see scale 2 maps
(4)see scale 3 maps
(5)Such analysis will reveal for example that a warehouse building 4 blocks from DPM stations converted to architecture and planning offices that rent for $3.50 per sq.ft. is not vulnerable because new space will be much more expensive while an older office building renting primarily to lawyers at $7.50 per sq.ft. may easily lose tenants to new and more accessible space near the DPM.
(6)This potential however varies somewhat with the size and quality of the new developments. For instance, the Faneuil Hall Market Place in Boston has drawn more outside clientele than any conventional market projection may have predicted and is now having spillover benefits on other downtown retail. Such potential "major attractions" should be analyzed separately and compared to similar cases in other cities.

DPM IMPACTS: URBAN DESIGN

• **STREETSCAPE**

Problem: The elevated structure of DPM guideway and stations can have a detrimental visual effect on existing streets, sidewalks and buildings. Noise and vibration, loss of light and other changes in microclimate may have undesired consequences. Supports may block traffic, parking or curb lane loading operations or may obstruct sidewalk activity. The effect may be an overall degrading of the environment and attraction of the streets with DPM routes. At a time when other cities such as Boston are engaged in the removal and replacement of elevated transportation facilities because they are considered a blighting influence, it is critical that potentially similar impacts of DPM are avoided.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. Narrow streets and sidewalks.	1. Code on map(1) streets with width between property lines, 1) under 60', 2) 60'-90', 3) over 90'. Streets under 60' should generally not be considered as DPM routes.
2. Continuous existing building fabric at street line.	2. Mark continuous frontages of buildings over one story high on map(2).
3. People intensive activities at ground and second floor frontage.	3. Map retail frontages and number of shop and building entrances on ground floor map; indicate people intensive occupancy (office, shops, services, etc.) and architectural treatment (open with windows or blank wall) on second floor map along all DPM routes and stations(3)(4)
4. Northern climate.	4. List average number of days per year with snow, rain, winds over 20 mph and temperatures below 40° F (+5° C).
5. Marginal activity and economic strength along street.	5. Map occupancy rates, ground and second floor rents, retail sales and last 5 year trends for all buildings adjoining DPM route (5).

- continued -

Contributing Factors	Predictive Measures
Downtown Characteristics	
6. Structures particularly vulnerable to visual disruption.	6. Map historic districts, special monumental structures and all buildings in the historic register.
7. Poor standards of street maintenance.	7. Observation, photos, interviews covering all streets on route; comparison to other parts of downtown, metropolitan area and to other downtowns.
DPM Characteristics	
8. Design of elevated guideway, stations and supports.	8. Analyze plans and sections to show footprint on ground, shadows cast, obstruction of vehicular or pedestrian activity, architectural relationship to buildings including effect on views, character and other functions, water drainage from structure, induced wind patterns, and accumulation of trash along supports. Examine all station structures, turning and street crossing sections as well as typical segments.
9. Noise and vibration characteristics of vehicles and guideways.	9. Obtain test results of system. Apply to street cross sections with guideway. Consider reverberation from building walls. Project decibels of noise and extent of vibration at: 1) sidewalk level and 2) adjacent second story windows. Study turning sections and stopping and starting action at stations.
10. Maintenance of structure and support.	10. Examine budget and personnel commitments for cleaning, painting, repair and replacement. Compare with provisions and needs at other local facilities.
11. Lighting under structure.	11. Check lighting plan including provisions for maintenance and operation. Map any dark spots (illumination less than 5 foot candles)(6).

Procedures for Testing

- Streetscape impacts are difficult to quantify, yet they are likely to be one of the most controversial aspects of DPM. A high indication of any of the contributing City Characteristics (1-7) makes a DPM route on that street likely to produce serious negative impacts. A combination of 2 or more such high indications suggests that a street may be unsuitable as a DPM route without major modifications in the proposed DPM designs or extensive alterations in the environment.

- Streetscape impacts should be carefully considered in the early stages of feasibility analysis and the study of alternative routes since once a route is selected, the impacts are difficult to mitigate.

- Streetscape impact analysis should occur systemwide in the early stage of planning (7) and then separately for each route segment and station area during the design phase(8).

Actions to Minimize Negative Impacts

- Select routes with low indications in 1-7: wide streets, service sides of blocks, along parking lots and garages, or past new development sites where new construction can make appropriate architectural accommodations for DPM.

- If guideway must run over pedestrian areas and retail frontages, design structure to appear as a pedestrian arcade from below. Build guideway as complete roof over sidewalk, provide suspended sound insulation and lighting, provide glazed enclosure and climate control in extreme climates. Furnish arcade with signs, plants, street furniture and other pedestrian amenities. Minimize pedestrian's awareness of vehicles overhead.

- If DPM must run in front of buildings with activities facing in its direction, funds must be provided for alterations within the buildings,and condemnation and aquisition of the buildings by the authority may be legally required.

References and Footnotes

(1)see scale 2 maps
(2)see scale 2 maps
(3)see scale 2 maps
(4)see scale 3 maps
(5)see scale 2 maps
(6)Ramsey and Sleeper, Architectural Graphic Standards, 1970, John Wiley and Sons, p. 639: minimum illumination standards for parking lots and public walkways.
(7)Based on scale 2 maps
(8)Based on scale 3 maps and cross sections

DPM IMPACT: URBAN DESIGN

● CONSTRUCTION

Problem: A minimum of two year construction periods are estimated in the DPM proposals and with common construction difficulties of city centers this period could easily extend to 3 or 4 years. During this time, serious disruptions of pedestrian and vehicular traffic patterns and environmental problems of confusion, noise and dust may occur. These in turn would disrupt shopping patterns and other business activity, cause discomfort and inconvenience to downtown users and reduce the attraction of downtown as a whole. Some of the discretionary downtown users may stop coming and some of the activities may disappear or may move elsewhere.

Contributing Factors	Predictive Measures
Downtown Characteristics	
1. "Tightness" of the physical fabric - the availability of alternative routes or bypass space within the rights of way.	1. Analyse street pattern for bypass routes for pedestrian and vehicular traffic(1). Superimpose actual obstruction created by construction operation on street right-of-way(2). Indicate available residual routes and spaces and test their workability for traffic volumes, access to facilities and reasonable clarity of pattern.
2. Density and type of activity en-route.	2. Overlay activity maps(3) on physical and construction plans from above. Project temporary alternative routes and locations for these activities.
3. Sensitivity of activities to disruption.	3. Analyze nature of activities along each route segment and project their response to the conditions mapped in 2. above (i.e., will stores have sufficient visibility and access? Will bus stops have adequate pedestrian facilities? Can snow removal be accommodated? etc.) Analyze for times of special sensitivity such as Christmas shopping season.

Contributing Factors	Predictive Measures
DPM Characteristics	
4. Construction system suitability for quick erection.	4. Analyze for foundation and utility reconstruction requirements, level of prefabrication and projected erection time for each segment, type of construction equipment, on site storage and maneuvering space required.
5. Phasing and construction management.	5. Analyze construction plans to determine phasing. Plot particular time and extent of construction activity for each route segment(4).
6. Protective measures and alternative access.	6. Plot specific provisions of alternative pedestrian routes with lighting, noise and dust protection and obstacle-free walking surfaces and of vehicular routes with sufficient pavement and clear flow directions and signing. Show areas where such provisions are absent.

Procedures for Testing

- Retail businesses are generally the most sensitive to disruptions of downtown access and environment. Once the mapping recommended in the above points 1-6 is completed making the construction impacts and provisions explicit, this material should be presented to the merchants and building owners along each route segment. Final plans for construction phasing and management could be best worked out in workshops where the merchants themselves are asked to contribute some creative ideas about ways of maintaining accessibility and attraction during construction.

- The continuity and environmental quality of pedestrian routes is often neglected with major construction. These are essential for the business and daily life of downtown and must be considered in all areas with pedestrian entrances, shop fronts or volumes over 100 people per peak hour.

- In analyzing construction impacts test alternative scenarios including ones with unanticipated delays.

- Identify facilities particularly sensitive to construction noise (schools, offices, auditoria, etc.) Locate on maps. Consider the cost of temporarily relocating these activities.

- Impact of construction on underground utilities and building foundations must be addressed by special engineering studies.

Actions to Minimize Negative Impacts

- Avoid routing DPM on narrow streets with dense activity (see also STREETSCAPE IMPACTS).

- Minimize on-site construction time even at the cost of more expensive technology.

- Avoid the shopping season between Thanksgiving and Christmas.

- Insure that a distinct phase is completed during each construction season.

- Build well protected continuous temporary walks with connections to all shops and building entrances. If roofed, lit, and decorated with displays of construction information and advertising, these enclosures could actually be an asset to the pedestrian environment.

- Provide improved ground-transit service along the DPM route during construction to give the public a taste of the benefits that may result from the temporary disruption.

- Provide strong promotion and special attractions in the downtown (street musicians, festivals, etc.) during construction to counteract the repellant effect of the disruptions.

- continued -

Actions to Minimize Negative Impacts

- Provide financial support or other compensation for businesses subject to unavoidable economic impact. Set up continuous monitoring during construction process and provide immediate emergency assistance to hardship cases as they occur.

References and Footnotes

(1)see scale 2 maps
(2)see scale 3 maps
(3)see scale 3 maps
(4)see scale 2 and 3 maps

APPENDIX 10-A

Worksheets for Travel Impact Estimation

+

Examples

WORKSHEET 10-1

ESTIMATION OF CHANGES IN NON-WORK TRIPS TO THE CBD

Trip Purpose ______________________

Market Segment ______________________

I. CHANGE IN TRAVEL TIMES - Trips to the CBD

Auto Trips

LN (Travel time using DPM (minutes)) = [ ]

LN (Existing travel time (minutes)) = [ ]

DIFFERENCE : ΔLN(AUTO TIME) = [ ]

Transit Trips

LN (Travel time using DPM (minutes)) = [ ]

LN (Existing travel time (minutes)) = [ ]

DIFFERENCE: ΔLN(TRANSIT TIME) = [ ]

II. CHANGE IN UTILITIES - Trips to the CBD

Auto Trips

ΔUTILITY = C(AUTO TIME)[1] [ ] x ΔLN(AUTO TIME) [ ] = [ ]

\+ C(AUTO COST)[1] [ ] x ΔAUTO COST(cents) [ ] = [ ]

TOTAL CHANGE = [ ]

Transit Trips

ΔUTILITY = C(TRANSIT TIME)[1] [ ] x ΔLN(TRANSIT TIME) [ ] = [ ]

\+ C(TRANSIT COST)[1] [ ] x ΔTRANSIT COST(cents) [ ] = [ ]

TOTAL CHANGE = [ ]

III. BASE TRIPS AFFECTED BY TIME AND COST CHANGES

	Existing Trips		Fraction using DPM		Base Trips Affected
To CBD By Auto	[ ]	x	[ ]	=	[ ]
	+				+
To CBD By Transit	[ ]	x	[ ]	=	[ ]
TOTALS	[ ]				[ ]

[1] From Table 10-1

(Cont'd)

Worksheet 10-1

IV. REVISED CBD TRIPS

	Base Trips				Revised Trips
To CBD By Auto	☐	x EXP	ΔUTILITY ☐	=	☐
					+
To CBD By Transit	☐	x EXP	ΔUTILITY ☐	=	☐
			TOTAL	=	☐

V. ABSOLUTE AND PERCENTAGE CHANGES

	Revised Trips		Base Trips		ΔCBD Trips		Existing Trips		Percent Change
To CBD By Auto	☐	-	☐	=	☐	*100/	☐	=	%
To CBD By Transit	☐	-	☐	=	☐	*100/	☐	=	%
TOTAL	☐	-	☐	=	☐	*100/	☐	=	%

WORKSHEET 10-1 EXAMPLE

ESTIMATION OF CHANGES IN NON-WORK TRIPS TO THE CBD

Trip Purpose: Social/Recreational

Market Segment: Total Trips

I. CHANGE IN TRAVEL TIMES - Trips to the CBD

Auto Trips

LN (Travel time using DPM (minutes))	=	2.56
LN (Existing travel time (minutes))	=	2.64
DIFFERENCE : ΔLN(AUTO TIME)	=	-.08

Transit Trips

LN (Travel time using DPM (minutes))	=	2.69
LN (Existing travel time (minutes))	=	2.82
DIFFERENCE: ΔLN(TRANSIT TIME)	=	-.13

II. CHANGE IN UTILITIES - Trips to the CBD

Auto Trips

		Coefficient		Change		Result
ΔUTILITY =		C(AUTO TIME)[1]: -.993	x	ΔLN(AUTO TIME): -.08	=	.079
	+	C(AUTO COST)[1]: -.02560	x	ΔAUTO COST(cents): -15	=	.384
				TOTAL CHANGE	=	.463

Transit Trips

		Coefficient		Change		Result
ΔUTILITY =		C(TRANSIT TIME)[1]: -.993	x	ΔLN(TRANSIT TIME): -.13	=	.129
	+	C(TRANSIT COST)[1]: -.04039	x	ΔTRANSIT COST(cents): +10	=	-.404
				TOTAL CHANGE	=	-.275

III. BASE TRIPS AFFECTED BY TIME AND COST CHANGES

	Existing Trips		Fraction using DPM		Base Trips Affected
To CBD By Auto	108,960	x	.085	=	9,260
	+				+
To CBD By Transit	24,220	x	.120	=	2,910
TOTALS	133,180				12,170

[1] From Table 10-1

(Cont'd) WORKSHEET 10-1 EXAMPLE

IV. REVISED CBD TRIPS

	Base Trips		ΔUTILITY		Revised Trips
To CBD By Auto	9,260	x EXP	.463	=	14,710
					+
To CBD By Transit	2,910	x EXP	-.275	=	2,210
			TOTAL	=	16,920

V. ABSOLUTE AND PERCENTAGE CHANGES

	Revised Trips		Base Trips		ΔCBD Trips		Existing Trips		Percent Change
To CBD By Auto	14,710	-	9,260	=	5,450	*100/	108,960	=	+5.0 %
To CBD By Transit	2,210	-	2,910	=	-700	*100/	24,220	=	-2.9 %
TOTAL	16,920	-	12,170	=	4,750	*100/	133,180	=	+3.6 %

WORKSHEET 10-2

ESTIMATION OF CHANGES IN NON-WORK MODE SHARES FOR CBD TRIPS

Trip Purpose ______________________________

Market Segment ____________________________

I. EXISTING MODE SHARES

	Existing Trips[1]				Existing Mode Shares
To CBD By Auto		*100/		=	%
	+		↑		
To CBD By Transit		*100/		=	%
TOTAL		→	↑		

II. NEW MODE SHARES

	Existing Trips[1]		CBD Trips[2]		New Trips				New Mode Shares
To CBD By Auto		+		=		*100/		=	%
					+		↑		
To CBD By Transit		+		=		*100/		=	%
			TOTAL			→	↑		

1 From Worksheet 10-1, Section III

2 From Worksheet 10-1, Section V

WORKSHEET 10-2 [EXAMPLE]

ESTIMATION OF CHANGES IN NON-WORK MODE SHARES
FOR CBD TRIPS

Trip Purpose Social/Recreational

Market Segment Total Trips

I. EXISTING MODE SHARES

	Existing Trips[1]				Existing Mode Shares
To CBD By Auto	108,960	*100/	133,180	=	82 %
	+				
To CBD By Transit	24,220	*100/	133,180	=	18 %
TOTAL	133,180				

II. NEW MODE SHARES

	Existing Trips[1]		CBD Trips[2]		New Trips				New Mode Shares
To CBD By Auto	108,960	+	5,450	=	114,410	*100/	137,930	=	83 %
					+				
To CBD By Transit	24,220	+	-700	=	23,520	*100/	137,930	=	17 %
			TOTAL		137,930				

1 From Worksheet 10-1, Section III

2 From Worksheet 10-1, Section V

WORKSHEET 10-3

ESTIMATION OF CHANGES IN WORK-TRIP MODE SHARES FOR CBD TRIPS

I. CHANGE IN UTILITY FOR EACH MODE Market Segment ________

Drive Alone

ΔUTILITY = [-.03] x [$\Delta IVTT_{da}$] = [ ]

\+ [-.32] ÷ [Trip Length] x [$\Delta OVTT_{da}$] = [ ]

[-.0064] x [$\Delta OPTC_{da}$] = [ ]

TOTAL CHANGE = [ ]

Shared Ride

ΔUTILITY = [-.03] x [$\Delta IVTT_{sr}$] = [ ]

\+ [-.32] ÷ [Trip Length] x [$\Delta OVTT_{sr}$] = [ ]

[-.0064] x [$\Delta SOPTC_{sr}$] ÷ [Average Occupancy] = [ ]

[-.0064] x [$\Delta IOPTC_{sr}$] = [ ]

TOTAL CHANGE = [ ]

Transit

ΔUTILITY = [-.03] x [$\Delta IVTT_{t}$] = [ ]

\+ [-.32] ÷ [Trip Length] x [$\Delta OVTT_{t}$] = [ ]

\+ [-.0064] x [$\Delta OPTC_{t}$] = [ ]

TOTAL CHANGE = [ ]

(Cont'd)

WORKSHEET 10-3

II. BASE MODE SHARES - AFFECTED TRIPS ONLY

		Existing Trips		Fraction Using DPM		Base Trips Affected				Base Modal Share
To CBD, Drive Alone	=	[ ]	X (with Shared Ride)	[ ]	=	[ ]	/	[ ]	=	[ ]
						+				
To CBD, Shared Ride	=	[ ]			=	[ ]	/	[ ]	=	[ ]
						+				
To CBD, Transit	=	[ ]	X	[ ]	=	[ ]	/	[ ]	=	[ ]
AFFECTED TRIP TOTAL					=	[ ]				

III. REVISED MODE SHARES

		Base Modal Share		ΔUtility				Total		Revised Share
Drive Alone	=	[ ]	X EXP	[ ]	=	[ ]	/	[ ]	=	[ ]
						+				
Shared Ride	=	[ ]	X EXP	[ ]	=	[ ]	/	[ ]	=	[ ]
						+				
Transit	=	[ ]	X EXP	[ ]	=	[ ]	/	[ ]	=	[ ]
TOTAL					=	[ ]				

IV. NEW CBD TRIPS

		Existing Trips		Base Trips Affected		Revised Shares				New Trips
To CBD, Drive Alone	=	[ ]	-	[ ]	+	[ ]	X	[ ]	=	[ ]
				+						
To CBD, Shared Ride	=	[ ]	-	[ ]	+	[ ]	X	[ ]	=	[ ]
				+						
To CBD, Transit	=	[ ]	-	[ ]	+	[ ]	X	[ ]	=	[ ]
TOTAL			=	[ ]						

WORKSHEET 10-3 EXAMPLE

ESTIMATION OF CHANGES IN WORK-TRIP MODE SHARES FOR CBD TRIPS

I. CHANGE IN UTILITY FOR EACH MODE

Market Segment All Work Trips to CBD

Drive Alone

ΔUTILITY	=			-.03	x	$\Delta IVTT_{da}$: -2	=	.060
+	-.32	+	Trip Length:	9	x	$\Delta OVTT_{da}$: +1	=	-.036
				-.0064	x	$\Delta OPTC_{da}$: -15	=	.096
						TOTAL CHANGE	=	.120

Shared Ride

ΔUTILITY	=		-.03	x	$\Delta IVTT_{sr}$: -2			=	.060
+	-.32	+	Trip Length: 9	x	$\Delta OVTT_{sr}$: +1			=	-.036
			-.0064	x	$\Delta SOPTC_{sr}$: -25	÷	Average Occupancy: 2.4	=	+.067
			-.0064	x	$\Delta IOPTC_{sr}$: +10			=	-.064
							TOTAL CHANGE	=	.027

Transit

ΔUTILITY	=			.03	x	$\Delta IVTT_{t}$: -4	=	.120
+	-.32	+	Trip Length:	9	x	$\Delta OVTT_{t}$: +2	=	-.071
		+		-.0064	x	$\Delta OPTC_{t}$: +10	=	-.064
						TOTAL CHANGE	=	-.015

(Cont'd) Worksheet 10-3 EXAMPLE

II. BASE MODE SHARES - AFFECTED TRIPS ONLY

		Existing Trips		Fraction Using DPM		Base Trips Affected				Base Modal Share
To CBD, Drive Alone	=	107,380	×	.085	=	9,130	/	28,120	=	.325
To CBD, Shared Ride		69,510			=	5,910	/	28,120	=	.210
To CBD, Transit		108,990	×	.120	=	13,080	/	28,120	=	.465

AFFECTED TRIP TOTAL = 28,120

III. REVISED MODE SHARES

		Base Modal Share		ΔUtility				Total		Revised Share
Drive Alone	=	.325	× EXP	.120	=	.366	÷	1.040	=	.352
Shared Ride	=	.210	× EXP	.027	=	.216	÷	1.040	=	.208
Transit	=	.465	× EXP	-.015	=	.458	÷	1.040	=	.440

TOTAL = 1.040

IV. NEW CBD TRIPS

	Existing Trips		Base Trips Affected		Revised Shares				New Trips
To CBD, Drive Alone	107,380	−	9,130	+	.352	×	28,120	=	108,150
To CBD, Shared Ride	69,510	−	5,910	+	.208	×	28,120	=	69,450
To CBD, Transit	108,990	−	13,080	+	.440	×	28,120	=	108,280

TOTAL = 28,120

WORKSHEET 10-4

ESTIMATION OF CHANGES IN FREQUENCY OF INTRA-CBD TRIPS

I. BASE TRIPS

Existing Worker Trips (from Form VII)	[ ]
Existing Non-Worker Trips (from Form VII)	[ ]
TOTAL	[ ]

II. NEW TRIPS

	Speed Elasticity		Change in Average Speed		Base Speed		
	[ ]	x	[ ]	/	[ ]	=	[ ]
	Fare Elasticity		Change in Fare		Base Fare		+
+	[ ]	x	[ ]	/	[ ]	=	[ ]

TOTAL GROWTH FACTOR = [ ]

Total Growth Factor		Total Base Trips		Change in Trips
[ ]	x	[ ]	=	[ ]

WORKSHEET 10-4

EXAMPLE

ESTIMATION OF CHANGES IN FREQUENCY OF INTRA-CBD TRIPS

I. BASE TRIPS

Existing Worker Trips (from Form VII)	206,000
Existing Non-Worker Trips (from Form VII)	139,900
TOTAL	345,900

II. NEW TRIPS

	Speed Elasticity		Change in Average Speed		Base Speed		
	+.023	x	+5	/	10	=	+.0115
	Fare Elasticity		**Change in Fare**		**Base Fare**		+
+	-.0016	x	+5	/	10	=	-.0008
					TOTAL GROWTH FACTOR	=	+.0107

Total Growth Factor		Total Base Trips		Change in Trips
+.0107	x	345,900	=	3,700

WORKSHEET 10-5

TOTAL CBD TRAVEL SUMMARY

I. TOTAL DISTRIBUTION TRAVEL

Existing Trips (from Form VII) ______

New Non-Work Trips to CBD (from Worksheet 10-1) ______

TOTAL ______

II. DISTRIBUTION TRIPS BY MODE

Total		Mode Shares (from Form VII)		Trips by Mode
		Circulator/DPM	=	
	x	Regional Transit	=	
		Other	=	

III. TOTAL CIRCULATION TRAVEL

Existing Worker Trips (from Form VII) ______

Existing Non-Worker Trips (From Form VII) ______

New Intra-CBD Trips (from Worksheet 10-4) ______

______

IV. CIRCULATION TRIPS BY MODE

Total		Mode Shares (from Form VII)		Trips by Mode
		Circulator/DPM	=	
	x	Regional Transit	=	
		Other	=	

(Cont'd)

WORKSHEET 10-5

V. TOTAL CBD TRIPS BY MODE

	Distribution Trips		Circulation Trips		Total Trips
Circulator/DPM		+		=	
Regional Transit		+		=	
Other		+		=	
TOTALS		+		=	

VI. AVERAGE TRIP LENGTHS

	Distribution Trips	Circulation Trips	Total Trips
Circulator/DPM			
Regional Transit			
Other			
All Modes			

WORKSHEET 10-5

EXAMPLE

TOTAL CBD TRAVEL SUMMARY

I. TOTAL DISTRIBUTION TRAVEL

Existing Trips (from Form VII)	354,080
New Non-Work Trips to CBD (from Worksheet 10-1)	4,750
TOTAL	358,830

II. DISTRIBUTION TRIPS BY MODE

Total		Mode Shares (from Form VII)		Trips by Mode
358,830	x	Circulator/DPM .114	=	40,910
		Regional Transit .012	=	4,300
		Other .874	=	313,620

III. TOTAL CIRCULATION TRAVEL

Existing Worker Trips (from Form VII)	206,000
Existing Non-Worker Trips (From Form VII)	139,900
New Intra-CBD Trips (from Worksheet 10-4)	3,700
	349,600

IV. CIRCULATION TRIPS BY MODE

Total		Mode Shares (from Form VII)		Trips by Mode
239,600	x	Circulator/DPM .068	=	23,770
		Regional Transit .036	=	12,590
		Other .896	=	313,240

(Cont'd) WORKSHEET 10-5 EXAMPLE

V. TOTAL CBD TRIPS BY MODE

	Distribution Trips		Circulation Trips		Total Trips
Circulator/DPM	40,910	+	23,770	=	64,650
Regional Transit	4,300	+	12,590	=	16,890
Other	313,620	+	313,240	=	626,640
TOTALS	358,830	+	349,600	=	708,430

VI. AVERAGE TRIP LENGTHS

	Distribution Trips	Circulation Trips	Total Trips
Circulator/DPM			
Regional Transit			
Other			
All Modes			

11. OTHER PLANNING METHODS

The first ten sections of this report specify, in considerable detail, some alternative methods for estimating downtown circulator (particularly DPM) patronage, cost, revenue and environmental impacts. Collectively, these methods provide a means by which most of the measures relevant to downtown circulator planning can be calculated. However, there exist many other models and procedures that either complement or supplement the approaches described previously. The purpose of this last section is to briefly outline the key features of three particularly valuable model systems and to indicate how they might be employed in the DPM or other circulator planning process. The three model systems are:

- Urban Transportation Planning System
- DPM Simulation Model
- Transit Station Simulation Model

11.1 THE URBAN TRANSPORTATION PLANNING SYSTEM

The Urban Transportation Planning System (UTPS) is a product of the Planning Methods and Support (PMS) program. Supported and distributed jointly by UMTA and FHWA, UTPS provides the practicing transportation planner with a comprehensive set of methods for the analysis of multimodal transportation systems. It is composed of computer programs, attendant documentation, user guides, manuals, and audio visual materials covering both computerized and manual planning methods.

The UTPS models provide a flexible, user-oriented framework for the analysis of the supply and demand of various types of transportation systems including highway, transit, paratransit and automated systems such as DPM. The following paragraphs describe many of the components of UTPS, concentrating on those areas particularly relevant to the DPM planning process.

11.1.1 Network Development and Analysis

The assembly of data for the transportation systems or "networks" is a formidable task and a potential area for serious inefficiencies if there is a misunderstanding of the process. Speeds, capacities, headways, volumes, routes, and other data are needed and must be carefully assembled and processed. The widely used UTPS publication Characteristics of Urban Transportation Systems ("CUTS")*, provides estimates of speeds, capacities, costs, energy use, pollution emissions, noise and other impacts

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*Characteristics of Urban Transportation Systems (CUTS), FHWA and UMTA, a continually updated handbook available on UTPS magnetic tape or from NTIS, PB233 580/AS.

for a wide variety of modes from auto to light rail to "AGT" (automated guideway transit) systems.

After these data are gathered and coded, computer versions of the highway and transit networks are developed using UTPS programs HR and UROAD (highway) and INET or UNET (transit). These programs also produce reports and computer drawn maps of the networks for editing, evaluation and presentation purposes.

The way the network responds to demand is based both upon the physical characteristics of the system and upon considerations of how the traveller chooses his route and what time, distance, cost, safety, comfort, and other aspects the tripmaker perceives and weights in the decision. As a system loads up, or as the economic situation or public policies change, time, cost, and other aspects of routes and, indeed, entire modes, will change, thus affecting the travellers perception and his demand pattern. In practice, these many aspects of route choice are acceptably approximated by traversal time, distance, and cost, which will hereinafter be called "impedances."

The UTPS programs that estimate route impedance and choice over the networks are UPATH and UPSUM for transit and UROAD for highway. Each offers the transportation planner several optional ways of simulating the traveller's route selection process, since no one single route choice method is clearly best for all situations.

11.1.2 Demand Estimation

Given estimates of the impedances for auto or transit systems available to the potential traveller, demand estimation tools approximate how groups of potential travellers will respond. For example, poor transit service might cause the shopper to go downtown less often, but the downtown worker will still go every day. The demand model must represent such major groups of persons and reflect their responses to alternative system proposals.

As demand estimation is extremely complex, and technically demanding, UTPS does not presume to prescribe a single approach for forecasting under such complex circumstances. Rather, it provides a framework for the planner to insert his own model.

The demand models described in Section 7 and Appendix A were calibrated using UTPS models. An attempt has been made to generalize these demand models so that they would not have to be recalibrated for each new DPM site. However, UTPS provides generalized calibration tools which can be used wherever special requirements exist and suitable expertise is available.

Extensive data are needed for the calibration of demand models, including information on households, on trips made, the general environment, and the transportation system. For the handling of trip data and the building of "trip tables" (matrices of travel volumes between the zones) UTPS contains the program MBUILD. This program provides, in a single source, all the editing, screening, factoring, renumbering and other bothersome functions necessary to correctly process these sometimes massive trip files. The resulting zone-to-zone trip tables are used either for model calibration or, directly, for short-range transportation analysis.

Another UTPS program, UMODEL, also processes trip data as well as household, zonal and system impedance data and offers the planner great flexibility to combine datasets, convert data, and perform the data manipulations necessary prior to the use of the data for model calibration. The UMODEL program provides this flexibility by allowing the user to input his own program statements into a general framework that is already programmed to handle all of the massive data processing for him, thus keeping this task to a minimum.

Some simple models, consisting of curves or cross tabulations of data, may be calibrated directly within UMODEL. Other models, consisting of more complex equations, accept data files as output by UMODEL and then perform the calibration. Such programs are UREGRE and ULOGIT. The former program is for the fitting of linear equations to data and the latter is for fitting a certain type of non-linear equation, called a "logit" function, to data. These programs provide "best fit" relationships to the user -- input data and output statistics, plots, and other information necessary for the user to judge the accuracy of the model's representation of reality. Both are commonly used forms of demand models and thus are facilitated specifically in the UTPS software.

Another very commonly used demand model is the gravity model, which is used for the estimation of how travellers select their destination. UTPS contains the program AGM which provides for both the calibration and application of a gravity model. As is appropriate in the case of a model that is used as much as the gravity model, the AGM program was carefully designed to house all functions efficiently within a single program and to provide for inputs, outputs, reports, and plots that reduce to a bare minimum the time needed to utilize the gravity model.

After calibration, the demand models are used to estimate travel behavior under differing input data. The UTPS program for demand model application is, again, UMODEL. The structure of UMODEL and the provision for user-input program statements (such as equations), look-up tables, and curves make it most suitable for this purpose in addition to the data preparation functions discussed above.

For cases where model calibration is not warranted, various sources provide data and procedures which establish reasonable bounds on travel demand levels. Section 6 describes an aggregate approach to determining the feasibility of DPM systems. Other useful publications within UTPS include the handbooks Characteristics of Urban Travel Demand* and Traveler Response to Transportation System Changes.** These handbooks contain very extensive and consistently presented data on travel demand on existing urban systems, as well as data on how travel has changed in response to modifications in systems, speeds, costs, headways, and the like.

11.1.3 System Evaluation

The logical motivation for such extensive planning analysis is, of course, to allow the estimation of the benefits, costs, and other impacts of alternative transportation improvements. UTPS may be used to support project evaluation efforts such as those discussed in Sections 6 through 10 of this report.

For the transit or DPM system, the UTPS programs INET or UNET, and ULOAD output multiple measures for system evaluation. INET and UNET report aspects of the system itself while ULOAD summarizes measures of the passenger loading on the system. UNET, for instance, estimates the number of vehicles, vehicle miles, vehicle hours, and operating costs for each transit alternative. ULOAD, on the other hand, assigns the transit person trips to the transit system. ULOAD also reports the passenger loading of each transit line, the passenger miles, and the passenger hours spent in travel which includes walking time, transferring, and riding time. The peak passenger load on each line is compared to the "as planned" capacity, and headway adjustments are reported to better align the supply with the demand by line. Both programs UNET and ULOAD produce transit network plots, either on the computer printer or on a plotting machine, or display passenger volume information by line. Subsequently, for more detailed analysis of passenger flows, the program USTOS is used. This program focuses on a critical piece of the transit network, such as a DPM route, and provides data on arrivals at each station (by feeder mode), station-to-station flows, and other access-egress information.

For the auto-highway system, the UTPS program UROAD provides numerous options as to the loading of auto demand onto the highway system. UROAD provides for feedback betweeen route selection and congestion and thus assists in the determination of the "equilibrium" point between demand and supply.

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*Characteristics of Urban Travel Demand, FHWA and UMTA, April 1978, available on UTPS magnetic tape or from NTIS (under Project No. UMTA IT-06-0049-78-2).

**Traveler response to Transportation System Changes: A Handbook for Transportation Planners, FHWA and UMTA, February 1977, available from FHWA, HHP-22, Washington, DC. 20590, or from NTIS, PB 265 830/AS.

UROAD produces a comprehensive set of evaluation indicators including road volumes, congestion levels and congested speeds as well as summaries of these measures for subareas in the region and for major corridors. These measures, as well as others, may be output directly on network plots either on the computer printer or on a plotting machine. Impact measures include, on a subarea and regional basis, air pollutant emissions for three major types (CO, HC, NOX), fuel usage, auto operating cost, and accident estimates. In that the UROAD program also produces comparisons of estimated volume with counted volume, it is a very useful tool for the calibration of the demand and network models as well as for the evaluation purposes being discussed here.

UTPS software greatly facilitates the heretofore very difficult task of taking the tripmaker's viewpoint of the transportation system. This involves examining what trips are being made, what trips are not being well served, or what accessibility the system offers to disadvantaged subgroups for, say, job opportunities or shopping.

The UTPS programs USQUEX, UMATRIX and UFMTR, while also having many more mundane utility functions, are the programs which make this sort of user side evaluation feasible. The USQUEX program is for the expansion and compression of matrices, such as trip tables. For example, this program would be used to produce travel statistics like the percent of suburban workers who work downtown, or the percent of transit trips which are downtown shopping trips, and the like. This is done by the compression of zonal level tables to the geographical level desired.

The UMATRIX program allows the examination and comparison of a number of matrices in a single process. For example, if one matrix contained walking time to downtown locations and the other the DPM travel times, then with simple English-like statements, UMATRIX can be used to identify which trips have a walking travel time which is, say, some multiple of the DPM time.

UMATRIX also has a plotting capability which allows the user to post, for instance, the percent of low income DPM riders, on a scale "map" of the urban region for visual comparison. The UFMTR program has the capability of printing the contents of matrices in various reports and plots.

11.2 THE DPM SIMULATION MODEL

The Downtown People Mover Simulation (DPMS) model is a discrete event simulator designed to address issues specific to the sizing and deployment of a DPM system. The model was developed in conjunction with several other analytic and simulation models which are used to analyze Automated Guideway Transit (AGT) systems. The model has been designed to address the supply side of the deployment of DPM systems.

Although the model can be used to examine the impacts of varying station to station demand patterns, the location of stations, and the layout of the guideway network, the major applications focus is on specification of vehicle size and system operating characteristics given fixed values of demand and network configuration, and the operation of the system under anamolous conditions.

The basic question becomes one of selecting the most appropriate set of vehicle capacity and operating characteristics which will minimize total passenger travel time, under normal or abnormal circumstances, at the lowest life cycle cost.

The point of departure in the simulation process is the definition of the required throughput necessary to satisfy the demand. This required throughput can be determined in the static case by examining the peak load station to station demand and the desired operating characteristics of the system (route headways, dwell time at stations, route distances, operating speeds) to determine an initial capacity requirement. This capacity requirement can be satisfied by many combinations of vehicle size, train consists, and operating headways. With DPM system suppliers offering vehicles ranging from 20 to 100 people in capacity and operating headways varying from 15 seconds to 90 seconds, a wide range of solutions is possible. The Downtown People Mover Simulation model addresses these issues by testing the performance of various combinations of these parameters and calculating the desired performance measures, vehicle utilizations, and fleet sizes. In addition, the DPMS models the effects of stochastic variations in demand upon the designed system. It is this interaction of demands and system operation which, for all but trivial cases, is impossible to capture in an analytic model.

Instead of attempting to calculate average performance for any given deployment scenario, the DPMS simulates at the individual passenger and vehicle level the interactions between supply and demand. The model then collects representative statistics affecting both the passenger (e.g., waiting and travel times) and the fleet (e.g., vehicle load factors, vehicle miles, and number of stops). Based on these outputs, an evaluation of complex design and deployment issues can be carried out.

One of the key areas of concern in all DPM designs is the effect of failures and recovery strategies on the passengers in the system. The DPM simulation provides the capability to enter asynchronous events such as vehicle stoppages or degraded performance, or guideway/station failures during the simulation of system operation. Subsequent to the anamoly the DPMS models a variety of system responses such as automatic restart, push or tow. Alternative responses from the remaining fleet can also be modeled. The DPM simulation maintains a log of all completed trips such that distributions of passenger trip times can be determined on a station to station basis, under normal and abnormal conditions. The effects of these failures can be seen by comparing statistics from two separate simulation runs.

Figure 11-1 illustrates the use of the DPM Simulation model within the context of the DPM deployment analysis. Shown on the left of Figure 11-1 are the basic inputs to the models. The mode split model takes the zone to zone demand, a given network, and the performance of the DPM system in terms of travel times between each station pair and generates a station to station demand. The station to station demand generated by the modal split model is generally for a period such as the noon peak. The DPM Simulation model has the capability to manipulate this basic matrix in terms of different time intervals, different magnitudes, and can also use a series of matrices having different spatial distributions. All of these characteristics can be implemented in one run of the model to provide a more accurate representation of the peaking characteristics of the demand. By using a probabilistic distribution, the DPM Simulation model takes the station to station demand matrix (or matrices) and generates a list of randomly arriving trips.

Execution of the DPMS produces several kinds of outputs. First, the model generates a set of statistics to describe the state of the system at certain time intervals. Second, the model generates statistics at user specified intervals which can be displayed (plots and histograms) or statistically analyzed by the program. Third, the model produces summary reports over user specified intervals to characterize the system performance on each route, station, and link in the network. These statistics and measures describe the impacts of the system on the passenger (performance measures) and the resource utilization of the system. The model produces trip log data to be used to calculate station to station travel times, the number of passengers served, and the number of transfers required for each O/D pair.

The outputs of the simulation can be used in life cycle cost calculations. The DPMS calculates the number of vehicles required based on the routes, route headways, and link travel times. The DPMS accumulates statistics on total vehicle miles and hours and passengers served. In this way, the operational data from each analysis can be used to determine the cost of providing a particular level of service. Estimates can be made of the costs of responding to system anamolies under certain time specifications.

11.3 TRANSIT STATION SIMULATION MODEL (USS I)

The USS I model is a transit station simulation computer program developed for the Urban Mass Transportation Administration. The program is intended as a design and evaluation tool for transit planners, architects, and engineers to assist in developing alternative configurations for intermodal transit stations. USS I, a part of the Urban Transportation

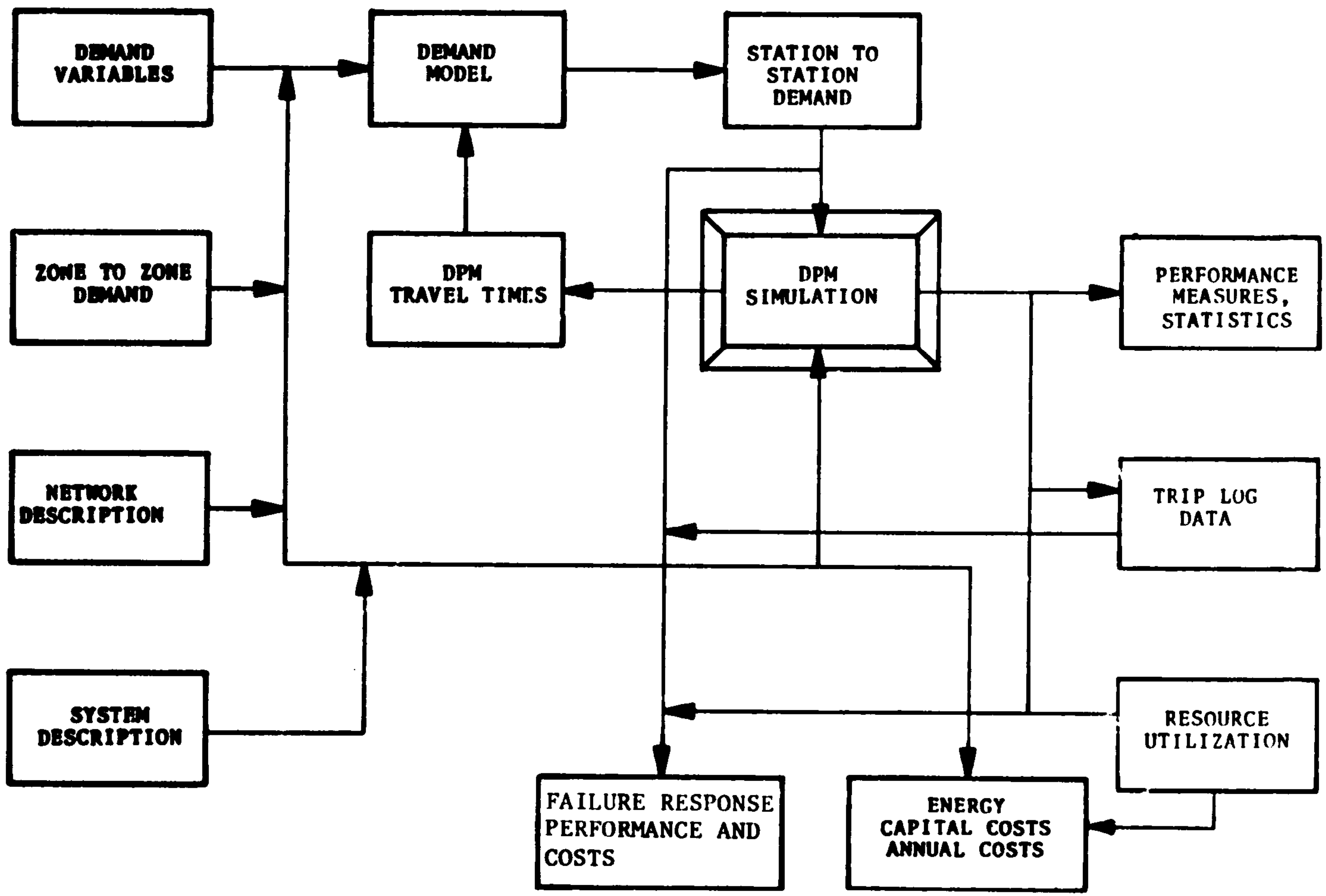

FIGURE 11-1 DPM DEPLOYMENT ANALYSIS FLOW

Planning System, is designed to operate on IBM 360/370 series computers and will be released shortly to UTPS users.

USS I is a discrete event, Monte Carlo simulation model, which permits the user to create a numerical model of his station and use the computer to generate a record of expected station performance over a period of time during which passengers and vehicles arrive and depart from the station. To use the program, the user must translate his proposed station design into a network consisting of a series of links (paths) and nodes (connections between paths or service devices). The program produces several standard output reports which permit station designers to evaluate proposed station designs on the basis of time spent walking through the station, time spent waiting in queue areas, and the number of devices required to handle expected passenger volumes. Several optional reports allow the user to trace the actual paths taken by individuals through the station and to observe the dynamics of individual link activity at discrete intervals.

While the USS I model is primarily oriented toward the analysis of conventional rapid transit stations, it can also be used for other intermodal applications such as commuter rail stations, airline terminals, moving walkway systems, etc. It can also be particularly useful for planning and evaluating Downtown People Mover stations. In the latter case, USS I can be used to model an on-line DPM station with feeder bus and pedestrian access modes.

Programming capbilities of the USS I model permit the input of the following characteristics of (DPM) stations:

(1) System Technology - vehicles (length of car, no. of doors/car, capacity per car, no. of cars/train), platform length, and headways (peak and offpeak)

(2) Station Location - boundaries, elevation, location of guideways, access/egress points, other modes (buses), and existing elements (pedestrian mall)

(3) Passenger Design Volumes - no. of inbound/outbound users during the peak/offpeak times by mode

(4) Passenger Processing Elements - boarding and deboarding procedures; fare collection system, desired levels of service and performance standards (comfort and safety), waiting areas, handicapped pedestrians, emergency evacuation, and intermodal transfers

Inputting the above data into USS I will allow the transit planner or designer to obtain time and cost data on the alternative schemes being evaluated. Output from USS I will aid the designer in determining answers to the following questions:

(1) How much area is required to accommodate expected passenger flows on platforms, concourses, and other station areas?

(2) How many turnstiles, security gates, and fare card readers are needed to accommodate expected passenger volumes?

(3) Are the pedestrian circulation elements accessible to handicapped passengers?

(4) How much time is required for passengers to process through the station under varying load conditions?

(5) What is the maximum number of passengers that can be processed through the station?

(6) How many vertical circulation devices such as escalators, elevators, stairs, and ramps are needed to accommodate passenger flows?

Designing a DPM station has a different set of objectives than that of conventional transit stations. For instance, providing extra passenger processing capacity may not be necessary for DPM stations since DPM systems operate on frequent headways which tend to evenly distribute passenger flows. USS I can be used mainly for purposes of modelling and evaluating the passengers processing subsystem of a DPM station.

A complete case study application using USS I in the design process of a DPM station is documented in the "USS I Reference Manual,"* prepared by Princeton University's Transportation Program. Further details on the description and use of the USS I program are found in both the USS I Reference Manual and the USS I User's Guide.**

11.4 CONTACT FOR FURTHER INFORMATION

For more information on the planning methods discussed in this section, please contact:

Mr. Granville E. Paules, Chief
Methods Division

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*Lutin, J. and G. Benz, USS I Reference Manual, Princeton University, March 1978.

**USS I User's Guide, U.S. Department of Transportation, Transportation Systems Center, September 30, 1978.

Office of Methods and Support
Urban Mass Transportation Administration (URT-41)
U.S. Department of Transportation
Washington, DC 20590