UMTA-MA-06-0039-83-2
DOT-TSC-UMTA-83-47.1

PB84-209238

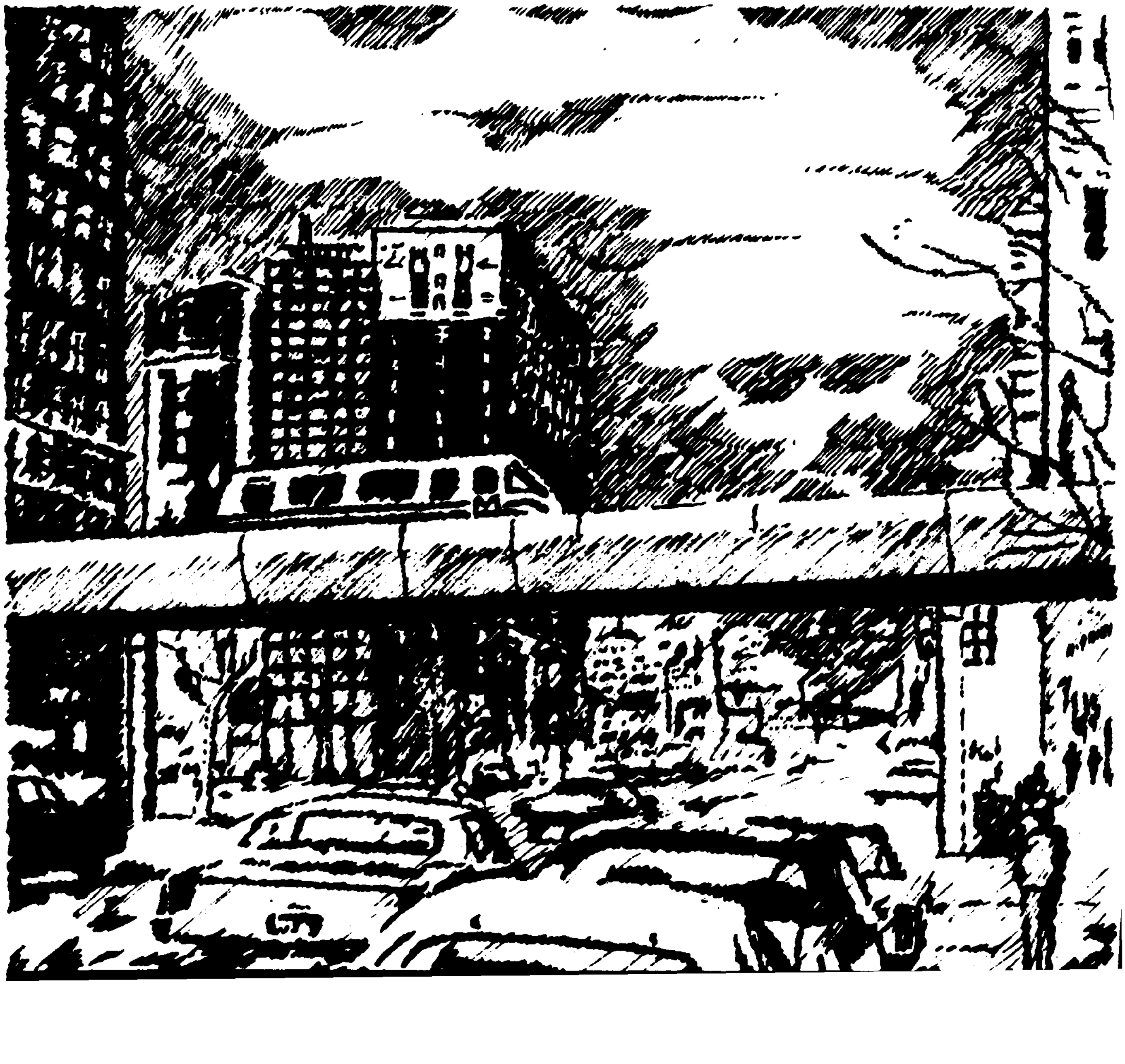
U.S. Department of Transportation
Urban Mass Transportation Administration

planning for downtown circulation systems

planning concepts volume 1

final report

october 1983



Technical Report Documentation Page

1. Report No. UMTA-MA-06-0039-83-2	2. Government Accession No.	3. Recipient's Catalog No. PB84 209238
4. Title and Subtitle Planning for Downtown Circulation Systems Volume 1 -- Planning Concepts		5. Report Date October 1983
		6. Performing Organization Code DTS-242
7. Author(s) Staff from TSC and organizations listed below*		8. Performing Organization Report No. DOT-TSC-UMTA-83-47.1
9. Performing Organization Name and Address DOT/Transportation Systems Center Kendall Square Cambridge, MA 02142		10. Work Unit No. (TRAIS) R-2646
		11. Contract or Grant No. PPA UM-217
12. Sponsoring Agency Name and Address U.S. Department of Transportation Urban Mass Transportation Administration Office of Planning Methods and Support Washington, D.C. 20590		13. Type of Report and Period Covered Final Report (June 1977 - December 1981)
		14. Sponsoring Agency Code UPM-20

15. Supplementary Notes

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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.

17. Key Words downtown circulation, circulator systems, DPM, feasibility analysis, demand, cost, revenue, impact estimation, manual sketch planning, computerized network analysis, planning process	18. Distribution Statement DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	294	

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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
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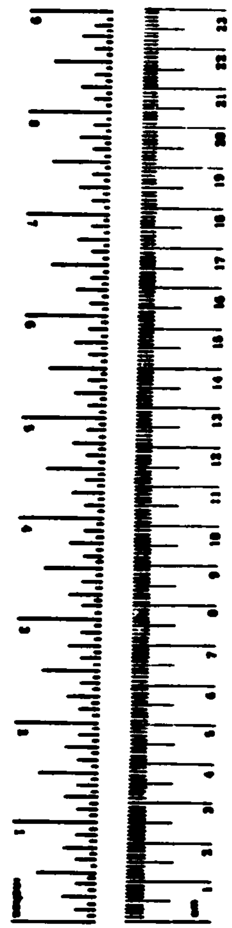
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

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		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		
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l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
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m^3	cubic meters	1.3	cubic yards	yd^3
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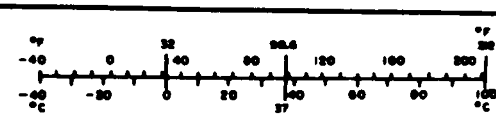

PREFACE

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
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U.S. Department of Transportation
Washington, DC 20590

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1. INTRODUCTION

Circulation of people -- workers, consumers of goods and services, tourists -- within the downtown area is a function vital to the health of practically any city. Downtown circulation systems can range from interconnected sidewalks for pedestrians to fully automated Downtown People Mover (DPM) systems. While experience in planning and implementing conventional circulation systems (i.e., sidewalks for pedestrians, streets and parking stalls for private autos) is vast, and some experience exists for downtown shuttle and minibus systems, there has been little or no such experience with regard to newer, more sophisticated forms of downtown circulators, such as DPM systems. Yet, in solving long-term downtown transportation needs, cities increasingly desire to examine the full range of circulator system alternatives, including innovative technologies. To bridge this gap between lack of experience and desire to assess new methods, a flexible planning process is needed which incorporates analysis techniques which can be adapted to innovative downtown circulation modes or systems.

1.1 WHAT THIS REPORT IS ALL ABOUT

This document attempts to bring together the state-of-the-art in planning concepts, methods and data for use by those cities proposing or considering comprehensive or innovative downtown circulation systems, particularly Downtown People Mover systems. DPM systems are a subset of Automated Guideway Transit (AGT) systems, a class of transportation systems that includes unmanned vehicles operating on fixed exclusive guideways. The first generation of Downtown People Movers will likely consist of elevated systems in which proven technologies are employed in Central Business Districts (CBD's) and adjacent areas of larger U.S. cities.

Although primary attention in the report is given to DPM systems, it should be emphasized that these are but one example of a downtown circulator system, and a relatively complex one at that. In studying the various sections and appendices of the report, the applicability of the planning concepts and analysis techniques to other types of circulator systems will become apparent. The advantage of using such a complicated circulator system example as a DPM is that the resulting report covers a broad range of planning issues, only a subset of which would be of concern in planning a simpler or conventional circulation system. The report thus tends to be a quite useful reference document for planning any type of downtown circulation system.

The report can be used merely as a guide and checklist of important planning issues or, with care, as a manual to aid in predicting patronage, impacts, and costs. It was prepared to accomplish the following objectives:

- Provide background data and information
- Identify major planning and development issues
- Discuss important design options
- Present alternative estimation procedures
- Provide worksheets for the estimation methods
- Document references and information sources

What this report does not do is provide a step-by-step procedure from circulation system concept to final design. It may be of most value used in particular stages of the planning process as shown in Figure 1-1. The chart depicts three general phases of plan development and indicates the kinds of activities that might take place in each, and which sections of this report provide some guidance at each stage.

The Concept Stage initiates the planning process with the development of goals and objectives, generation of alternative conceptual designs, familarization with the important planning and design issues, and crude feasibility studies of the alternatives. Section 2 is required reading for planners at any stage of the process; it describes typical goals and objectives, presents a comprehensive listing and concise discussion of the major planning issues, and provides a technical introduction to the rest of the report. Section 3 summarizes the experiences of several CBD circulation bus systems in this country. Section 5 describes design options related to system configuration, operations, and overall system development. Section 6 presents a method that requires only limited data and resources to quickly estimate ranges of expected patronage.

Institutional factors are, of course, of vital importance in the development of a project such as a downtown circulation system. Section 4 discusses alternative institutional arrangements between planners, local officials, the business community, and the public. Also described are the Alternatives Analysis and Environmental Impact Statement requirements for capital grant funding and several issues requiring inputs from many local interests, such as location decisions and joint development.

The Analysis Stage of the planning process is concerned with the evaluation of system options at a level of detail where particular tradeoffs of cost and service can begin to be examined relative to achieving the area's goals and objectives. Sections 7 through 10 describe methods of estimating patronage, impacts, costs, and revenues of downtown circulator systems, DPM systems in particular. These sections document what is felt to be the state-of-the-art in estimation procedures.

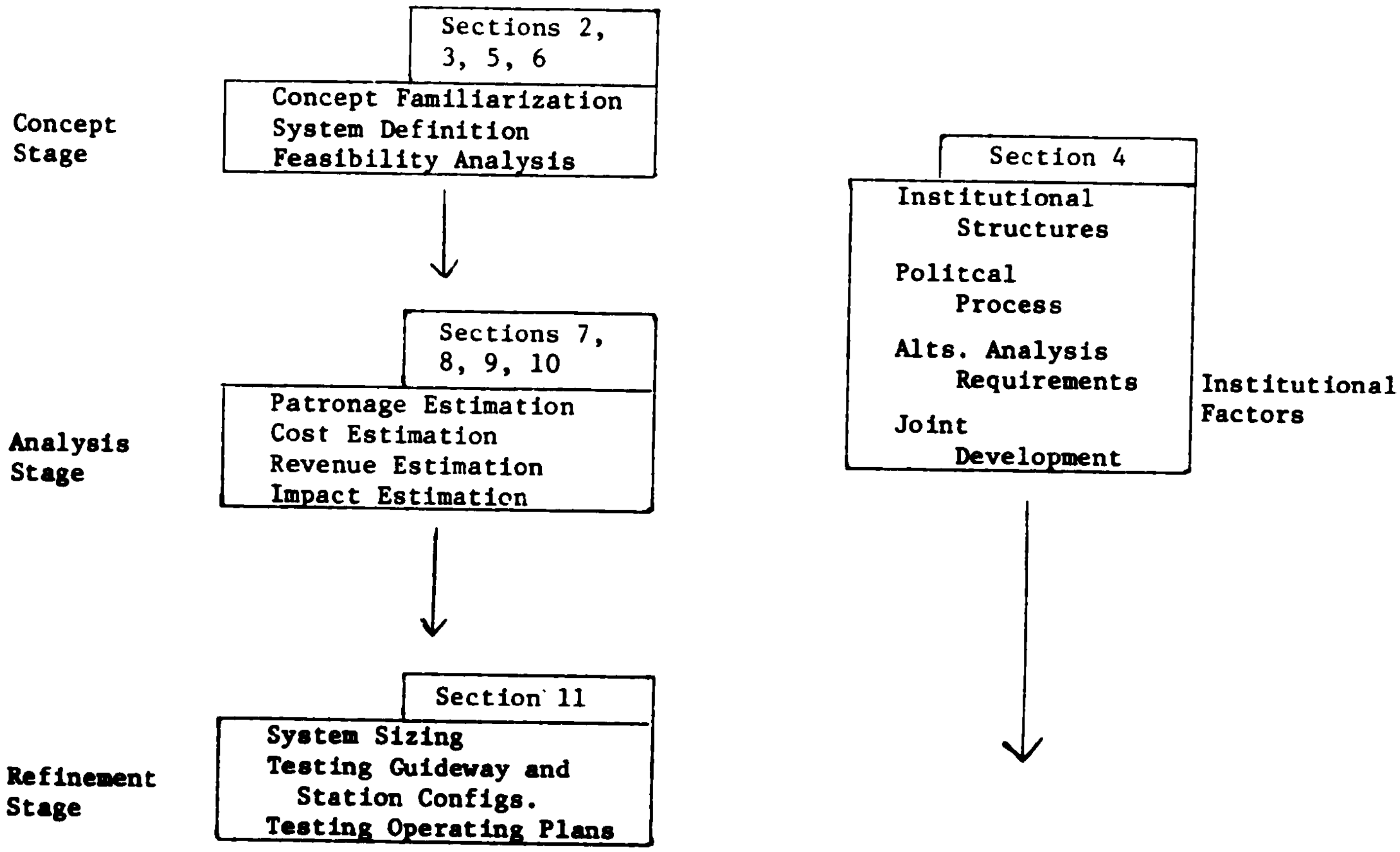


FIGURE 1-1

A GUIDE TO THIS REPORT

In the Refinement Stage, particular design aspects of the guideway, stations, and operating system, especially related to system sizing, can be examined at a higher level of detail through the use of computer simulation and other methods. Section 11 describes the Urban Transportation Planning System, the UMTA Station Simulation Model, the DPM Simulation Model, and other tools that are available through UMTA.

The Appendices to this report contain the worksheets and supporting documentation for the analysis techniques, discussions of the theory, estimation and application of the demand models presented, and a case study application using a Los Angeles DPM system example.

1.2 A FEW WORDS OF CAUTION

The methods and procedures presented here are suggested only; they are not prescribed nor even necessarily recommended. Although many of the techniques are described with worksheets to simplify their use, they should not be used in a "black box" or "turn-the-crank" manner. Each planner should make his/her own judgement as to whether the assumptions, data, and models presented are reasonable for the specific situation addressed. Analysts are encouraged to substitute better information and methods whenever possible.

The two methodologies for estimating ridership, in particular, need to be used with extreme care. The aggregate method (Section 6) is meant to be used for a rough assessment of overall feasibility and the effects of policy and service variations. The numbers generated by this procedure should be viewed as indications, not predictions. The advantage of this technique is that it can be performed in a matter of hours to produce ballpark estimates that are also useful as a check on more detailed forecasts.

The more detailed patronage estimation method presented in Section 7 is a system of disaggregate demand models developed with Los Angeles data. Although procedures for adjusting model coefficients for use in other cities are described, it is strongly recommended that testing or validation be performed if possible. Further, because the method for predicting DPM ridership is based on circulation bus experience and data, and because suitable data of all types were not available, assumptions were made that could not always be confirmed. It is suggested that adequate sensitivity testing of the parameters and coefficients be carried out to determine their effects on patronage prediction.

1.3 SELECTING AN IMPACT ASSESSMENT METHODOLOGY

As local areas structure their DPM or other circulation system planning process, explicit decisions must be made concerning which methods to be used (and when) to predict the impacts, including patronage, of these systems. These methods are important determinants of both the time and resource requirements of the overall planning effort. The availability of a number of impact assessment methodologies is important, because these methodologies provide varying levels of detail useful at different analysis stages. As described above, the first stage includes feasibility studies undertaken to determine, quickly and cheaply, whether or not a DPM system (or other type of circulator system) would be feasible for a specific downtown area, given that area's objectives. The second stage is the comparison of different feasible systems to determine which one best meets the area's objectives. Finally, the refinement stage includes system sizing activities which must be carried out to support the detailed engineering design of a system, once it has been generally specified with respect to route, station location, and interface facilities such as parking and regional transit transfer stations.

As the analysis process progresses from feasibility studies to evaluation of alternatives and system sizing, the analysis methodologies must become more detailed and have greater accuracy. With greater detail and accuracy, of course, comes greater cost. Therefore, for the analysis process to be most efficient, the relationship of accuracy to cost must be well understood. This section introduces a number of analysis options which are available, and the potential role of each in the system planning process. Typical ranges of analysis costs and accuracies are also presented for these methods.

1.3.1 A Classification of Impact Assessment Methodologies

Starting with the simplest and most approximate and progressing to the most detailed, a number of DPM impact assessment methodologies are identified in this section. The general character of each is described as well as the role it can take in a complete DPM planning strategy.

1.3.1.1 Rules of Thumb

Generalized information on the ranges of a number of DPM impacts can be used in initial "back of the envelope" tests which are useful as part of the process of determining the potential feasibility of DPM systems in a given area. This information can be expressed in the following ways:

- CBD worker pedestrian trip productions per day
- CBD visitors per CBD employee by type (retail, governmental, office, etc.)
- CBD shoppers per square foot of retail space
- Ranges of expected DPM mode splits by CBD trip type
- DPM construction and annual costs for guideways and vehicles, per guideway mile

- DPM construction and annual costs for stations, per station

Using generalized information of this type, along with a minimum of information about CBD employment and land use, an initial, ballpark estimate of the potential ridership, revenue cost, and surplus or deficit of a DPM system can be made. These estimates can then be used as one guide in deciding whether or not more significant resources should be allocated to DPM feasibility analysis. A structured method of this type, utilizing charts and nomographs, is provided in Section 6.

1.3.1.2 Manual Sketch Planning

At the next level of detail, the feasibility of DPM systems for a given analysis area can be tested using models which provide improved, location-specific estimates of DPM ridership to replace the range of generally applicable mode split percentages discussed above. Although specific travel models are applied, these models can be applied manually if the number of calculations is kept to a minimum. This can be achieved by choosing a limited number of typical, potential, and/or actual CBD trips; using specifically designed worksheets to obtain travel predictions, including DPM usage, for each typical trip; and then expanding these predictions to represent all CBD travel. Additional worksheets can then be used to estimate DPM costs and a number of non-travel impacts (such as noise, air pollution, and energy consumption) which are closely related to DPM demand levels.

In addition to their usefulness for studies of DPM feasibility, these manual methods can be used to obtain initial estimates of the differential impacts which can be expected for alternative DPM alignments, station spacing, and frequency of service. These techniques are detailed in Section 7 and succeeding sections.

1.3.1.3 Aggregate Network Analysis

Although manual sketch planning procedures are appropriate for testing broadly-defined DPM alternatives, there are practical limitations on the number of typical CBD trips which can be considered manually. Due to these limitations, the manual methods are not appropriate for evaluating the differential impacts of DPM alternatives which are very similar. Examples of such similar alternatives would be two guideway alignments which differ only in that they run over parallel streets one block apart, or in that a major station is displaced by two blocks in one of the alternatives. Although the basic models and procedures provided by the manual worksheets remain valid in these cases, a computerized approach is required due to the increased number of computations, as the number of typical trips increases. Such a computerized approach is available for studies of DPM alternatives. In shifting from manual sketch planning to computerized network analysis, a shift is made from analyzing typical trips to analyzing CBD travel between all zone pairs. Typically, for aggregate network analysis the number of zones can be kept in the range of ten-to-twenty, so that specifications of the characteristics of travelling by alternative modes for each zone pair can still be done manually rather than using coded networks for each mode. Aggregate network analysis is described in Section 7.

1.3.1.4 Detailed Network Analysis

When the number of zones used in the computerized methodology described above increases beyond about twenty, then the explicit specification of travel times, costs, and distances for each zone pair becomes prohibitive. As a result, the coding for computer input of modal networks becomes cost-effective. When this is done, the analysis method can be more logically termed detailed network analysis. Within this method, further variations in zone size and network level of detail are possible, with the maximum detail probably being zones which are block faces and walk networks which recognize each sidewalk (two per each block of street) as a separate facility.

At this level of detail, the differential impacts of minor variations in guideway and station location, DPM vehicle headways, fares, and street-to-station access facilities can be estimated. The resulting estimates of ridership and financial impacts would normally be accurate enough for all preliminary engineering purposes, including initial estimates of vehicle requirements, operating policies, and station sizing. This level of detail can normally be handled only by comprehensive transportation planning packages, such as the Urban Transportation Planning System (UTPS), described in Section 11. Detailed network analysis is described more fully in Section 7 and Appendix B.

1.3.1.5 Facility Operations Studies

At the most detailed analysis level, simulation can be used to study the operation over time of specific components of a DPM system, such as stations and vehicle routing and scheduling. These studies, which must be based on demand levels predicted using detailed network analysis, can be used to test proposed station design and vehicle control system strategies. The results can be used as an aid in designing facilities which will operate efficiently while at the same time keeping their costs as low as possible. These types of methods are described in Section 11.

1.3.2 Cost and Accuracy Factors in Selecting a Methodology

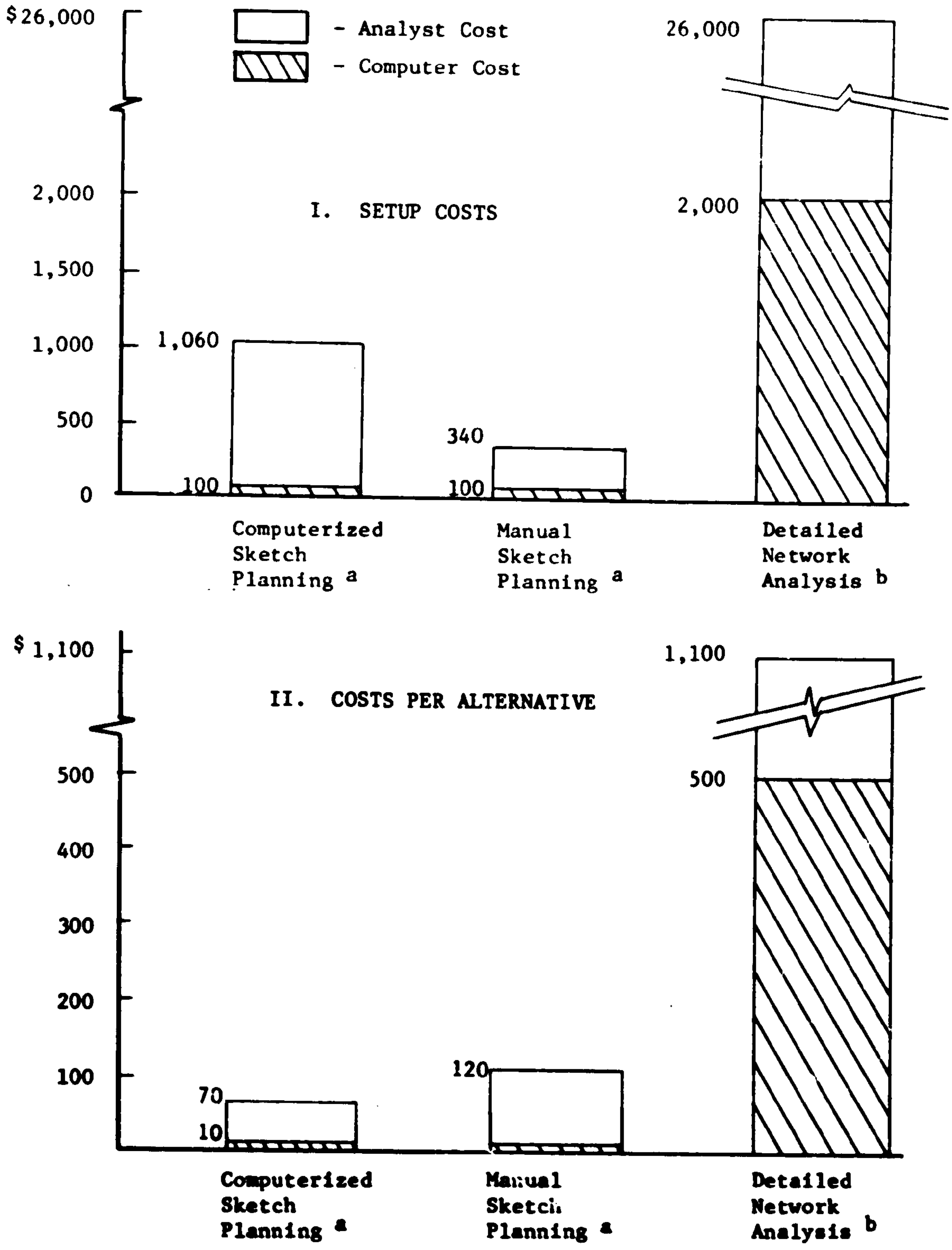
The relative accuracies and costs of the various impact assessment methodologies discussed in the previous section relate directly to their levels of detail. Rules of thumb, therefore, are very approximate and can be applied very cheaply, while facility simulation studies may represent the operations of a specific facility very well and are quite costly to apply. Further variation in accuracy and costs occurs within each of the five types of methodology, depending on the number of typical trips analyzed (in the manual sketch planning approach) and the number of zones analyzed (in the aggregate and detailed network analysis approaches).

Typical analysis costs for the three methods discussed in detail in this report are shown in Figure 1-2. Both set-up costs and per-alternative costs are shown. These costs were those observed in carrying out the Los Angeles case study described in Appendix C. Because the sketch planning method and aggregate network analysis (termed computerized sketch planning in Figure 1-2) were applied after set-up had been completed for detailed network analysis, their set-up costs were lower than they would have been if only sketch planning had been done.

Although manual sketch planning is potentially the least expensive analysis approach, because it can be applied to the fewest trip interchanges, it is not the cheapest per interchange for a given alternative. As shown in the figure, when the same number of trip interchanges is used, computerized sketch planning (i.e., aggregate network analysis) is the least expensive.

In Figure 1-3, the corresponding accuracies are illustrated in terms of the deviations in DPM ridership estimates provided by the sketch planning analysis approaches, compared with the detailed network analysis approach to demand estimation. These results show that the relative errors of manual and computerized sketch planning are inversely related to their costs, when they are used to predict the impacts of changes in DPM alternatives. The relative errors shown occur when the same number of interchanges is analyzed with both methods. Manual sketch planning is relatively more accurate because it predicts changes from a base case directly, and, therefore, avoids the additional errors inherent in predicting both base case and alternative results.

A final selection of a DPM analysis method must be made based on the unique data availability and output requirements of each project, along with a tradeoff between cost and accuracy, such as that illustrated in Figures 1-2 and 1-3.

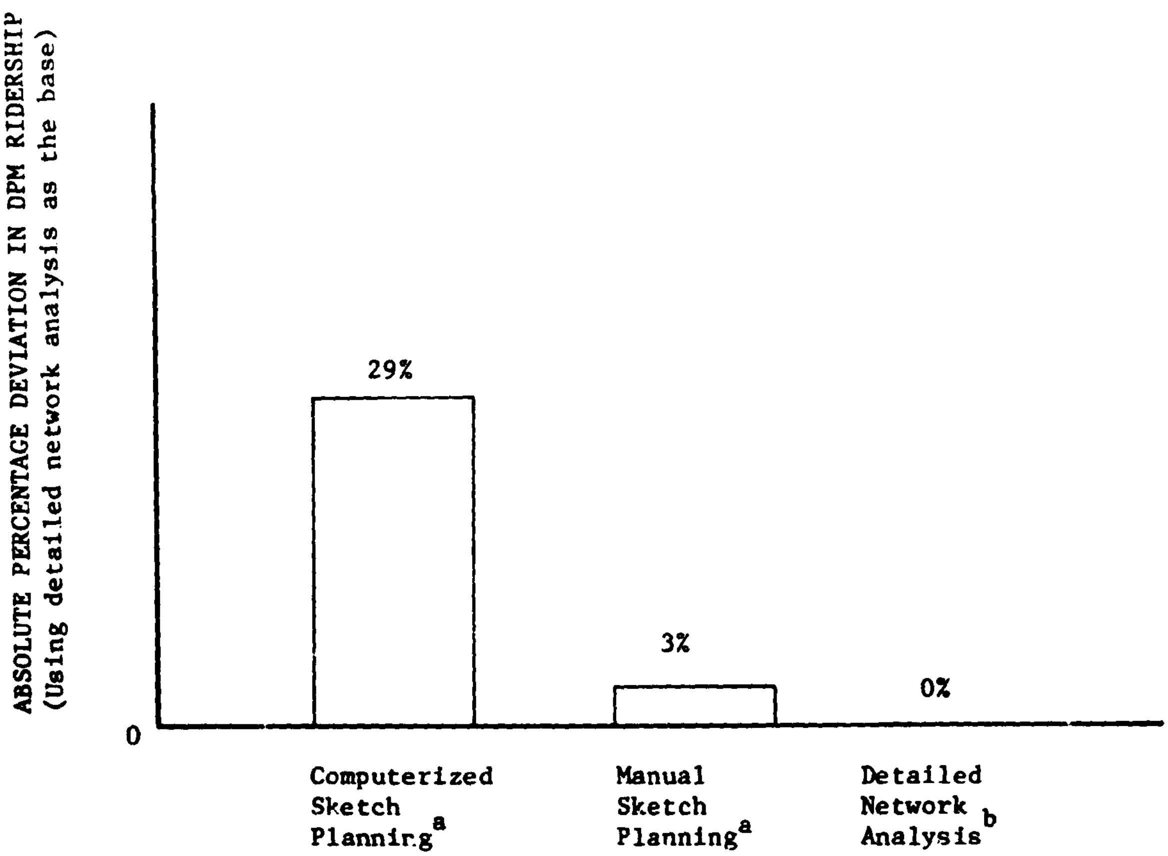


[a] For all interchanges in a 6-zone CBD

[b] For all interchanges in a 100-zone CBD

FIGURE 1-2

RELATIVE ANALYSIS COSTS



[a]For all interchanges in a 6-zone CBD

[b]For all interchanges in a 100-zone CBD

FIGURE 1-3

RELATIVE ANALYSIS ACCURACIES

2. OVERVIEW OF PLANNING ISSUES

This section outlines the issues that the downtown circulation system planner should be aware of throughout the planning process. Most of these issues are discussed in detail in later sections with respect to techniques for estimating ridership, impacts, revenues, and costs. Here they are described in terms of general implications for circulator planning.

A diagram depicting various steps to be taken in planning a system, a DPM for example, is given in Figure 2-1. The sub-sections of this section are devoted to discussing issues related to each of the planning steps shown in this figure.

2.1 IDENTIFICATION OF THE PROBLEM

Identification of the problem is the most important step in the planning process because it directly influences each subsequent step. Here, the very reason for a circulator system, such as a DPM, is questioned. Circulator systems must be planned in response to some problem, need or desire, or set of problems, and it is here that these problems are clearly isolated and stated. Examples of the types of problems for which a DPM system might be suggested as a solution are:

- The storage requirement for automobiles is robbing the CBD of land that could be used in a more productive manner
- Traffic congestion in the CBD is making internal circulation by automobile slow and agonizing, by bus slow and expensive to provide, and by foot dangerous and unpleasant
- Traffic congestion in the CBD is resulting in slow moving traffic, high levels of vehicle exhaust, and, therefore, poor air quality
- Employment concentrations, retail activities, restaurants, parks, and cultural events are separated by such distances in the CBD that little midday activity is taking place
- Stores are separated by such distances that shoppers are relucant to walk from store to store when shopping, resulting in the increased use of the automobiles for CBD shopping trips, and in fewer trips to the CBD for shopping
- Unpleasant weather prevents CBD midday activities from prospering year-round

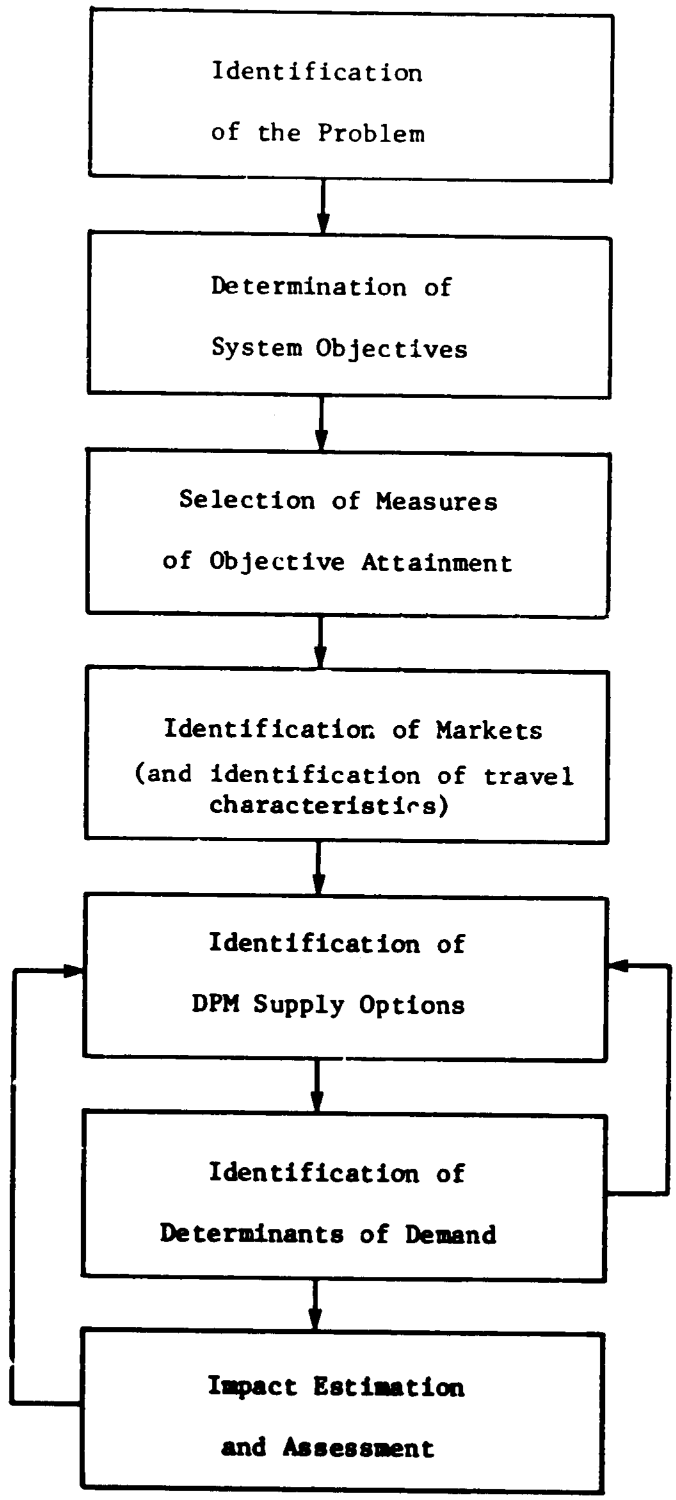


FIGURE 2-1

STEPS IN THE DPM PLANNING PROCESS

Such a list of problems should be developed as the first step in any downtown circulation planning study to provide guidance in each of the subsequent steps. The list of problems that is generated should, at a minimum, reflect the attitudes of:

- CBD residents
- CBD employees and employers
- CBD business owners
- Elected officials of the city
- Regional or city transit authority
- City planning or redevelopment agency.

The process of generating the list of problems should therefore include representation from each of these groups.

2.2 DETERMINATION OF SYSTEM OBJECTIVES

In the most general sense, the intended purpose of a circulator system such as a DPM is to improve the economic health, vitality, and attractiveness of a city's downtown. A DPM might assist in achieving such a purpose in a number of ways. It could ease travel between related land uses within the CBD, e.g., hotels and entertainment, thereby inducing greater use of existing facilities. A DPM could improve the distribution of transit trips from outside the CBD, leading to a shift from auto to transit, thereby leading to a strengthened transit system, with important air quality and energy benefits. It could be designed to improve the trip to the CBD for auto travellers, intercepting them at park and ride facilities by the CBD's edge, thereby eliminating the slowest portion of their journey. Coupled with auto-free zones and a reduction of parking spaces within the CBD, air quality and energy gains could also be achieved. Finally, the DPM could be designed, along with appropriate zoning incentives, to strengthen and focus land use near transit stops to improve the competitiveness of transit and to strengthen portions of the CBD.

In initiating the DPM demonstration program in the 1970's, the Urban Mass Transportation Administration stated that the objective of the program was to test:

- The operating cost savings which an automated transit system might deliver

- The economic impact of improved downtown circulation systems on the central city

- The feasibility of surface or elevated people movers both as feeder-distributors and as potential substitutes for more expensive fixed guideway systems such as subways

Each of the cities which responded to the request for specific proposals based a system design on a unique set of objectives. The following list of representative objectives was chosen from among the available DPM proposals:

1. To reduce reliance on the automobile for travel within the CBD

2. To promote internal activity (retail, social, recreational)

3. To strengthen the employment base of the CBD

4. To promote use of the regional public transportation system

5. To reinforce public activities (convention centers, libraries, city halls, or redevelopment districts)

6. To improve the environmental quality of the CBD (reduce auto congestion)

7. To improve safety by separating vehicular and pedestrian movements

8. To improve the image of public transportation

9. To minimize the system costs of CBD transportation

10. To improve mobility of transportation disadvantaged or transit dependents

11. To improve CBD transportation reliability

12. To increase city tax revenue

13. To increase the productivity of CBD land

14. To provide good public transit service at a fare which reflects the ability of the passenger to pay

15. To promote the CBD

16. To equalize the costs and benefits of the CBD transportation system.

The process of selecting system objectives should also include representation from those groups charged with planning for the city and those groups that would be directly affected by the system.

2.3 SELECTION OF MEASURES OF OBJECTIVE ATTAINMENT

Having developed a list of objectives for a DPM system, the planner must next identify means for measuring how well these objectives are attained. This process is important for two reasons: first, the measures are necessary for an assessment of the system impacts; and second, identification of the measures themselves will provide insights into the ways that the objectives can be attained. The measures selected give concrete meaning to the objectives selected in the previous step. Provided below are examples of measures of attainment for each of the sample objectives listed previously.

Objective	Measure of Attainment
1. Reduce reliance on automobiles	a. Lower parking demands in the CBD b. Less auto traffic in the CBD
2. Promote internal activity	a. Higher retail sales in the CBD b. More midday trips
3. Strengthen CBD employment base	a. Higher employment in the service area
4. Promote regional public transit	a. Increase in regional public transit ridership
5. Reinforce public activities	a. High ridership volumes to public activities b. Increased attendance at public activities
6. Improve environmental quality	a. Improved air quality--lower pollutant concentrations b. Lower noise levels c. Improved visual appearance of CBD
7. Improve safety	a. Fewer accidents b. Less conflict between pedestrians and automobiles
8. Improve image of transit	a. Increase in ridership on other transit modes b. Increase in support for transit from citizenry
9. Reduce transportation system costs	a. Long term reduction in the total cost per passenger trip b. Reduced public expenditures for construction and maintenance of roads and parking locations

10.	Improve mobility of the transportation disadvantaged	a. Increase in the number of elderly or handicapped making trips into or within the CBD
11.	Improve transit reliability	a. Greater on-time performance b. Fewer breakdowns
12.	Increase city tax revenue	a. Increase in tax revenue b. Increase in retail sales c. Increase in CBD land value
13.	Increase CBD land productivity	a. New construction b. Denser commercial development c. Higher employment d. Higher output per land area
14.	Reflect ability of the passenger to pay	a. Representative distribution of incomes among the ridership
15.	Promote the CBD	a. Return of jobs and sales to the CBD
16.	Improve the distribution of costs and benefits from the transportation system	a. Revitalization of deteriorated or declining areas

2.4 IDENTIFICATION OF THE POTENTIAL RIDERSHIP MARKETS

Early planning stages of a downtown circulator system should include a feasibility assessment. For this assessment, a technique is needed for determining quickly, and with only a limited amount of data, whether a system, such as a DPM, makes sense at all.

The most closely watched indicator in this respect is usually the predicted system ridership. When coupled with cost estimates, the comparison of cost per passenger carried is most often the bottom line in an initial evaluation of a new system. Without a consideration of additional factors, however, such an approach to the assessment of a proposed DPM system would be inappropriate and very misleading. Cities have proposed DPM systems for many different reasons, and each city has a unique set of objectives which the system is designed to attain. Ridership is ultimately necessary if any of the objectives are to be attained, but the specific nature of the ridership is very important in the assessment of objective attainment.

An understanding of the specific markets from which a DPM system will draw its passengers is important in the estimation of ridership, the determination of its characteristics, and the assessment of the impact of the DPM system on the individual markets. Just as the technology and the setting of the DPM systems are new and to a large extent untested, there are also uncertainties about the markets which will be served by these systems and the likely magnitude of the ridership from each segment. This section identifies major CBD activities that would be connected with a DPM, and the major types of trips that are candidates for DPM systems, and then discusses how travel by each of these types typically varies in magnitude by hour of day and day of the week. The conclusions are summarized in a table which qualitatively ranks the relative importance of each trip type.

2.4.1 Activity Types

The relative attraction of different activities for each other can be represented in an affinity matrix, such as in Table 2-1, listing downtown activities including two transportation-related land-use activities, automobile parking, and public transportation terminals or stations. While not activities per se, these are land uses that connect activities external to the downtown to activities within the downtown and are, therefore, logical candidates for connection by a DPM. As such they conveniently raise the distinction between the function of a DPM to serve travel completely internal to the downtown and its function to distribute travel within the downtown that either originated or is destined outside the downtown.

Table 2-1 includes in the matrix cells a subjective estimate of the affinity between each pair of activities, reflecting a particular set of trip purposes. In completing the matrix it was considered that, for most categories, the same activity can occur in two separate locations and for those cases the affinity between two locations of the same activity is evaluated. (Note particularly the importance given to connecting separate public transportation facilities, but the unimportance of connecting separate parking facilities.) These evaluations allow a sense of activities that are most important to connect. For example, if the internal distribution function alone is considered it would appear to be important to connect the office and retail activities in a downtown and to connect the hotels to the entertainment and convention centers. Adding the distribution function for external trips to the analysis would suggest a DPM that connects parking facilities and public transportation to the office, retail and convention centers, and connects public transportation facilities to one another. Of course, it may not be feasible to connect all land use pairs receiving high priority.

TABLE 2-1

AFFINITY MATRIX FOR DOWNTOWN ACTIVITIES

Downtown Activity	resid.	office	gov't. ctr.	retail	hotel	ent.	c.c.	ind.	park.	pub. tr.
residential	M	M	M	M	L	L	M	M	L	L
office	x	M	H	H	M	L	M	L	H	H
government center	x	x	x	M	M	L	L	L	H	H
retail	x	x	x	M	L	M	L	M	H	H
hotel	x	x	x	x	M	H	H	L	M	L
entertainment	x	x	x	x	x	L	H	L	M	M
convention center	x	x	x	x	x	x	x	L	H	H
industrial	x	x	x	x	x	x	x	L	M	M
parking	x	x	x	x	x	x	x	x	L	M
public transit terminal	x	x	x	x	x	x	x	x	x	H

L = low, M = medium, H = high

2.4.2 Trip Types

The following types of trips* are candidates for DPM travel:

- Workers employed within the DPM service area making the following types of trips:
  - trips from a parking location to a work location in the service area, as part of home to work travel by automobile
  - trips from a regional transit stop to a work location in the service area, as part of home to work travel by transit
  - home to work travel when both residence and work location are within the service area
  - business related trips from work to other businesses within the service area
  - trips for purposes other than work, such as shopping, eating, or personal business, or from work to other business or retail establishments within the service area
- Workers employed outside of the DPM service area making the following types of trips:
  - trips by automobile or transit into the service area for work-related business for which the DPM system provides a useful and convenient connection
  - trips by automobile or transit into the service area for nonwork purposes for which the DPM system provides a convenient connection or a convenient means of circulation when more than one stop is made within the service area
  - trips from home to a regional transit stop for home to work travel when the worker's residence is within the DPM service area
  - transit trips through but not into the service area - (In some cities the regional transit system may be designed such that many routes focus on the CBD but do not provide through service. In situations such as this, the DPM system may serve as a connector between the regional routes.)
- Nonworkers making trips of the following types:

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*All trips are identified here as one directional, but it should be recognized that in most cases a return trip is also possible.

- trips from a parking location to a nonwork destination in the service area, as part of home to nonwork travel by automobile

- trips from a regional transit stop to a nonwork destination in the service area, as part of home to nonwork travel by transit

- circulation trips within the service area by travellers making multiple stops for nonwork purposes

- home to nonwork destination when both residence and nonwork destination are within the service area

- trips from home to a regional transit stop for a home based nonwork trip when the traveller's residence is within the DPM service area

- transit trips made through but not to the service area, for which the DPM system serves as a connector

- Visitors to the city staying in hotels/motels or other accommodations within the service area making trips of the following type:

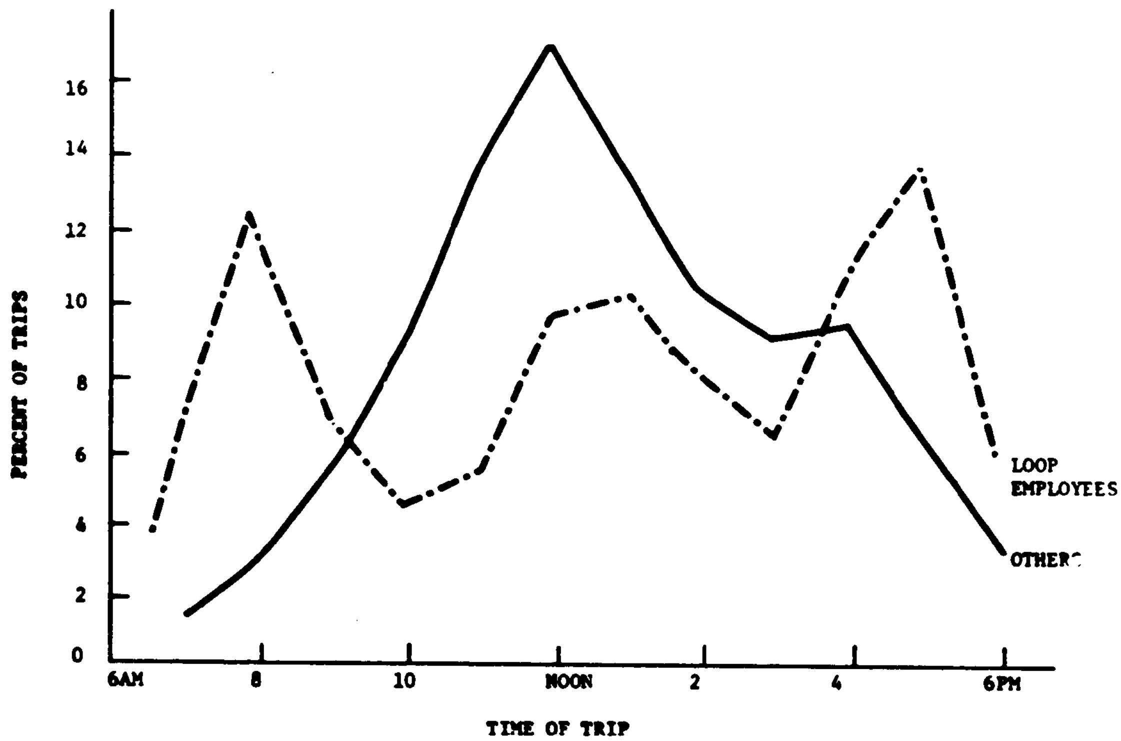
    - to destinations within the service area for conventions or work-related business

    - for nonwork purposes to destinations within the service area

    - to regional transit connections for trips outside of the service area

2.4.3 Time of Travel

The time of travel of each market segment is an important consideration in the sizing of a DPM system, because of the dramatic peaking characteristics of intra-CBD travel. Figure 2-2 illustrates this peaking and the differences in the intra-CBD trip making patterns in Chicago for downtown employees and for others in the downtown area. The pattern reported here and in other cities basically indicates that there are three substantial peaks. The trips by non-CBD employees tend to build to a single peak period at midday. The consideration of travel by time of day can be further disaggregated by considering smaller time periods, and the role that each of the market segments (identified in the previous section) plays in DPM demand during that period. Eight time periods have been selected for discussion because of the implications that the ridership in each



Source: Rutherford, G. Scott and Joseph L. Schofer, Analysis of Pedestrian Travel Characteristics, January, 1976.

FIGURE 2-2

PERCENT OF TRIPS BY TIME OF DAY FOR CHICAGO LOOP EMPLOYEES AND OTHERS WITHIN THE CHICAGO CBD- ALL PURPOSES period has on service planning and system sizing. The eight periods are as follows:

<u>Morning Peak</u> - This period corresponds to the morning rush hour or peak commuting period. In the case of the Chicago Loop, as represented in Figure 2-2, this period would be roughly from 7:30 to 8:30 AM. Travel during this period is predominantly by CBD workers and the primary market for DPM trips would be trips from parking and regional transit terminals to places of employment.

<u>Morning Offpeak</u> - Travel in this period is generally light, being composed primarily of the end of the morning commuting period, the arrival of early CBD shoppers, and the beginning of the lunch period. For the case of the Chicago Loop, the morning offpeak period would roughly be from 8:30 to 11:30 AM.

<u>Midday Peak</u> - As illustrated by the data from the Chicago Loop, this period, roughly from 11:30 AM to 1:00 PM, constitutes the highest trip demand during the day, with high levels of travel by both employees and non-employees being combined. Unlike other periods of the day, however, trips during this period are almost entirely on foot and are generally of shorter length, as illustrated by the lower than average median trip length for trips to eat (see Figure 2-3).

<u>Afternoon Offpeak</u> - This period, from 1:00 PM to roughly 3:30 PM, generally exhibits a higher trip demand than the morning offpeak hours. This demand may be quite substantial, depending on the amount of retail, tourist, and convention activity in a city. It is these trips, by non-CBD employees, that will comprise most of the ridership during this period.

<u>Evening Peak</u> - This period corresponds to the evening commuting period which, for the case illustrated in Figure 2-2, is roughly from 4:00 to 5:00 PM. While there is usually very little nonwork travel during the morning peak period, during the evening period many CBD workers make trips for shopping or eating before returning home. When combined with trips by CBD shoppers returning home, the non-work component of travel can be substantial and can result in a very significant peak.

<u>Evening Offpeak</u> - This period runs from the end of the evening commuting period until the end of the DPM operation. The amount of ridership that will be generated by a DPM system during this period will depend entirely upon the amount of night life in the CBD and the volume of tourist and convention travel in the city.

<u>Saturday</u> - Many cities (for example, San Antonio, Texas) have found the ridership on a CBD circulator bus system is

highest on Saturday, due to high volume of shopping and tourist-related trips, although parking is often much less pronounced. However, other systems have generated little or no ridership on Saturdays. Again, ridership on a DPM system during this period will totally depend on the retail and tourist activity in the CBD.

Sunday - Sunday will undoubtedly be the lightest period of all, and, in many cases, operation of a DPM system on Sundays will not be warranted. Ridership during this period depends upon either a high downtown residential population or strong tourism.

2.4.4 Relative Importance by Trip Type

Table 2-2 illustrates graphically the peaking characteristics of each of the market segments identified in the previous section and the approximate magnitude of the peak in relationship to the total trip volume. The relative importance of each trip type in each of the weekday time periods has been indicated by either an "H" (indicating extreme peaking and a significant magnitude), an "M" (indicating either moderate magnitude or moderate peaking and significant magnitude), an "L" (indicating either moderate peaking and moderate magnitude, extreme peaking but of little significance, or only slight peaking but of a significant magnitude), or a blank indicating no peaking and of no significant magnitude. The Saturday and Sunday periods have not been included in this table because of the uncertainties about travel during these periods. There is generally little peaking on these days, but the travel volumes may be of significant magnitude if there is sufficient retail trade and tourism in the CBD.

2.5 IDENTIFICATION OF SUPPLY OPTIONS

An integral part of the demand estimation and the impact assessment process is the consideration of the physical characteristics of the transportation system being considered. The purpose of this section is to enumerate the physical characteristics of a DPM system that are important elements in the planning and impact assessment process. This discussion will not be sufficient to answer all of the questions about tradeoffs in physical design, but it will be useful in structuring the process for examining the possible tradeoffs in the characteristics of the major physical components of DPM systems.

The characteristics considered in this section represent the major items which determine the form, size, and function of a DPM system. The options discussed below are generally considered in the earlier stages of alternative system design. More detailed supply characteristics, which can be varied in response to demand

TABLE 2-2

CANDIDATE DPM TRIPS - RELATIVE IMPORTANCE BY TIME OF DAY

Trip Maker / Trip Purpose	Relative Importance: Morning Peak	Morning Off-peak	Mid-day Peak	Afternoon Off-Peak	Evening Peak	Evening Off-peak
1. Service Area Workers						
a. Work to/from parking	H				H	
b. Work to/from transit	H				H	
c. Work to/from home	H				H	
d. Business to/from business		M		M		
e. Non-work to/from work			H		M	
2. Other Workers						
a. Business to/from auto		L		L		
b. Business to/from transit		L		L		
c. Non-work to/from auto			M		L	
d. Non-work to/from transit			M		L	
e. Non-work to/from non-work			L		L	
f. Transit to/from home	M				M	
g. Transit to/from transit	M				M	
3. Non-Workers						
a. Non-work to/from parking					H	
b. Non-work to/from transit					H	
c. Non-work to/from non-work			L	M		
d. Home to/from non-work					M	
e. Home to/from transit					L	
f. Transit to/from transit			L		M	
4. Visitors						
a. Hotel to/from business (convention)	M				M	
b. Hotel or business to/from non-work			M		L	L
c. Hotel to/from transit	L				L	
TOTAL MARKET	M	L	H	L	M	L

after the system is in operation are discussed in later sections. The major DPM options are as follows:

2.5.1 System Technology

The DPM systems under consideration will have the following characteristics in common, as mandated by UMTA:

- They must be fully automatic with no operator required on the vehicle while it is in operation
- The vehicles must travel on an exclusive guideway

In addition, it has been clearly stated that "the candidate cities (for the DPM demonstration project) must be willing to select ... one of the existing people mover technologies, and, with minimum modifications, adapt it to urban deployment. The project is not designed to develop new technology." The technologies from which the DPM cities may choose have been implemented in a variety of controlled environments including airports, amusement parks, and shopping centers, but have never been implemented in the heart of a major city. UMTA approved eight manufacturers of people mover systems to bid for the construction and operations contracts, based on their previous operating experience. The firms and the location of installation sites are listed below:

Boeing	West Virginia University, Morgantown, West Virginia
DEMAG/MBB	Ziegenhain, West Germany (Hospital site)
Ford	Fairlane Shopping Center, Dearborn, Michigan
Rohr	Houston International Airport, Texas
Universal Mobility	Kings Dominion, Richmond, Virginia Kings Island, Cincinnati, Ohio Carowinds, Charlotte, North Carolina Magic Mountain, Los Angeles, California Hershey Park, Hershey, Pennsylvania California Expo, Sacramento, California EXPO 67, Montreal Canada
Vought	Dallas/Ft. Worth Airport, Texas
Walt Disney CTS	Disneyland, Anaheim, California Disney World, Orlando, Florida
Westinghouse	Seattle--Tacoma Airport, Washington Tampa International Airport, Florida Busch Gardens, Williamsburg, Virginia

Five additional firms have experience in the field and may be eligible for competition by the time the bids are requested. The five firms are Otis Elevator Co., Alden Self Transit Systems Corp., Mobility Systems and Equipment Co., PRT Systems Corp., and General Motors Corporation's Transportation Systems Division.

Propulsion for all of the systems developed by the above manufacturers has been supplied by electric motors, and all have been designed to operate on rubber tires rather than steel rails. While most systems have operated on top of a guideway, some have been suspended from a rail.

2.5.2 Route Configuration

There are three basic options in route configuration:

Loop - In this configuration, the vehicles operate over a closed loop, either in one direction or in both directions around the loop. Bi-directional operation increases the required guideway width, but also results in significantly shorter travel times, especially in large systems. Loop operation is best suited for situations in which the CBD activity is dispersed over an area spanning several streets in each direction.

Linear (or Shuttle) Operation - Linear operation is always bi-directional with turnaround terminals at each end of the system. Linear operation is generally best suited for a high volume corridor where key land uses are strung out in a line.

Network Operation - The network operation simply represents multiple linear or loop operations and is best suited for situations in which the CBD activity is either heavily concentrated on two or more intersecting corridors, or occurs over a wide area. Network operation requires the interfacing of lines and is a complex and expensive option. Cities planning linear systems should, however, consider the necessity for going to a network system if expansion of the DPM system is seen as desirable in the future.

2.5.3 Station Operation

Station operation specifically deals with the location of the station with respect to the guideway, and with the routing of the vehicles with respect to the station. There are basically two options:

On-line Stations - This option requires that the station platforms be directly adjacent to the main guideway and that all vehicles stop at each station on the route. A passenger using the system would then be required to stop at each station passed between his/her origin and destination stations. This option may result in somewhat longer trip times but is considerably less complex and expensive than off-line stations.

Off-line Stations - This option provides for stations off the main guideway with auxiliary tracks running through the station. Vehicles can be scheduled to remain on the main guideway and bypass selected stations in an express operation. Off-line stations require additional guideway track, larger structures in station areas, more complex control systems, and additional switching and sensing technology for determining automatically when a vehicle should enter a particular station. The off-line station option provides an operational advantage only when the system is large enough to warrant specialized express runs between high volume stations, or when the demand is so low that individual stations would frequently have neither boarding nor departing passengers.

2.5.4 Service Type

This category was briefly introduced in the previous section on station operation and basically involves the following options:

Scheduled service to all stations - This mode of operation is the simplest and basically requires that each vehicle stop at each station along the route regardless of the demand at the station or the destinations of the passengers on board. Because of the simplicity of route configurations of recently proposed DPM systems, most of the first DPM systems built will be of this type.

Service upon request - When the system is sufficiently complex in its configuration to warrant express or direct service (skipping stations where there is no request for boarding or alighting), the "service upon request" option can result in significant time savings for passengers. This option does require additional control equipment for requesting a vehicle at a station, for indicating the desired destination station, and for automatically scheduling and routing vehicles to satisfy the requests. The added expense of this option is warranted only when there are branches in the system and boardings and alightments are concentrated at a few stations.

2.5.5 Vehicle Grouping

This category describes the number of vehicles that are operated together. The vehicles can be operated singly or together in trains. When demand is light, operation of vehicles singly allows greater frequency (less time spent by travellers waiting for vehicles) than operation of trains with the same total system capacity. The use of single vehicles in high volume situations is less desirable even though the carrying capacity of the system is the same, because of congestion due to loading from a smaller area on the platform. The use of trains for high volume lines increases the loading area and also reduces the risk of having more passengers waiting at a particular station than can be accommodated by the next departure.

2.5.6 Guideway Location

The location of the guideway, both vertically and horizontally, is of concern in the estimation of travel demands and the assessment of the system impacts. Location of the guideway either above ground or below ground eliminates conflict with street traffic and, therefore, minimizes the travel times on the system. However, the additional time required to obtain access to an elevated or depressed system may reduce or eliminate completely the travel time advantage gained by grade separation. The tradeoffs between time spent in a vehicle and time spent out of a vehicle are discussed in more detail in Section 2.6, but basically, the travel time advantage gained by an elevated or depressed guideway is a function of site specific traffic conditions.

2.5.7 Interface with Regional Transportation System

The ways in which the DPM system interfaces with regional transportation systems will generally determine the DPM system's function. A system which does not provide for an interface with either regional transit or with major parking facilities will function primarily as a circulator system serving only the travel previously categorized as entirely intra-CBD trips. This design severely limits the potential ridership, and may result in a severe midday ridership peak during the lunch period. Interfacing with the regional system will increase the total market for trips and will add two additional peak periods resulting in a tri-modal distribution of demand during the day. Because the system sizing is more a function of peak period demand than of the total daily demand, service for a tri-modal or three peak period demand is far more cost-effective than service for a single peak.

2.5.8 Fleet Size

The size of a DPM fleet will both determine and reflect the expected ridership on the system. The number of vehicles in operation at one time determines the frequency of service (for a given travel speed and vehicle grouping) which, in turn, is a determinant of demand. A lower frequency requires fewer vehicles and will produce lower ridership and vice versa. But rather than overdesigning the system to guarantee maximum ridership, an equilibrium assessment relating the supply (represented by the system capacity and frequencies) to the system demand will provide an estimate of the service characteristics which will yield the most appropriate level of ridership.

Because of the peak in intra-CBD trips, the planner must pay close attention to the maximum hourly (or even half-hourly) demand which might be generated by the system. It is this maximum period demand, not the average daily demand, which determines the fleet size required. In addition, the distribution of boardings and alightings among the stations in the system will influence the fleet size. An even distribution of demand among stations will minimize the fleet size requirement.

Trip lengths also may influence fleet size requirements. Very short trips will result in lower fleet size requirements than longer trip lengths.

2.5.9 Station Spacing

There are four important considerations in station location:

- Access times
- In-vehicle times
- Station capacity
- Station construction

The number and location of stations influences both average access time and in-vehicle time. The more stations in the system, the lower the average access time; however, in many cases the average in-vehicle time increases directly with the number of stations. The increase in the resulting in-vehicle time is caused by an increase in the number of stops required and reduction in the average operating speed.

The capacity of the stations in a system is an important determinant of the station spacing, as is the cost of station construction. The planner must evaluate the tradeoffs between cost, capacity, and service and select the station spacing which is the most cost-effective in the ridership it produces.

2.5.10 Expansion Capabilities

There are many uncertainties inherent in planning for a new and innovative service such as the proposed DPM systems. The uncertainty in ridership demand and the specific patterns and configuration of that demand makes sizing of the initial system difficult. Because of this uncertainty, each city planning a DPM system should consider options for expanding the system. Expansion can take place in three areas:

Expansion of the hours of operation - This is the simplest type of expansion that can be implemented because it generally involves no additional capital expenditures. The expansion simply involves additional operating costs. Expansion of this type would occur when potential system ridership during certain offpeak periods is significantly greater than expected. Weekend and late evening service are the two most likely periods for which service may not initially be provided, but may later be added.

Expansion in the carrying capacity - This can be accomplished by:

- Adding vehicles to each train
- Increasing the frequency of the trains
- A combination of both of the above

Increasing the system carrying capacity would generally require the purchase of additional vehicles. It is possible, however, that because of extreme peaking in the demand, the required station capacity would be gained only by modification of station tesigns, or construction of additional stations. Station capacity can be limited by any one of the following:

- Access walkway, stairs or escalators
- Fare payment equipment
- Platform size

Expansion of the service area - This type of expansion is expensive and the most disruptive, yet it may be necessary if the route configuration is inadequately planned initially, or if demand for the DPM system arises outside of the service area. This option involves the construction of additional lengths of guideway and new stations, the purchase of additional vehicles, and the revision of the control system. Minimal disruption to the existing system would call for the construction of a completely new route, with its guideway and control system independent of the existing system. This would imply, however, some loss in service flexibility and some duplication of system components, in comparison with the strategy of expanding existing guideways and routes.

2.6 IDENTIFICATION OF DETERMINANTS OF DEMAND

The determinants of travel demand are of four types:

- Characteristics of the area served by the transportation system
- Characteristics of the transportation system
- Characteristics of the trip
- Characteristics of the individual trip maker

Close examination of each of the travel demand determinants should provide a better understanding of the demand forecasting techniques which are offered in Section 7 of this report. Whenever possible, the discussion of determinants is supported by typical ranges of the value of the determinant in actual operating experiences (based on studies of downtown circulation on foot and on circulator bus systems).

2.6.1 Characteristics of the Service Area

The service area characteristics are probably the strongest determinants of demand for a DPM system and are important elements of the demand forecasting techniques to be described in this report. The important characteristics are employment location, density and character, the location of high-activity centers within the CBD, the spatial separation of employment and activity centers, parking supply and location, residential density, topography and weather conditions and potential for future development or land-use conversion. This section of the overview will discuss the role that each land-use characteristic plays in DPM demand and the possible sources of the type of data necessary for the demand impact and cost analyses.

2.6.1.1 Employment Density

The amount of employment within a DPM service area is an important determinant in two, often conflicting, ways. First, the greater the employment within the service area, the greater are the opportunities for trips by CBD workers -- according to the categorization of potential trips from parking and transit stops to work, this would include trips from work to shopping or eating, and those business related trips from outside the service area to offices or employment centers within the service area.

The second effect of employment density is to decrease trip lengths (and sometimes frequency) as the density increases. High employment density often indicates that there are many opportunities for nonwork trips such as shopping and eating very close to the place of employment for a CBD worker. The higher density, therefore, tends to reduce the average trip length for nonwork trips. (This is generally not true of the distance from parking or transit stop to work in the home-to-work trip, however.) In many cases, large office buildings provide restaurant and retail space within the building which acts to reduce the number of trips (which might be candidates for a DPM system) made by employees each week.

The overall effect of employment density on DPM ridership is, therefore, not clear. There is certainly a minimum amount of employment that is necessary to support a system, but very dense employment may also result in fewer midday trips of sufficient length to warrant using a DPM.

2.6.1.2 Trip Attractions and Productions

Trip attraction is used loosely here to represent the qualities of an area which enable it to attract intra-CBD trips. The characteristics which determine the trip attraction density are, therefore, dependent on the purpose of the trip under consideration. The major determinant of shopping trip attraction is the amount of shopping opportunities, measured by retail floor space. The major determinant of work trip attraction is employment. These two land use categories are the major determinants of trip attraction, but other types of land use such as governmental, service, educational, and office should be considered in developing trip rate estimates. Table 2-5 presents a set of trip rates developed from a collection of CBD-oriented surveys in St. Paul, Minnesota; New York City; Seattle, Washington; and Los Angeles, California.

The rates were developed to estimate the volume of nonwork trips that would be generated within a CBD during the peak one-hour midday period. Similar types of rates have also been developed for the morning and evening periods.

The number of trips produced by an area (or the number of trips originating in the area) is a function of the residential density of the area, as well as the employment density (the importance of which was described in the previous section). Production rates related to residential density and employment density have also been developed and are presented in Sections 6 and 7 of this report.

2.6.1.3 Regional Mode Choice for Trips to the CBD

The relative usage of auto and transit for regional trips to the CBD is important for two reasons:

- The regional mode choice will determine the availability of automobiles as a mode of intra-CBD travel (someone who travels to the CBD by transit does not have the option of making an intra-CBD trip as an auto driver). This will be of significance only in

TABLE 2-3

TYPICAL CBD TRIP GENERATION RATES FOR THE PEAK MIDDAY HOUR

Land-Use Type	Trip Generation Rate (non-worker trips produced per thousand square feet of building area during peak noon-time hour)
Private Office	0.4
Government Office	0.4
Retail	1.9
Service, Hotel, Institutional	0.5
Manufacturing, Wholesaling	0.1

Source: Barton-Aschman Associates and Cambridge Systematics, Inc., Internal CBD Travel Demand Modelling, 1976.

cities in which the CBD parking supply allows for a significant use of automobiles for intra-CBD trips. Auto use is very often constrained by limited parking availability during the midday, by high short-term parking rates, and by high levels of congestion on the CBD streets.

- The regional mode split indicates where the emphasis should be placed in the interfacing of the DPM system and regional travel. A high transit mode share would indicate a large potential DPM market if the regional system and the DPM are properly interfaced. Conversely, a high auto mode share for regional trips would indicate that an emphasis on interfacing with peripheral parking access might be more appropriate.

  The regional mode choice will generally determine the potential for interfacing with either the transit system or peripheral parking, but the location of the parking supply and the regional transit system with respect to employment and shopping areas will ultimately determine the success of the DPM in attracting trips. The DPM will only be successful in competing for walk trips from the transit stops or parking to the final destination if the trip length is sufficiently long to warrant the waiting time, riding time, and fare (if one is charged) associated with using the DPM system. Inexpensive and convenient parking near the major employment and shopping areas would minimize the chances of successfully interfacing with peripheral parking. Likewise, a transit intercept plan will only succeeed if most regional transit operations within the CBD are terminated at the DPM interface station.

2.6.1.4 Potential for Growth

One commonly stated objective of DPM systems is to stimulate CBD growth. If growth is stimulated by the improved level of intra-CBD transportation provided by the DPM, the growth will result directly in increased DPM patronage. For cities which have the potential for growth in employment, retail activity, business activity, or public activities, changes in land use intensity may be a significant determinant of future demand.

Vacant property, land in use as parking lots, redevelopment districts, and major construction projects are areas in which the trip attraction or trip production density may change significantly over time. Special consideration should be given to tracts of this type when ridership projections are made for future periods. Future land use potential is particularly important in the sizing of the system and the location of the guideway.

2.6.1.5 Topography and Weather Conditions

Because the most likely source of DPM trips are trips currently made on foot, the existing conditions for walk trips are an important determinant of DPM demand. Extreme weather conditions or significant grades can make the time spent walking much more onerous than time spent in a transit vehicle. Such extreme conditions can produce unusual loadings on the DPM system. For example, a DPM system which provides service on a hill will generate greater ridership up the hill than down the hill. Similarly, the ridership in bad weather will generally be higher than in good weather. This phenomenon has been demonstrated by circulator systems in cities, such as Boston, where both significant grades and severe weather occur. Consideration of grades in the demand analysis is rather straightforward because their existence can be identified on a link by link basis in a DPM system. Weather conditions, however, are not predictable and should, therefore, be considered only in terms of how severe weather might occasionally affect the peak period demand.

2.6.2 Characteristics of the Transportation System

The ridership on a DPM system will depend upon the competitiveness of the "cost" of using the DPM system with respect to all other available modes and also with respect to the "cost" of making no trip at all. "Cost" here is intended to mean a generalized price which includes the value to the traveller of such impedances as:

- Out of pocket costs actually paid in fares
- Time spent in walking to and from the DPM system
- Time spent waiting for a vehicle
- Time spent on the vehicle
- Aesthetic appeal of riding the system
- Improvement in the range of alternative destinations provided by the DPM system's increased speed

Each competing mode (walk, automobile, taxi, circulator bus, regional transit, etc.) has its own generalized price for the trip being considered, and the probability of the DPM system being chosen is dependent upon the generalized price of each of these competing modes.

2.6.2.1 Travel Time

There are several distinctly separate components of travel time that should be examined in any travel choice analysis. C basic division is between time spent in a vehicle and time spent out of a vehicle. These components are considered separately because empirical data generally show that travellers place different weights on them. Table 2-4 provides a comparison of the relative importance of in-vehicle and out-of-vehicle travel

TABLE 2-4

COMPARISON OF VALUES OF TIME

Work Trips

City	Year of Survey	Average Income ($1000)	Value of Time IVTT*	Value of Time OVTT*	Ratio**	Researcher
1. Washington, DC	1968	12	$3.85	$5.00	1.3	CSI (6)
2. Los Angeles, CA.	1967	10	$3.59	$5.02	1.4	CSI (7)
3. San Francisco, CA.	1965	15	$3.42	$9.38	2.7	CSI (9)
4. New Bedford, MA.	1963	9	$1.23	$3.13	2.5	CSI (3)
5. Milwaukee, WI.	1972	12	$1.11	$3.04	2.7	SEWRPC (22)
6. Pittsburgh, PA.	1967	8.8	$1.10	$3.04	2.8	CRA (10)
7. San Diego, CA.	1972	9.5	$3.19	$5.21	1.6	PMM (18)

Non-Work Trips

City	Year of Survey	Average Income ($1000)	Value of Time IVTT*	Value of Time OVTT*	Ratio**	Researcher
1. Washington, DC	1968	12	$14.5	$18.71	1.3	CSI (1)
2. Pittsburgh, PA.	1967	10	$ .96	$ 5.46	5.7	CRA (10)
3. Milwaukee, WI.	1972	12	$ .62	$ 1.12	1.8	SEWRPC (22)

* IVTT = in-vehicle travel time; OVTT = out-of-vehicle travel time.

**Ratio of the Value of Out-of-Vehicle Time to In-Vehicle Time.

Source: Cambridge Systematics, Inc., Tert of Transferability and Validation of Disaggregate Behavioral Demand Models for Evaluating the Energy Conservation Potential of Alternative Transportation Policies in Nine U.S. Cities, 1977.

time for urban travel choices in various U.S. cities. The values of time reported in this table were derived from models of mode choice estimated on data sets from the cities listed and in the year designated. There is considerable variation in the values of time among the cities, but this can be due to differences in the year of the data set, the average income represented by the households in the data set, or differences in specification of the model structure. What is significant is the fact that out-of-vehicle time consistently has a higher cost value than in-vehicle time. The ratio of the value of out-of-vehicle time to the value of in-vehicle time for work trips ranges from 1.3 to 2.8, and this ratio for nonwork trips ranges from 1.3 to 5.7.

Even among the out-of-vehicle times, there is often a differentiation made between time spent walking and time spent waiting. In a model estimated in the San Francisco-Oakland Bay Area* the following weightings on time components were implied:

Time Component	
In-Vehicle	1 (index)
Walk	4.6
Wait	2.9
Transfer	3

All of the components of out-of-vehicle time are clearly more onerous than in-vehicle time, but even among the out-of-vehicle time, walk time is weighted about 1.5 times as onerous as either wait or transfer time.

In estimating demand for a transportation system, it is not always possible to evaluate each component of travel time individually, but a knowledge of the differences in the weighting given to each is helpful in making subjective decisions in service planning.

In-vehicle time on the DPM system will be a function of:

- The individual trip maker's trip length
- The number of stations
- The average dwell time in a station
- The average speed between stations

Walk time to DPM stations is a function of:

- Guideway location with respect to activity center location
- Station spacing on the system

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*McFadden, Daniel and Antti Talvitie. Demand Model Estimation and Validation, The Urban Travel Demand Forecasting Project, Phase I, Volume V, Institute of Transportation Studies, University of California, Berkeley, June 1977.

- Location of the stations with respect to the pedestrian (sidewalk) system, to parking areas, and to regional transit stops

Waiting time on a DPM system will be determined by the frequency with which vehicles enter the stations. Waiting time for transit service is generally considered to be one-half of the headway (time between vehicles) when the headways are small and the schedule adherence is reasonably good.

2.6.2.2 Travel Costs

The fare that is charged for use of a DPM system, when compared with the costs of using alternative modes of travel (auto, bus, taxi, or walk) is an important determinant of DPM ridership. The fare levels that have been suggested for the proposed DPM systems have ranged from no-fare to 25¢. The money cost of using "walk," as the most competitive modeis nothing, of course, but the costs of using an automobile, taxi, or bus can be quite high. Short-term parking costs are generally high in the CBD's of the cities considering DPM systems, as is the taxi fare for short trips. Bus fares vary from free to 50¢ depending on the city.

The value of time discussed in the previous section provides a guide for evaluating the tradeoff between time and money and is a useful planning tool. A value of time of $3.00 per hour (5¢ per minute) indicates that a trip maker would be willing to pay up to 5¢ for each additional minute in travel time that is saved by the DPM system. The values of time that were reported in the previous section were primarily estimated from data on longer (regional) trips and for which the transit fare was higher than the fares that have been considered for the DPM system (0 to 25¢). The experience to date with intra-CBD trips, of which a very high proportion are on foot, indicates that the value of time is much lower than that indicated for regional trips.

Because of the unique nature of the DPM concept, the location and the level of service to be provided, it is difficult to find examples of systems operated at different fares and the ridership attracted at the different fare levels. The closest comparison that can be made is with CBD circulation bus systems. Although the level of service is much different, the function served by the systems is roughly the same. In two experiences with fare changes on CBD circulator bus systems (San Antonio, Texas, and Denver, Colorado), a reduction in the fare from 10¢ to free fare resulted in roughly a doubling of the ridership.

2.6.2.3 System Capacity

It is important that the ridership estimated for a DPM system be within the practical limits of the system capacity. It is very easy to violate this restriction by estimating daily ridership without relating the daily ridership to a maximum peak period demand. In sizing a proposed system, it is important to compare the maximum hourly demand on the system to the maximum effective one-hour capacity of the system.

The characteristics of a DPM system which determine the system capacity are:

- Route length
- Vehicle seating capacity
- Operating schedule (vehicles in operation or frequency of service)
- Operating speed
- Number of stations

The maximum capacity of the system is determined by the peak period capacity (the period in which the greatest number of vehicles are in operation). The maximum peak period capacity is determined by the relationship:

$$C_{max} = \frac{N*C_{veh}*V*S}{L}$$

where C_{max} = Maximum one-hour capacity

N = Vehicles in operation

C_{veh} = Capacity of each vehicle

V = Operating speed

S = Number of stations

L = Length of the route

This assumes that each passenger travels on only one link of the system. The effective capacity (C_{eff}) is, therefore, between the maximum capacity C_{max} and C_{max}/S, which, in effect, allows a space for each passenger for the vehicle's round trip.

The relationship above is a simplification of the actual capacity determination because in actual operation, the operating speed is a function of both the number of passengers carried and the number of vehicles in operation. For the sake of a rough estimate of a system capacity, C_{eff} calculated from a typical operating speed under high demand conditions is a useful indicator of the constraints on ridership imposed by the system.

Table 2-5 shows some typical values for N, C_{max}, L, V, and C_{eff} for operating systems.

In some cases, the operating speed used in developing these maximum effective hourly capacities is the maximum operating speed while the actual operating speed is lower. In estimating the capacity of a proposed system, it is important to use a realistic value for operating speed.

TABLE 2-5

EFFECTIVE OPERATING CAPACITIES OF AUTOMATED GUIDEWAY TRANSIT SYSTEMS IN OPERATION

System	Vehicles in Operation	Vehicle Capacity (Persons)	Route Length (Miles)	Operating Speed (MPH)	$C_{effective}$ (Persons/hour)
Cabinenlift Ziegenhain Hospital, West Germany	1	12	.4	4	120
Fairlane Town Center	2	24	.5	30	2,880
Houston International Airport	18	12	1.0	8	1,728
Busch Gardens	2	100	1.4	30	4,285

Source: The values for Vehicles in Operation, Vehicle Capacity, Route Length, and Operating Speed are from People Mover Profile, U.S. Department of Transportation, Urban Mass Transportation Administration, Transportation Systems Center, 1977.

2.6.3 Characteristics of the Trip

2.6.3.1 Trip Purpose

The importance of trip purpose in determining the choice of mode, the time of travel, and the frequency of travel has been illustrated in the previous discussions on the peaking characteristics of CBD travel and on the role of travel time and travel cost in determining DPM demand. The stratification of trips, by trip purpose, aids also in applying trip rates for specific land use types and, as will be discussed in Section 2.6.3.2, is helpful in estimating average trip lengths.

From a survey of the users of a downtown circulator bus route in the Los Angeles CBD* the following breakdown of trips by purpose was reported among the users:

	Noon Peak	Evening Rush
Work	13%	20%
Shop	33	35
Eat	26	26
Business	28	19

From a similar survey of pedestrians in the Los Angeles CBD*, the following breakdown of trips by purpose was reported:

	Noon Peak	Evening Rush
Work	42%	56%
Shop	19	21
Eat	17	9
Business	22	14

One very important consideration that should be given to trip purpose is the stability or frequency of travel among the various trip purposes. Work trips, for example, are generally made five times per week by each trip maker, while trips for nonwork purposes may be only once a week or less and, further, may be made to different destinations. The regularity of work trips allows the trip maker to learn the details of a system, for example, its routing, stop location, fare, seating conditions, and transfer facilities. Based on this knowledge, the worker will tend to make a long-term decision to ride or not ride the system for the trips to and from work. Nonwork trips, however, are generally of such a discretionary nature that the trip maker must be aware of the benefits of using the system for the variety

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*Barton-Aschman Associates, Inc., Los Angeles Central Business District Internal Travel Survey, Working Paper prepared for the Los Angeles Bunker Hill and Central Business District Circulation Distribution Program for the Community Redevelopment Agency of the City of Los Angeles, Los Angeles, CA October 1975.

of purposes and destinations that are likely to be considered. This implies that simplicity in the system design and a rigorous market effort are necessary to attract nonwork trips, while work trips will develop naturally over a short period of time if the system serves the needs of the CBD workers.

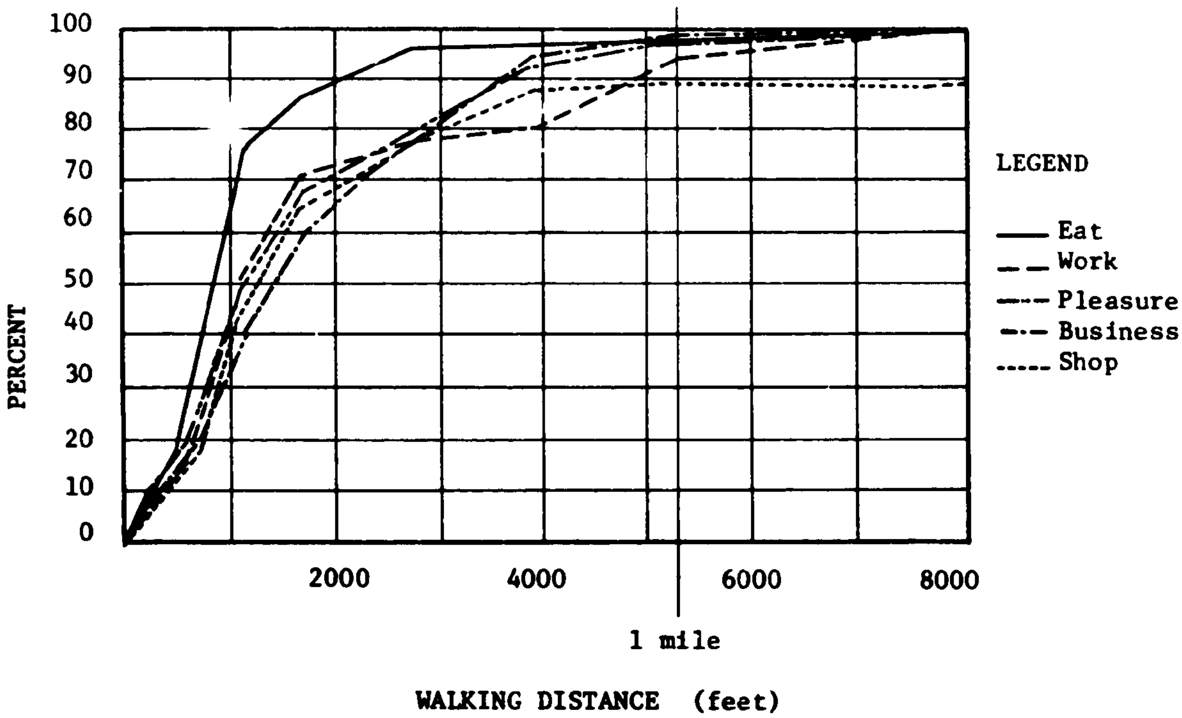
2.6.3.2 Trip Length

The discussion of employment density illustrates the importance of trip lengths in the determination of DPM demand. The length of a trip within the DPM service area will, to a large extent, determine the ability of the DPM system to compete with other modes in serving that trip. Only when the DPM system can reduce or match the generalized price of an existing trip is there a high probability of the DPM being chosen. This does not mean that the total time must be reduced because, in an evaluation of the generalized price, time spent walking or waiting is generally weighted more heavily than time spent riding in a vehicle. A longer trip by DPM may, therefore, result in a lower generalized cost if the amount of walk time has been reduced. In predicting DPM demand,the planner should carefully consider the trip length distribution of the candidate DPM trips. Although this alone is not sufficient for a demand estimate, a pattern of very short trips within the service area would raise some doubts about the likelihood of system success.

Figure 2-3 illustrates the distribution of walk trip lengths by trip purpose for travel within the Manhattan CBD in New York City. Trips for the purpose of eating were generally shorter (with a median trip length of 810 feet and an average length of 1073 feet) than trips for other purposes. Trip length distributions for other purposes were very closely grouped.

The variation of trip lengths by trip purpose for travel in various city centers is illustrated in Figure 2-4. Although there is significant variation in the median values for each city, the pattern is consistent in that the trip length for shop trips is lower in each case than trips for work; and trips for business, whether work related or personal, are longer than both shop and work trips.

The importance of trip length in the determination of mode choice is illustrated by the median trip lengths by mode for intra-CBD travel in Los Angeles as represented in Figure 2-5. The figure demonstrates that the median length for trips by the downtown circulation system (minibus) is more than four times the median walk trip length at noon, and three times the median walk distance in the evening peak. It is among these longer trip lengths that a DPM system will most successfully compete for ridership. The median and mean trip distances for walk and for minibus are provided in Figure 2-5.



	All Trips	To Eat	To Work	Pleasure	To Shop	Business
Average Walk Distance (ft.)	1,720	1,075	1,880	1,666	2,253	1,737
Median Walk Distance (ft.)	1,070	810	1,120	1,130	1,250	1,405

FIGURE 2-3

CUMULATIVE WALKING DISTANCE DISTRIBUTION BY PURPOSE AT TWO MANHATTAN OFFICE BUILDINGS

Source: Pushkarev, Boris and Jeffrey M. Zupan, Urban Space for Pedestrians, Regional Plan Association, 1975.

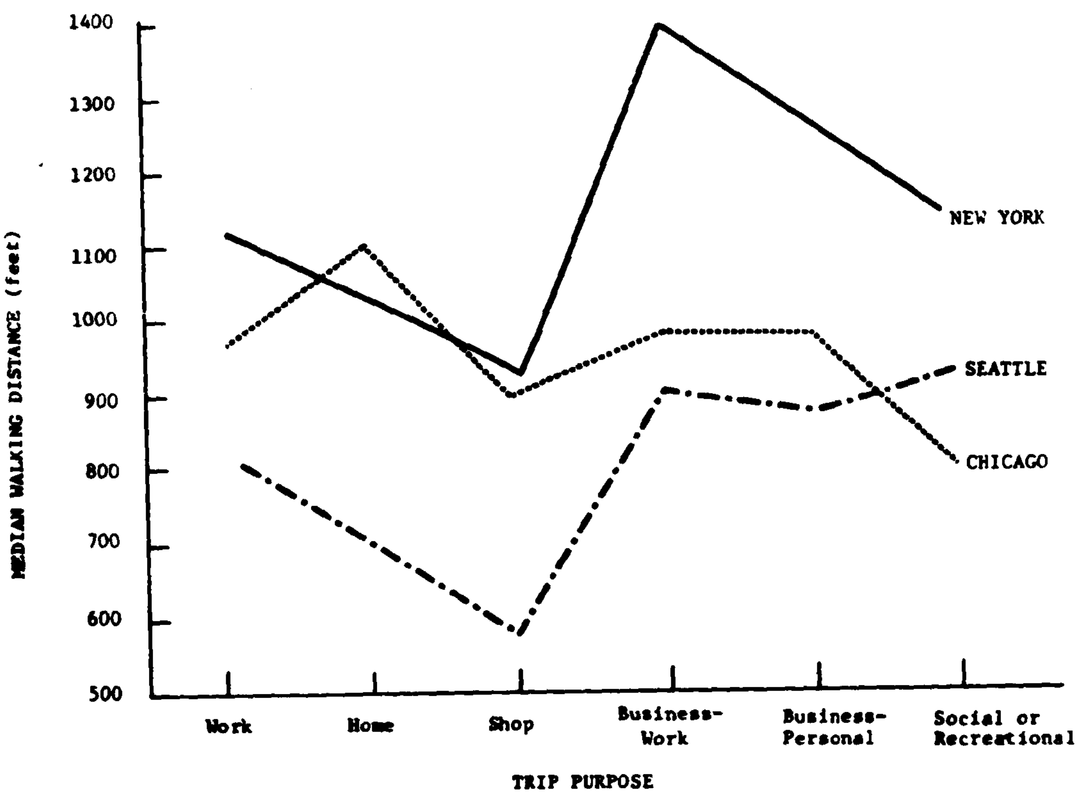
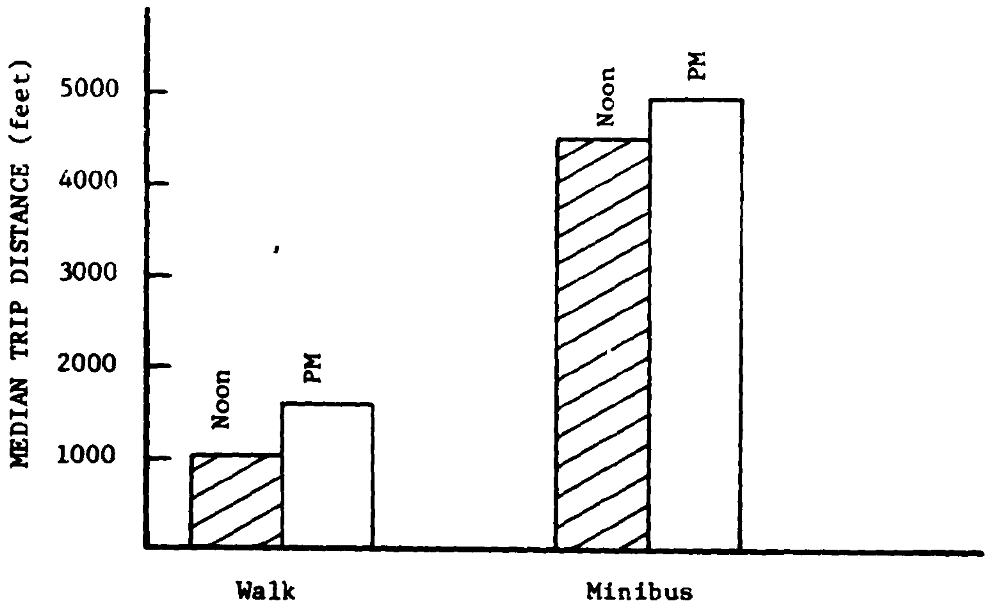


FIGURE 2-4

MEDIAN WALK DISTANCE BY PURPOSE FOR THREE CITIES

Source: Rutherford, G. Scott and Joseph L. Schofer, Analysis of Pedestrian Travel Characteristics, 1976.



		Walk		Minibus	
		Noon	Evening Peak	Noon	Evening Peak
Average	Distance (ft.)	2,017	2,491	4,150	4,141
Median	Distance (ft.)	1,100	1,600	4,500	5,000

FIGURE 2-5

MEDIAN TRIP DISTANCE BY MODE FOR INTRA-CBD TRIPS IN LOS ANGELES (FOR THE NOON PERIOD AND THE EVENING PEAK PERIOD)

Source: Barton-Aschman Associates, Inc., Los Angeles Central Business District Internal Travel Survey, 1975.

2.6.4 Characteristics of the Trip Maker

2.6.4.1 Reason for Being in the CBD

The discussion of potential DPM markets demonstrates the value of stratifying trip makers by the reason for being in the CBD. The basic breakdown is as follows:

- CBD residents
- CBD employees
- CBD shoppers (or other nonwork trip makers)
- Non-CBD employees in the CBD for business-related purposes
- Conventioneers, tourists, and other visitors to the city

This stratification provides useful information about:

- Trip maker's frequency of travel in the CBD
- Likely access of the trip maker to modes other than walk and DPM
- Time of travel
- Familiarity with the system

The relative values for each trip maker type for each of the above trip characteristics are illustrated in Table 2-6. These are rough approximations and may vary depending upon the nature of the city under consideration.

2.6.4.2 Perception of the Travel Mode

Not all characteristics of a transportation system can be represented or measured in a quantitative way. Comfort, convenience, reliability, safety, cleanliness, and aesthetic appeal are attributes of a transportation service that are not easily quantifiable but which significantly affect ridership. It is generally recognized that a fixed guideway system will be preferred over a bus system even when all level of service variables are equal, because potential riders are more confident about the routing and the stop locations.

Cities which have tried both fare-free zones within the CBD (using regional bus lines for intra-CBD circulation) and separate CBD circulation buses have found the circulator bus to be much more attractive and much more easily marketed than the fare-free zone.

2.7 IMPACT ESTIMATION AND ASSESSMENT

This discussion of impact assessment methodology is designed for a specific level of detail--that being a rather preliminary assessment of the likely magnitude of impacts. The methodology suggested herein is not designed for the detailed assessment of

TABLE 2-6

CHARACTERISTICS OF CBD TRIP MAKERS

Reason for being in the CBD	Trip Frequency	Access to Auto	Familiarity with System	Time of Travel
1. CBD Resident	High	Good	Good	All Times
2. CBD Employee	High	Fair	Good	Morning Peak Midday Peak Evening Peak
3. CBD Shoppers (or other non-work)	Moderate	Good	Fair	Midday Peak Afternoon Offpeak Evening Peak
4. Non-CBD Worker on business	Moderate	Fair	Fair	Morning Offpeak Midday Peak Afternoon Offpeak
5. Visitor	Low	Poor	Poor	All Times

impacts that should eventually become a part of the planning process. The purpose of this section of the overview is to present 1) the types of impacts that should be considered, 2) suggestions as to how the impacts might be predicted, and 3) the likely magnitude of each of the impacts.

At a sketch planning level of detail, each of the non-travel impacts of a DPM system can be expressed as a function of either:

- Travel demand impacts
- Physical characteristics of the DPM system
- Operational characteristics of the DPM system

Table 2-7 summarizes the relationship between the non-travel impacts and each of the three determinants listed above.

In Section 10 of this report, impact rates will be provided which will allow rough estimates of the non-travel impacts on the basis of values determined for one or more of the three determinants. The remainder of this overview section (Section 2), will be devoted to a discussion of each of the impact areas and, when possible, some typical values for impacts from similar people mover systems.

2.7.1 Travel Demand Impacts

This area will receive the greatest attention in this report because many of the non-travel impacts are directly or indirectly related to the level of demand and can be represented as functions of demand. An insight can be gained into the impact estimation process by examining the types of travel demand impacts that can occur. The areas of travel change are basically:

- Changes in the mode of travel
- Changes in the destination of a trip
- Changes in the frequency of travel

These changes may also occur in combination. Illustrations of the possible travel demand changes that may occur in response to a DPM system are provided in Figure 2-6.

In general, DPM ridership can represent travel that is:

- Diverted - from another mode (Combination 1 in Figure 2-6)
- Converted - from another destination and from another mode (Combinations 2 and 3)
- Induced - representing an increase in the trip frequency due to the improved level of transportation service or because of the increase in the opportunities provided by the DPM system (Combinations 4 and 5)

TABLE 2-7

DETERMINANTS OF NON-TRAVEL DPM IMPACTS

Impacts	Determinants		
	Travel Demand Characteristics	Physical Characteristics of the DPM System	Operational Characteristics of the DPM System
Economic Impacts			
a. Increase Retail Sales	Increase in nonwork trips		
b. Increasd Business Volumes	Increase in work trips or work-related trips		
c. Increased Land Values	(Indirectly related to increased trip making)		
d. Revitalization of CBD	(Indirectly related to increased trip making)		
Environmental Impacts			
a. Pollutant Emission	Regional shift to transit or parking shift to CBD fringe	Power source location interface with parking and regional transit	
b. Noise		Guideway location Design Specifications	
c. Aesthetic Quality		Guideway location Guideway design	
d. Energy Consumption	Regional shift to transit	Interface with regional transportation systems	Vehicle miles operated

TABLE 2-7 (continued)

Social Impacts			
a. Mobility	**Induced tripmaking (particularly among the physically handicapped)**	System coverage	Frequency of service
b. Accessibility		**Barrier free design**	Fare
c. Safety	**Modal shift from auto to DPM**	Station Design Guideway Design Accident Safeguards	
Financial Impacts			
a. Cost			
• **Capital**	**Peak period ridership**	Stations size and number Guideway miles Controls Vehicle size and number	
• **Operating**	**Ridership by time-of-day and day-of-the-week**		Vehicle miles travelled Vehicle hours operated
b. Revenue			
• **Farebox**	**Total DPM passengers**		Fare
• **Sales tax**	**Induced non-work trips**		
• **Value capture**	**(Indirectly related to induced trip-making)**	Joint venture development	

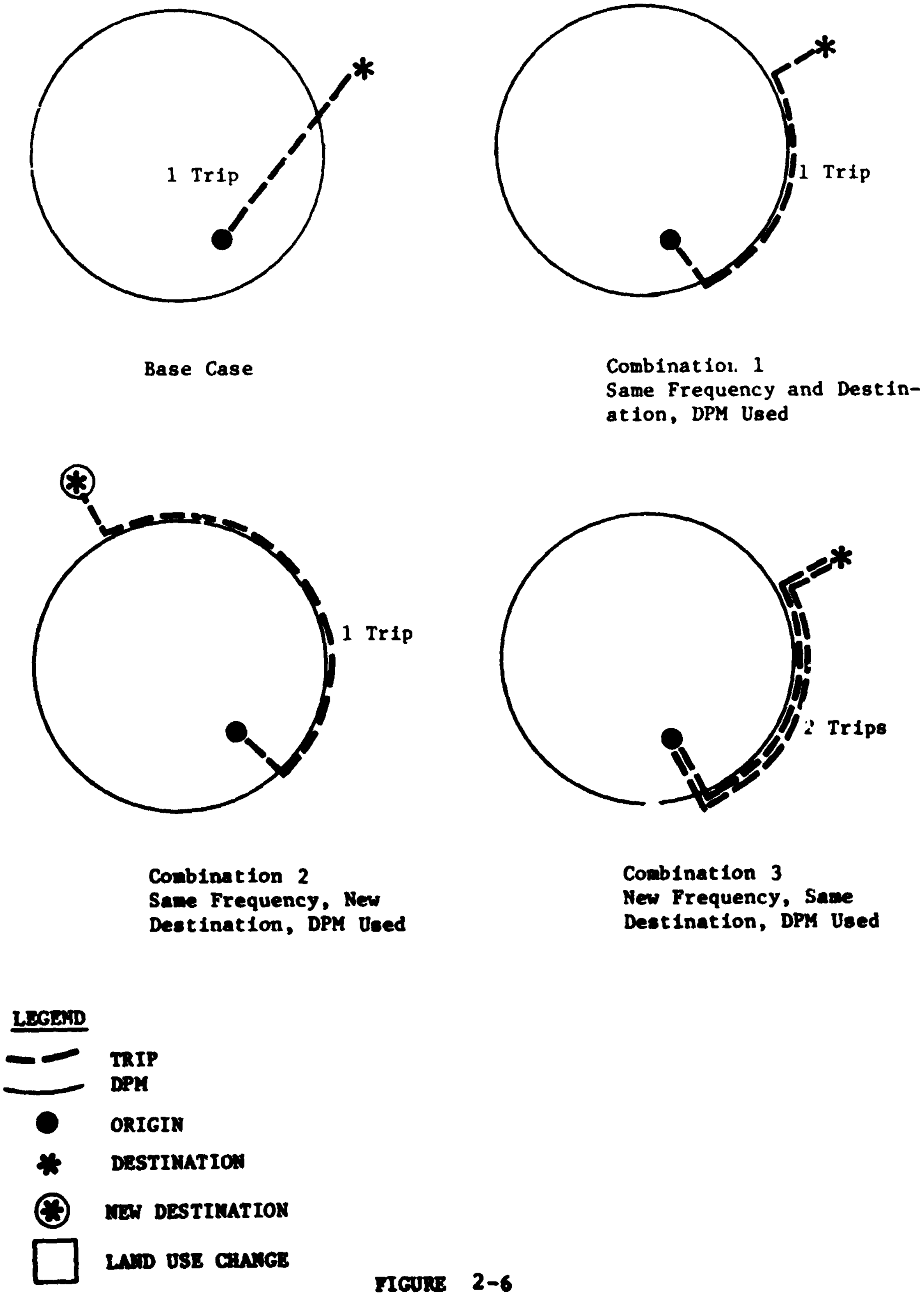
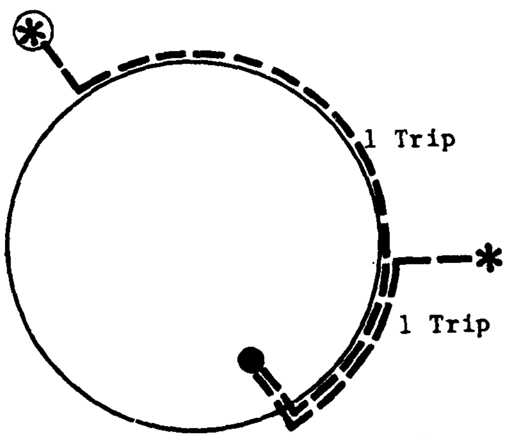
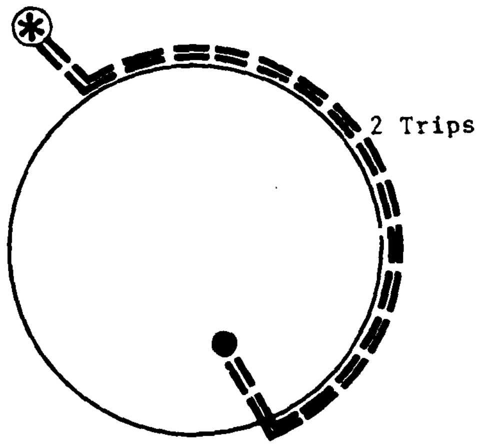


FIGURE 2-6

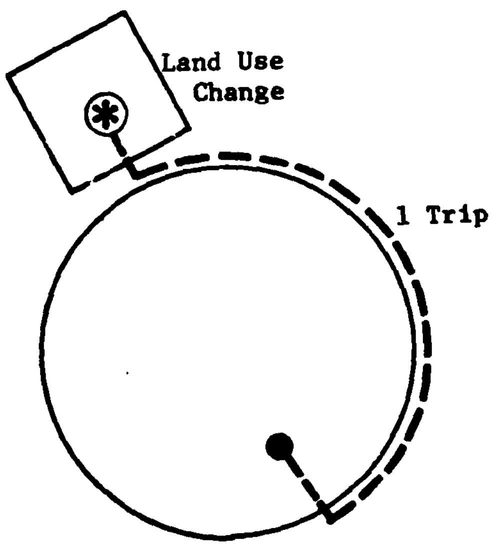
ILLUSTRATION OF DPM RELATED TRAVEL DEMAND IMPACTS



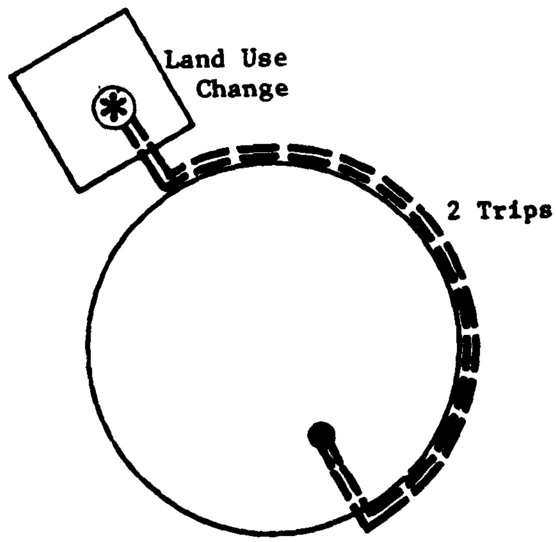
Combination 5
New Frequency, New and Old
Destination, DPM used



Combination 4
New Frequency, New Destination,
DPM Used



Combination 6
Same Frequency, New Destination,
DPM Used, Land Use Change



Combination 7
New Frequency, New Destination,
DPM Used, Land Use Change

FIGURE 2-6 (continued)

- Generated - by new development that is stimulated or supported by the DPM location service (Combinations 6 and 7).

Diverted, converted and induced trips can be considered as short run changes that may occur within a few weeks after the beginning of operation. Generated trips, on the other hand, are considered as long-term changes that develop in the years following implementation. As illustrated in Figure 2-6, these generated trips are a product of land use changes.

Figure 2-7 represents an attempt to place the discussion of the elements of DPM demand in a common framework. The common thread running through the flow chart is that the combination of land use and transportation supply defines "accessibility" and that this accessibility leads to tripmaking. Thus, demand diverted or converted to DPM's from other modes occurs because a DPM with certain characteristics is added, perhaps in conjunction with changes in how the existing system is allowed to operate, and this changes the relative accessibility of alternative modes. For example, auto commuters to a CBD might shift to transit if a DPM is inserted into the CBD, eliminating a long walking link between the transit station and the work location. If, simultaneously, a policy decision is made to eliminate some CBD parking spaces, thereby reducing the relative accessibility of the auto, further diversions to transit, and to a DPM might occur. For induced travel, since the addition of a DPM system increases transportation supply, accessibilities also increase, even with no changes in land use. This added accessibility leads to new travel, induced solely by the existence of the DPM. For changes in land use, if land use policies intensify activities, accessibilities increase even with no further changes in the transportation supply. This added accessibility likewise adds to the amount of travel, much of which may find its way onto the DPM. An example of this would be the DPM demand created by a special zoning district that encourages placement of extra floorspace over the site of an existing or planned DPM station.

In actual experience with new transit services, the ridership is made up predominantly of diverted trips. Figure 2-8 illustrates the approximate proportions of the different components for ridership on the Transbay section of the Bay Area Rapid Transit System. The figure implies that 9,000 additional trips were made (from a base of 129,000 trips per day) but only 2,000 of these additional trips were made on the new BART system. The remaining 7,000 were made by automobile and were induced by the improved driving conditions after the BART opening. The actual BART ridership was made up of the following types of trips:

Diverted from auto	11,000	(42%)

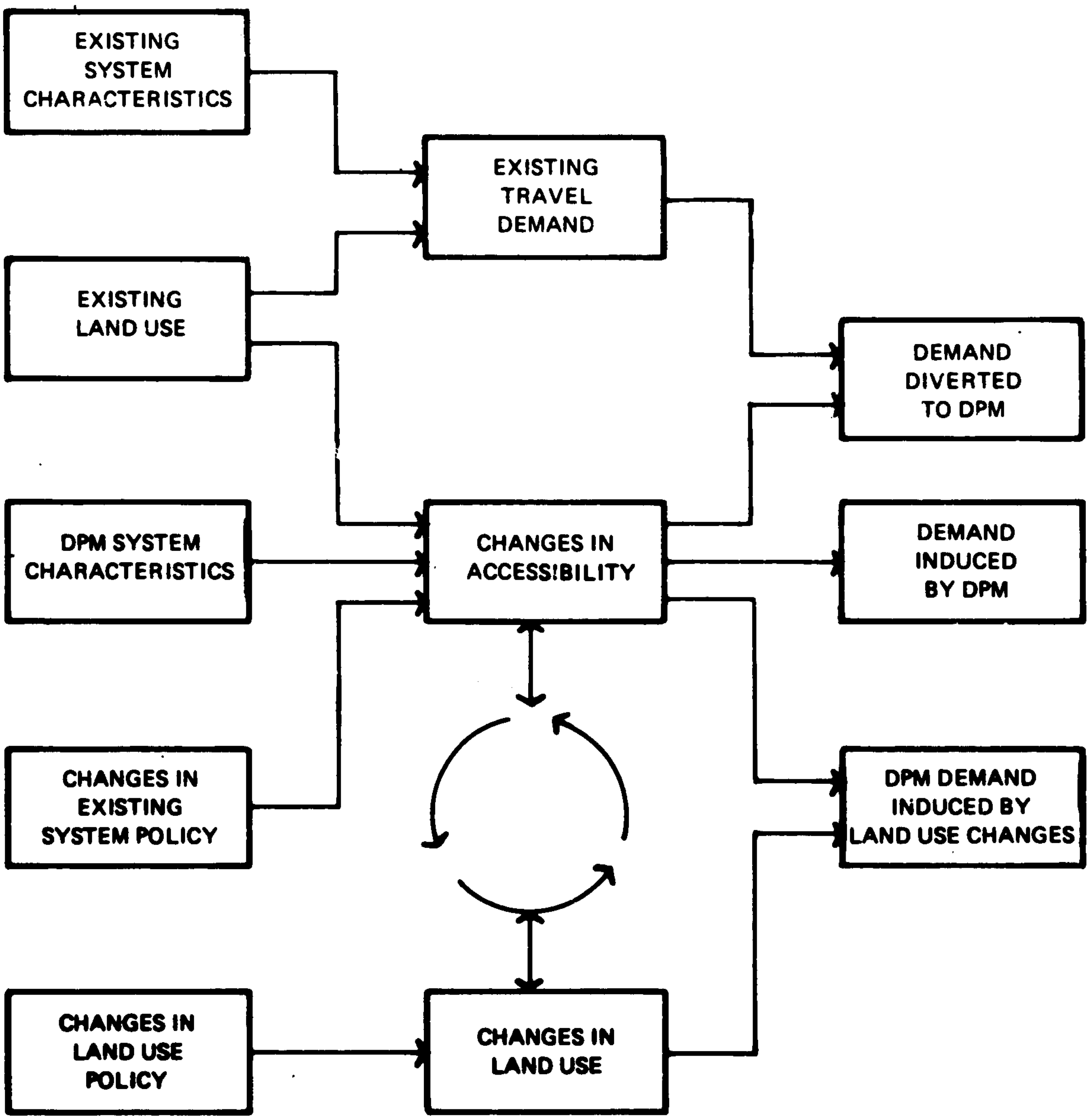


FIGURE 2-7

INTERRELATIONSHIPS OF TRAVEL DEMAND, LAND USE AND ACCESSIBILITY

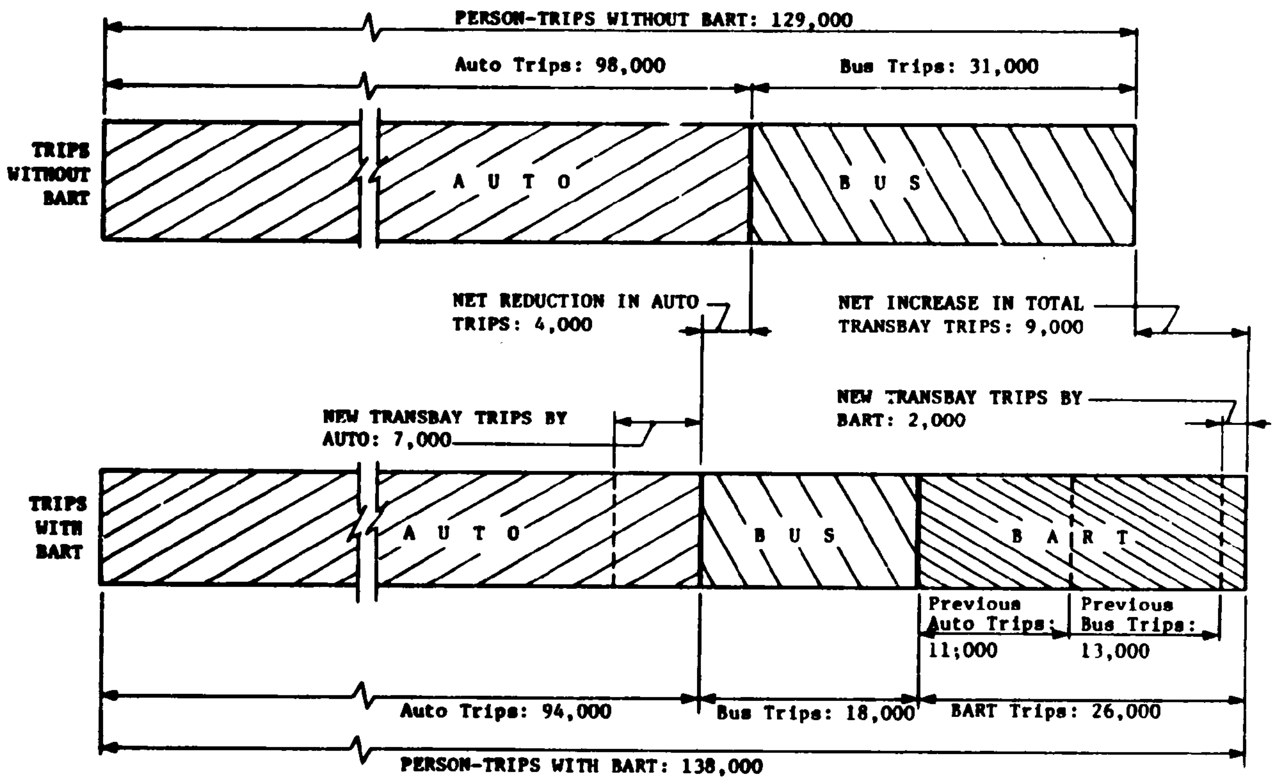


FIGURE 2-8

TRAVEL IN THE SAN FRANCISCO - OAKLAND BAY BRIDGE CORRIDOR, 1974
(AVERAGE DAILY MIDWEEK WESTBOUND PERSON-TRIPS, 6:00 AM - 8:00 PM)

SOURCE: Worrall, R., Peat, Marwick, Mitchell & Co., "Impacts of Interim BA[illegible] Service on Traveler Behavior and Transportation System Performance", Impacts of BART - Interim Findings. Proceedings of the TRB Annual Meeting, p. 25, Jan.'77.

Diverted from bus	13,000 (50%)
Induced or converted*	2,000 (8%)
generated	not applicable
TOTAL	26,000(100%)

Table 2-7 identifies the travel impacts which are important determinants of the other, non-travel impacts. The methodology which the DPM planner uses to estimate the travel impacts should identify the following short-run impacts:**

- Components of the DPM patronage (induced, diverted, converted trips)
- Changes in CBD traffic volume during the peak periods
- Changes in the choice of mode for regional trips to the CBD
- DPM ridership by market segment (CBD workers, non-CBD workers, CBD residents, shoppers, visitors)
- DPM ridership by trip purpose (work, nonwork)
- DPM ridership by time-of-day and by day-of-the-week
- Change in the total volume of trips to the CBD

Reasonably accurate estimates in each of these areas will enable the DPM planner to estimate the impacts of each of the non-travel impacts that are related to travel demand.

2.7.2 Economic Impacts

Economic impacts can be classified according to the following categories:

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

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

- Increased city revenue through "value capture", increased property tax from higher land values, increased sales tax from higher sales volumes, and increased income tax from higher employment levels

Revitalization, changes in employment density and value capture from 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

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*Changes in trip frequency were not differentiated from changes in destination.

**The long-run impacts produced by land use changes can then be roughly estimated on the basis of the estimation of short-run impacts.

relationship is assumed between retail employment and the volume of trips for nonwork 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. This process is illustrated in Figure 2-9.

It is only the increase in sales volumes and sales related taxes that can be estimated directly on the basis of the demand forecasting techniques to be suggested in this report. Relationships have been estimated between the transportation level of service and the total volume of nonwork trips for trips within the CBD. The relationships were based on trip data from the Los Angeles CBD and basically relate the number of trips per person in the CBD to the amount of activity in the CBD and the transportation level of service.

The effect of transportation level of service on CBD trip making was recently demonstrated by the opening of the downtown section of the METRO rail system in Washington, DC. As illustrated in Table 2-8, 46% of the METRO trips made for the purpose of shopping were "induced" or would not have been made if Metrorail were not available. Of all of the riders surveyed, 21% indicated that the trip would not have been made if the METRO system were not available. The relationship of these survey results to DPM systems is highly speculative and subject to interpretation, yet it supports the general theory that a higher level of service will generate additional trips within the CBD.

2.7.3 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 increased noise and visual intrusion. Only if the DPM system is designed to intercept vehicle 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

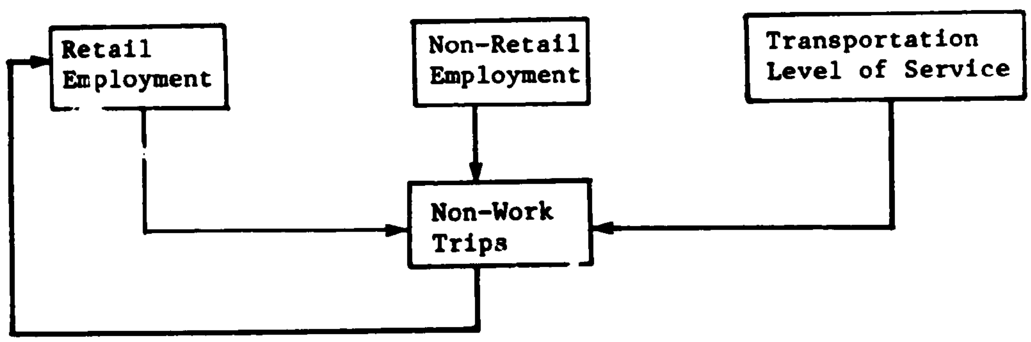

FIGURE 2-9

RELATIONSHIP OF EMPLOYMENT CHANGES TO LEVEL OF SERVICE CHANGES

TABLE 2-8

INDUCED TRIPS BY DESTINATION PURPOSE - WASHINGTON METRORAIL

	Trip Destination Purpose				
	Home	Work	Shop	Other	TOTAL
Trips that would be made without Metrorail	87%	84%	54%	69%	79%
Trips that would not be made without Metrorail	13%	16%	46%	31%	21%
TOTAL	100%	100%	100%	100%	100%

SOURCE: "Dupont Circle Metrorail Station Interview Survey Findings," Metropolitan Washington Council of Governments, April 1977. (The survey was conducted in March, 1977, at the Dupont Circle Station on the Metrorail Red Line.)

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.

2.7.3.1 Pollutant Emissions

Because existing people mover technology relies on electrical propulsion energy, the direct pollutant emissions will be isolated to the location where the electrical energy is generated. Because this location will generally be outside of the CBD, the negative impacts on the CBD will be negligible. Positive impacts on the CBD will result from any diversion from auto to DPM for intra-CBD trips and from the elimination of parking and regional transit operations in the CBD. Pollutant emission impact rates can be derived given the relationship between the volume of pollutants emitted to the number of auto and bus miles eliminated from CBD operation. The number of auto miles can be derived from the intra-CBD mode shift analysis and from the projected success of parking intercept plans. The number of bus miles eliminated will be dependent upon the operational changes made by the transit operating authority.

2.7.3.2 Aesthetic Quality

The aesthetic qualities of a DPM should be the most important environmental concern in an impact assessment. The impact of a DPM system on air quality, noise, and energy consumption will be of very little magnitude, but the construction of a guideway through a downtown area will have a definite impact on the physical appearance of the area. Many steps can be taken to minimize the negative impact of the guideway on the appearance and character of the surroundings and, in some cases, the physical presence of the guideway may be aesthetically pleasing. The purpose of this section of the overview is to point out the areas in which a DPM guideway and stations can detract from the physical appearance of the CBD, to alert planners to the existence of these elements and to insure proper consideration of the elements in planning. Some of the areas in which a DPM system can detract aesthetically from a CBD are:

- Producing a visual barrier between different parts of the city
- Producing shadows or dimly lit areas which appear cold and/or uninviting
- Distracting from the architectural design of existing buildings

- Interfacing with the view from windows in existing buildings

- Obstructing the view of parks, monuments, waterways, or other aesthetically pleasing sights

- Constituting an eyesore if poorly maintained

Little more can be provided here than description of the areas of concern. Detailed design planning by qualified architects or urban designers is necessary for the proper assimilation of the DPM system into the city landscape.

2.7.3.3 Energy Consumption

Positive impacts of a DPM system are likely to be very small because the primary change in travel patterns will be a shift from walk trips to DPM trips. The DPM system will reduce energy consumption only if intra-CBD trips are shifted from auto to DPM or if regional trips are shifted from auto to transit. Listed in Table 2-9 are the reported energy requirements from some of the operating people mover systems. For comparison, the average operating energy requirements for U.S. rail transit systems and bus transit systems have been provided along with the energy requirements for operating a typical automobile. The figures demonstrate that, in a comparison of the energy efficiency of each mode in moving passengers, the relative efficiencies are highly dependent on the utilization of the system.

2.7.3.4 Noise

The extent to which noise generated by a DPM system will impact the CBD is dependent upon the guideway location, the frequency of service (the number of vehicles per hour), the hours of operation, the design specifications of the system, and the ambient noise standards at different times of the day. The ambient noise level in a CBD is generally high and small amounts of DPM-generated noise would, on the average, be of little consequence. In special situations, however, even the impact of low noise levels on a frequent basis could be significant. Examples of such situations would be operation in the early morning or the late evening, or in quiet areas such as residential areas and hospital zones.

The most commonly used measure of sound level is the "A-weighted decibel scale" or dbA. The reported noise levels in dbA's for people mover systems in actual operation are shown in Table 2-10. These reported sound levels have little meaning unless referenced to common noise levels. The following list shows typical A-weighted sound levels for everyday situations:

TABLE 2-9

COMPARISON OF ENERGY REQUIREMENTS OF AUTOMATED GUIDEWAY TRANSIT AND OTHER TRAVEL MODES

System	Vehicle Capacity (Seated & Standing)	Kilowatt-Hours per Vehicle Mile	Kilowatt-Hours per Passenger-Mile (Capacity Load)
Automated Guideway Systems			
1. AIRTRANS	16 + 24 = 40	2.4	.060
2. Fairlane	10 + 14 = 24	3.6	.15
3. Sea-Tac	12 + 90 = 102	3.2	.031
4. Morgantown	8 + 7 = 15	1.4	.093
5. Cabinentaxi (Germany)	3 + 0 = 3	0.3	.10
Other Modes			
1. U.S. Rail Transit (national average)	75	6.1	.08
2. U.S. Bus Transit (national average)	50	3.5*	.07
3. Automobile (assumes 20 miles per gallon)	4	0.6*	.15

*Assumes that one gallon of gasoline is equivalent in propulsion energy to 13.6 kwh of electrical energy.

Sources: AGT Systems - Nussbaum, E., and B. Zumwalt, Mitre Corporation, Environmental Impact Issues for Automated Guideway Transit Systems, 1976.
U.S. Transit Systems - American Public Transit Association, 1976-77 Transit Fact Book, 1977.

TABLE 2-10

OBSERVED NOISE LEVELS FOR AUTOMATED GUIDEWAY TRANSIT SYSTEMS IN OPERATION

System	Line Speed (mph)	Observed Noise (25 feed from guideway at elevation of vehicle)
Transpo:*		
Dashaveyor	17	70-74 dbA
Ford	12	75-77 dbA
Monocab	10	65 dbA
TTI	14	66-68 dbA
Cabinentaxi	22	61 dbA
Fairlane (Ford)	30	78 dbA

Source: Nussbaum, E. and B. Zumwalt, Mitre Corporation, Environtal Impact Issues for Automated Guideway Transit Systems, 1976.

*Transpro was an exhibition of Automated Guideway Systems held at Dulles Airport in Washington, D.C., in 1972. The noise levels reported here were for test vehicles.

soft whisper at 5 ft. distance -------	30-35 db
business office ----------------------	50 db
large store --------------------------	60 db
vacuum cleaner at 10 ft. distance ----	70 db
normal speech at 1 ft. distance ------	70 db
passenger car, 65 mph at 25 ft. ------	77 db
diesel truck, 40 mph at 50 ft. -------	84 db
loud motorcycle at 25 ft. ------------	90 db

Because of the logarithmic nature of the dbA scale, adding two sounds of the same intensity does not result in a doubling of the dbA level but an increase of 3dbA, regardless of the base noise level. Thus, if a DPM system at 70 dbA is added to an ambient street noise level of 70 dbA, the resulting noise level is 73dbA.

2.7.4 Social Impacts

The primary social impacts that can be anticipated from a DPM system are in the areas of mobility and safety.

2.7.4.1 Mobility

The improvement in mobility will be the most substantial for those desiring to make trips within the CBD which are too long.

The elderly and the physically handicapped are two groups whose mobility improvement can be significant, if the DPM system itself is free of barriers and is, in general, easily accessible. Improvement in mobility for fully ambulatory employees or shoppers within the CBD will be in the form of accessibility to a greater number of places. The social significance of this improved mobility for the fully ambulatory will depend uon the socio-ecnomic makeup of the CBD population and of the DPM ridership.

2.7.4.2 Safety

There are two aspects of safety which should be considered in an assessment of DPM impacts:

- Safety of the DPM passenger
- Safety of non-DPM users.

Among the safety concerns for DPM users should be the likelihood of accidents while on the DPM system. Poor weather conditions or malfunctioning control equipment have been the cause of numerous transit accidents. There should be safeguards and fail-safe failure modes to prevent even the remotest possibility of injury-causing accidents.

Passengers are also concerned with safety from crime while on or near the DPM system. Crowded transit systems have historically attracted pick-pockets, vandals, and other lawbreakers. The incidence of crime can be minimized by stations that are well lighted and open, so that all parts of the loading platform are clearly visible; by providing service at a level which prevents extreme crowding; and by a guideway and station design which minimizes the number of places in which criminals can hide.

A third way in which a DPM can affect the safety of system users is by separating pedestrian and vehicular travel. Normally, most of the trips made by a DPM system would otherwise be made on foot on a sidewalk system which frequently requires an interface with the street system. Trips made on the DPM, therefore, reduce the possibility of auto-pedestrian or bus-pedestrian accidents.

The safety impacts of DPM systems on non-DPM users are similar to those for users, but of different magnitudes. Non-users are less likely to be affected by crime or vandlism induced by the system, but there is still the possibility of crime around DPM structures which may affect non-users. The same types of safeguards to prevent crimes against users would also benefit non-users.

Non-users will also be positively affected by the separation of vehicular and pedestrian movements. If a DPM system is successful in eliminating significant amounts of auto or bus traffic from city streets, through intercept strategies or through modal shifts in intra-CBD trips, the remaining pedestrian trips will be safer due to reduced conflicts with traffic.

2.7.5 Financial Impacts

The financial impacts of a DPM refer to the net cost of providing the service. The determinants of the financial impacts are the capital costs (the costs of all structures, vehicles, and equipment), the operating costs (the costs associated with providing the service on a day-to-day basis) and the revenue generated from the system operation (including revenue from DPM fares, from value capture arrangements and from indirect sources such as increased property or sales tax revenue).

2.7.5.1 Capital Costs

The capital costs of a system are directly related to the physical characteristics of the system, such as:

- Guideway size and length
- Station size and number
- Vehicle size and number
- Extent of accouterments

- Control equipment
- Energy generating equipment
- Administrative offices and maintenance facilities

Typical costs for each of these components of the people mover systems in operation are reported in Section 8 of the report, and rates such as "dollars per mile of guideway" will be developed for use in estimating cost impacts.

2.7.5.2 Operating Costs

Operating costs consist of a wide range of expenses, such as:

- Fuel (energy)
- Operating labor
- Maintenance
- Administrative costs

For simplicity in cost estimating, total operating cost can be represented as a function of either the number of vehicle hours of operation or vehicle miles of operation. Rates of this type will be based on operating experiences for existing people mover systems.

2.7.5.3 Revenue

The primary source of revenue (other than Federal, state, or local subsidy) will be fares collected from DPM patrons. Because the amount of revenue collected from fares is related directly to the fare level and to ridership on the system, fare revenues can be estimated directly from the ridership estimates.

Another source of revenue is the proceeds from value capture arrangements, which are dependent on special arrangements made by the city prior to construction of the system, and on the success of the system in attracting new trips to the value capture parcels.

A final source of revenue is taxes received by the city indirectly as a result of the DPM system. If the DPM system is successful in generating additional shopping trips, the city will receive additional sales tax. If the increase in retail sales results in higher CBD property value, the city may receive an increase in property taxes.

All these sources of revenue are discussed in greater detail in Section 9.

3. EXPERIENCE WITH CBD CIRCULATION SYSTEMS

3.1 SYSTEM DESCRIPTIONS

Many U.S. cities currently operate circulation systems in the downtown area in the form of shuttle bus or minibus routes. These shuttle routes differ from routes in the regional bus system because they typically serve only the downtown and often only the retail core. These shuttle systems are important in the analysis of DPM systems because they represent observable data on demand for travel by public transportation within a CBD. The characteristics of shuttle bus routes are similar in many ways to those of a DPM, and, even where they differ, shuttle data can be used in conjunction with other inputs to estimate demand for the DPM system. The technique for estimating DPM demand on the basis of observed circulator bus ridership is presented in Section 7. The purpose of this section is to report on experience gained about the characteristics of the trips made on CBD circulator modes and the characteristics of the trip makers themselves.

In many cases, shuttle bus routes are further distinguished from the regional bus system by

- Lower fares
- Smaller vehicles
- Frequent midday service

In all but one city investigated, the shuttle bus fare was lower than the base fare on the regional bus system. Many cities charge only 10¢, while in Boulder, Denver, and San Antonio, a ride on the shuttle bus is free. Atlanta charges its systemwide base fare of 15¢ for a shuttle ride.

Small vehicles of approximately twenty-to-thirty passenger capacities are used in many cities for three reasons:

- Ridership levels would make the use of large buses inefficient and less economical
- Small buses are faster and more maneuverable in downtown streets and traffic
- Uniqueness of small buses draws attention of potential riders to the shuttle service and allows current riders to easily recognize the vehicle to board for intra-downtown trips

Service on the shuttle bus routes is frequent and, in most cities, buses are five-to-ten minutes apart. Since the trips served by the shuttle buses are usually short, an infrequent service could make walk time for the entire trip less than the time required waiting for and riding the bus. In addition to frequent midday service some shuttle routes differ from regional bus because they only offer midday service (no morning or evening peak service).*

3.2 DEMAND CHARACTERISTICS

3.2.1 Trip Purpose

Since shuttle bus routes generally circulate through the retail area of downtown, it is not unreasonable to expect a large number of shopping purpose trips. In Washington, DC, the Downtowner user survey results showed 42% of trips were for shopping. In Minneapolis, the survey response was 38% of shuttle trips for shopping; in Milwaukee, the response was 31%; in Atlanta, 30%.

While trip purposes for shuttle riders are not always similar across cities, work-related travel typically comprises the second largest percent of trips (after "shopping"). In Atlanta, "work-related trip" was the purpose indicated by 33% of the shuttle riders; in Minneapolis, the response for work-related trips was 27%; in Washington, DC, 25%; and in Milwaukee, 21%.

The results of three surveys of Milwaukee Shuttlebug riders gave these trip purposes:

Purpose	Percent
Shopping	31.0
Personal business	21.5
Work-related	21.0
Restaurant	15.3
Social/recreational	5.9
Other	5.3

3.2.2 Travel by Time of Day

The trip purpose of shuttle riders varies significantly by time of day. During the morning and evening peak periods, work trips account for a majority of trip purposes, while during the midday, shopping and personal business (bank, doctor, etc.) trips dominate. The implication of this is that the distribution of trip purpose over the day is affected by the shuttle hours of operation. A shuttle route, which operates from 10 AM to 3 PM, will generally have a lower percentage of work-related trips than a route which operates from 8 AM to 6 PM.

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*Houston has a unique approach with two midday (9 AM-4 PM) shuttle routes serving government buildings, hotels, and retail stores and two peak period (7-9 AM and 4-6 PM) routes meant to distribute workers from parking lots to workplaces.

Shuttle ridership generally peaks around the noon hours. If the hours of operation extend all day, there are also peaks during the morning and evening rush hours. Table 3-1 shows the distribution of riders by time of day in Milwaukee and Atlanta.

3.2.3 Alternative Mode Choice (to Shuttle)

Shuttle buses are in competition with several other modes which are available in the downtown: principally walk, auto, and regional bus. In surveys in Milwaukee and Los Angeles, shuttle bus riders were asked how they would make the trip if there were no shuttle bus. In both cases, walk was the mode which was most often mentioned: 57% of the responses in Milwaukee were walk, and 35% in Los Angeles. Regional bus was the next most chosen alternative mode, and auto was third. Some riders (8.2% and 16.5%, respectively) indicated that they would not have made the trip if the shuttle did not exist.

3.3 IMPLICATIONS FOR DPM PLANNING

3.3.1 Similarities in Trip Purpose

Trip purpose similarity by time of day for different shuttle routes is due in part to similarity in the level of service provided (cost, wait time, travel time, station spacing) and the area served. Just as a change in hours of operation influences the trip purpose distribution for the day, so may the station spacing, route location, cost, etc. This is an important implication for DPM planning because DPM station location, fare, and travel speed may be dramatically different from these for minibus shuttles.

3.3.2 Inducement of New Trips

Although shuttle buses are in competition with walk, auto and regional bus, and typically divert trips from these modes, they also induce trips (create new travel demand) by making travel easier within the CBD. When shuttle riders in Los Angeles were asked how they made their trip before the shuttle existed, 30% responded that they had not made the trip. When asked how they would make the trip now if the Los Angeles shuttle were eliminated, 16.5% responded that they would not make the trip.

In response to similar questions, 8.2% of Milwaukee Shuttlebug riders indicated that they would not make the trip if the Shuttlebug service were ended, and 12.8% of Phase I Metrorail riders in Washington, DC indicated that they did not make the trip before Metrorail existed.

TABLE 3-1

DISTRIBUTION OF SHUTTLE RIDERS BY TIME OF DAY

	Milwaukee	Atlanta
8-9 AM		3.2%
9-10 AM	12%*	15.5
10-11 AM		5.6
11-Noon	16	18.4
Noon-1 PM	30	14.6
1-2 PM	20	10.6
2-3 PM		10.0
3-4 PM	22**	5.4
4-5 PM		11.7
5-6 PM		4.9
	100%	99.9%

* 9:30-11 AM

** 2-4:30 PM

3.3.3 Passenger Characteristics

Occupation

The results of surveys in Milwaukee indicate that 70% of Shuttlebug users are employed downtown. This shuttle route is operated only in the midday and it is likely that, if the hours were extended to include the peak periods, the percent of downtown employees among the ridership would increase.

In Los Angeles and Houston, the employment category of shuttle riders was found to be:

	Los Angeles		Houston	
Clerical/sales	32%		38%	
Professional	30		14	
Manager/proprietor	9		33	
Other	10		9	
		81%		94%
Housewife	8%		3%	
Retired	6		2	
Student	5		1	
		19%		6%
		100%		100%

Age

The age of shuttle users is typically between 18 and 40. There is limited shuttle use by students and by the elderly because of the small number of these groups in the downtown on weekdays.

Surveys in Minneapolis, Milwaukee, and Los Angeles indicate the following age distributions:

Minneapolis		Milwaukee		Los Angeles	
Age	Percent	Age	Percent	Age	Percent
18	4%	18	1.2%	25	19%
18-64	61	18-40	55.5	25-44	46
		41-65	30.8	45-64	29
65+	35	65+	12.5	65+	6
	100%		100%		100%

Sex

In each city where the shuttle rider's sex was asked in the survey, women dominated in the responses by about a 2:1 ratio. This could be the result of many factors including:

- More frequent midday trips from work by women
- Higher auto availability or use of taxis by men
- more frequent downtown shopping trips by woMen not in the labor force
- Multiple destination trips of long length made by women

Survey results indicated that 60% of shuttle riders in Los Angeles were women; 63% in Houston were women; 60% in Atlanta were women.

3.3.4. Impacts on the CBD

The impacts of shuttle bus service on the CBD can be measured in terms of the objectives of the service. Generally, the objectives as indicated by reports from Milwaukee, Wisconsin, and Washington, DC. were:

- Increase transit ridership to the CBD by making travel within the CBD convenient
- Decrease auto use (and congestion and pollution) within the CBD
- Support and strengthen the economy of the CBD.

Mode Split to the CBD

There is conflicting evidence for changes in the regional mode split of trips to the CBD. In Los Angeles, auto use to the downtown by shuttle riders decreased from 70% to about 50% in the first three years of operation. In Milwaukee, survey results indicated that among Shuttlebug riders, auto use to the downtown increased from 44% to 52%. The Shuttlebug operators believe that these results are due to survey dates during different seasons (less people walk in the winter) and not from introduction of the shuttle service.

Auto Use in the CBD

Auto use in downtown areas surveyed is not necessarily lower than before shuttle service was initiated, but there are indications that it is lower than it would have been now without the shuttle bus. In Los Angeles, 15% of the shuttle riders surveyed indicated that they would have travelled by auto if the shuttle were not available. This means that about 560 fewer autos are operated in the Los Angeles CBD during each weekday because of the shuttle service.

In Milwaukee, 19.8% of riders indicated they were using their autos less within downtown and only 1.1% said they were using their autos more than before the shuttle service started. Although "more" and "less" are not good quantitative indicators, the net result is a reduction in auto use in the downtown by shuttle riders.

Increased Use of Downtown Services

Seventy-eight percent (78%) of Milwaukee Shuttlebug users said they increased their use of downtown services since the Shuttlebug began operation. Of these, 73% and 39% indicated an increased patronage of stores and restaurants, respectively. About one-third of the downtown merchants surveyed reported an increase in the number of customers due to the Shuttlebug, and only 29% of these merchants reported no apparent change in dollar volume of business.

3.3.5 Public Acceptance

In Milwaukee, when riders and downtown merchants were asked if Shuttlebug service should be continued, over 90% in each group responded "yes." Also, few riders gave negative responses about Shuttlebug service frequency, hours of service, stop location, route, or fare. In Atlanta, 80% of the shuttle riders gave the shuttle service a "good" rating. In Los Angeles, only 2% of shuttle riders thought a 10¢ fare was "too much."

A final measure of public acceptance is ridership on the system. Table 3-2 indicates the average weekday ridership on 12 shuttle bus services in U.S. cities. Also included in the table are characteristics of the service and the service areas.

TABLE 3-2

CHARACTERISTICS OF DOWNTOWN CIRCULATOR BUS SYSTEMS

City	Beginning Date	Number of Routes	Total Route Mi.	Service Area Employment	Hours of Operation	Regular Fare	Average Weekday Headways	Vehicles Operated in Peak Hour	Peak Hour Ridership	Weekday Riders	Annual Operating Cost	Passengers Per Hour (Average)
Atlanta	May 77	2	3.0 mi.	87,750	8-6 M-F	15¢	10 min.	6	175	911	~$200,000	15
Boulder		1	~7.8 mi.		9-3:30 M-F	free	15 min.	3		600	~$94,000	31
Dallas		1	2.6 mi.	65,773	6:30-6:30	10¢	6 min.	5	304	2500		42
Denver		4	7 mi.		9-4:30 7:45-4;6-10	free	17 min.	10	485	2080	$93,400	30
Houston	1975	4(2)*	7.7 mi.	46,500	7-9,9-4,4-6	10¢	5 min.	13		5000	$306,000	43
Kansas City	July 72	2	5.6 mi.	51,428	7-5:00	10¢	~8 min.	6	375	2100	$225,000	35
Los Angeles	Oct. 71	1**	8.4 mi.	200,000	7-6:30 9-4 Sat.	15¢	5 min.	14	850	4500	$1,299,000	44
Milwaukee	July 75	1	3.2 mi.		9:30-4	10¢	6 min.	7		2800	$181,560	66
Minneapolis	1971	1	2.4 mi.	100,000	7-6:15 9-6	10¢	9 min.			1800***	$190,000	54
St. Louis	1975	2	5 mi.	100,000	11-2	10¢	5 min.	5	400	800-1000	$173,000	60
Washington, D.C.	1972	1	7 mi.	128,000	10-3:30	10¢-25¢	6 min.	12	1200	2500-3000	$346,000	41
San Antonio		1	1.8 mi.	29,483	9-6:30 M-S	free	5 min.	5	860	5600		120

*Two at any one time of the day.

**Two routes were recently combined to form one long route.

***Competing 10¢ buses following same route.

4. THE PLANNING PROCESS

4.1 THE ROLE OF THE EXISTING PLANNING PROCESS

4.1.1 Identifying Needs and Objectives in the Downtown Area

There are many ways in which the circulation and distribution needs of a downtown area of a city may be satisfied. The alternatives range from automobile and taxi travel (with no public transportation) to various forms of public transportation combinations (including CBD bus, local bus, rail options, and automated guideway transit (AGT) -- with the DPM being a form of AGT). The appropriate solution to downtown circulation and distribution needs and, specifically, whether a DPM system can totally or in part satisfy these needs depends on many factors. Thus, the planner must focus on downtown needs from the perspective of linking retail, residential, industrial, recreational, and public sector activities into one integrated operating unit. This is especially true of a DPM system, since the intent of this system is not only to alleviate existing transportation problems in the downtown, but also to strengthen downtown economic activity, to improve the social and urban/aesthetic environment, and, in the course of so doing, to generate new transportation demands in the downtown.

Prior to the planning of any specific services in the downtown area, the appropriate agencies must identify, as part of the existing long-range planning process, the goals, needs, and objectives for the downtown, addressing, in an integrated manner, both transportation and land use considerations. The development of a downtown policy plan should include participation from elected officials, city and regional planners, transportation planners and operators, business representatives, and citizen groups. It is through the interaction of these public officials and private interest groups that conflicting objectives can be debated and reconciled and an agreed-upon set of plans and projects can emerge. Additionally, it is through this process that relationships among groups evolve and participant interests are established. The technical and organizational base of a DPM proposal must of necessity grow out of these established working relationships which have evolved through previous planning efforts.

In developing a general approach for downtown development and revitalization, including initial consideration of the kind of transportation network that can best support and encourage these target plans, choices must be made on some difficult issues. Most downtowns will have evolved a series of master plans or policy documents by the time a DPM system is first considered. As a prerequisite to a DPM, such plans should include an official concensus on the following issues:

- General concept of the role of downtown, the type of activities and the share of regional growth it will try to capture and accommodate

- General attitudes on conservation, redevelopment, and intensity and type of proposed land uses

- Policies for the organization of downtown activities -- a choice between distinct activity centers vs. even distribution of activities throughout parts of the street network

- Transportation patterns, existing traffic and parking conditions, and public transit operations, policies, plans, and public resources earmarked for each

- Classification of downtown streets for their primary future role as traffic distributors, local access streets, transit ways, delivery or pedestrian streets, or particular combinations of these functions (the Downtown Street Classification Policy adopted by the Portland Oregon City Council in 1975 is a good example)

- Joint development programs with private developers including choice of management, financing, and taxing schemes

- Specific action areas for new and redevelopment projects, schedule, level of commitment, and projected activity mix for each

The preparation of such policy plans generally requires the cooperation of city planning and regional transportation agencies and of private business interests and is often a good vehicle for creating a core planning group that can later coordinate DPM planning.

4.1.2 Identification of Specific Transportation Options for the Downtown Area

The type of transportation alternatives most appropriate for the downtown should reflect consideration of a broad range of travel, economic, social, and urban design issues, in addition to the institutional and financial capabilities of the area to plan for, manage, and operate the selected alternative. Because the DPM projects are significantly different from the more traditional transportation projects in the objectives for which they are designed, the project planning and implementation must also proceed in a different manner. A description by planners for the St. Paul project illustrates the point:

"...within downtown St. Paul today there is no critical need for the proposed system in the traditional sense that transportation planners have come to define need. There are no major traffic jams such as might occur at a restricted bridge. Vehicle congestion in the downtown area of St. Paul is, by most standards, not serious. Parking is not immediately a problem. Mobility within the downtown is provided for by a combination of circulation by bus and pedestrian movement by sidewalk and weather controlled second level skyways, not to mention driving if one is willing to park and unpark. Use of the system is predicated by analysts on new patterns of either diverted trips, induced trips or substantial new development which will increase 'within downtown' travel. The development of the system will provide solutions to future, typical urban problems."

"Therefore, one must look at a combination of other needs or objectives in order to understand the reasons for proposing such a system. Paramount among these are the opportunities for impact on and inducement of further development in the downtown. This includes the intensification of traditional CBD roles in office employment, retailing, entertainment and cultural activities. It also includes the desire to induce new residential development and link that development to other activities in such a way that travel can be handled in a new and more convenient fashion."*

A DPM system is generally intended not only to meet existing transportation needs but also to generate new ones and to help to revitalize the downtown. While these objectives are explicitly endorsed by Federal urban policy as well as by the regional and local policies in many metropolitan areas, there is a lack of experience in the planning and implementation of projects which combine transportation and urban development. This presents difficulties at both the local and Federal level in planning for DPM programs and evaluating their potential.

In particular, comparing the expected benefits from a DPM system to those of conventional transportation systems is extremely difficult since the traditional transportation benefit measures are less applicable for DPM projects. Basically, the primary DPM benefits must be evaluated as synergistic results of the new facility and other related development efforts. Because the related development efforts are contingent on the DPM and many other factors (market, economic conditions, public acceptance, etc.), it is difficult to predict their probability of success and, in particular, the DPM's contribution to them.

It is, therefore, extremely important to identify any features from an area's past experiences and from its formal and informal decision-making structure that can be useful in planning

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*Alderson, Stephen R. and Barry L. Engen, People Mover Significance for Development in Downtown St. Paul, Paper presented at AIP annual conference, Kansas City, MO, October 1977.

for a DPM system. Section 4.4.1 describes a set of indicators that can be extracted from an area's past history and existing structure and activity patterns that can assist in identifying the appropriateness of a DPM to a particular downtown area.

4.2 ADAPTING THE LOCAL PLANNING PROCESS TO DPM PLANNING

The Urban Mass Transportation Administration has issued a policy which outlines its procedures and requirements for metropolitan areas seeking Federal funding for major urban mass transportation investments.* A major element of this policy is the requirement for localities to conduct an analysis of alternatives before qualifying for Federal capital funds.** In addition to these requirements, UMTA has issued downtown people mover implementation guidelines that are applicable to the first round DPM cities.*** These two documents are the primary sources of information for this section.

The objectives of this section are to assist local planning efforts by:

- Reviewing the requirements contained in the separate UMTA documents, with particular emphasis on the alternatives analysis process
- Relating the DPM specific guidelines to the guidelines for all fixed guideway facilities by suggesting a phasing of the planning process consistent with the UMTA requirements and appropriate to a DPM study
- Specifying key participants, products to be generated, and decisions required at each phase of the process
- Reviewing appropriate techniques for conducting an alternatives analysis at the various stages of the planning process
- Structuring a sample report outline that can be produced for each stage of the planning process

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*Federal Register, "Major Urban Transportation Investment," September 22, 1976.

**The first selected DPM cities were not required to conform to these guidelines since the DPM is considered to be a demonstration of an advanced technology and, as such, was excluded from these requirements. However, it is UMTA's intent that all future cities considering DPM projects will be required to comply with the formalized requirements on major urban mass transportation investments.

***"Downtown People Mover Project Implementation Guidelines," issued February 25, 1977, revised March 14, 1977.

requiring a submittal to UMTA, with regard to format and analysis methodology

4.2.1 Downtown People Mover Project Implementation Guidelines

In February 1977 (revised March 1977), UMTA issued project implementation guidelines for the DPM demonstration cities. These guidelines supplement the normal capital grant requirements contained in the UMTA External Operating Manual (EOM). The responsibilities of the local applicant and the Federal Government are included in this document.

The guidelines are divided into phases: Phase I is Preliminary Engineering and Phase II is Project Implementation. Presented in Appendix 4-A are the elements required in each phase and the roles and responsibilities of UMTA and the grantee during these two phases. Appendix 4-B specifies the required submittals to UMTA at the completion of each phase of the process. (A more detailed discussion of these requirements and the elements contained in Appendix 4-A are contained in the UMTA guidelines.)* An approach for integrating the current UMTA alternatives analysis requirements and the DPM Project Implementation Guidelines is presented in Section 4.2.4.

As illustrated in Appendix 4-A, the Phase I activities are designed to establish the preliminary engineering feasibility of the system and occurs prior to an UMTA award for system implementation. Many of the systems engineering studies conducted in Phase I are also applicable to Phase II, but the Phase I level of effort is at a lower level of detail.

The Phase II objectives are to complete the final engineering design, construct the system, and carry out the system integration activities and initial DPM operations. As observed in Appendix 4-A, a requirement for the first round DPM systems is that the selected system manufacturers be responsible for delivering a "turn-key" system to the grantee. The grantee, however, must specify the work tasks, and manage and review the system manufacturer's day-to-day activities. In that regulations for future DPM cities have not yet been issued, it is not known whether the turn key provision will be similarly required for future DPM cities.

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*It should be noted that these guidelines were designed specifically for the first round DPM cities and as such, do not necessarily conform to the UMTA alternatives analysis requirements from which the Demonstration Cities were exempted. However, the steps recommended for the DPM cities will likely benefit cities planning for DPMs in the future. Many of these guidelines should be integrated into the alternatives analysis process required of future applicants.

4.2.2 Major Urban Mass Transportation Investments

Current (FY82) administration policy (although stated formally in the Federal Register), encompasses no new fixed guideway starts or extensions funded with Section 3 monies, at least until the economy improves. However, some localities nonetheless are planning major investments with the expectation of using Interstate transfer monies, or that the policy will be altered in the future.

For these localities, the September 1976 Policy still applies, and future DPM projects will be required to adhere to this policy, which sets forth several principles.

- Long-Range Plan - The long-range plan is intended to establish the overall priorities and directions for transportation services in the major corridors and activity centers of the region. This element of the planning process was described in Section A as a component of the existing planning process to take place prior to specific identification of a DPM as an appropriate transportation alternative.

- Incremental Development - This element of the policy requires that all fixed guideway systems be planned and built in individually-operable segments according to highest need. The objectives are to direct limited financial resources to greatest need areas first, to maintain the flexibility to respond to changing technology, and to adapt to local plan modifications; and to achieve a balance between long- and short-range needs and regional versus local needs.

- Evaluation of Alternatives - An analysis of alternatives is required for each area in which a fixed guideway facility is proposed. The objective is to consider a variety of transportation alternatives that range from those utilizing existing facilities (transportation systems management options) to capital intensive fixed guideway projects. Combinations of alternatives should also be considered. The merits of each of the alternatives should then be assessed using a set of evaluation criteria that is locally developed but which addresses major UMTA concerns. Sample evaluation measures used by some of the cities which have recently undergone an alternatives analysis are contained in Appendix 4-C.

  Transit project planning, including the alternatives analysis process, is currently the subject of extensive study by the Federal government. Given its importance in the realm of Federal decision making, the alternatives analysis process is discussed further after this summary of the UMTA policy statement on "Major Urban Mass Transportation Investments."

- Transportation Systems Management (TSM) - TSM measures are designed to take maximum advantage of low cost transportation options which utilize existing facilities. The intent is to consider TSM actions as supplementary and complementary actions to a fixed guideway facility with particular TSM emphasis on areas within the study corridor that would not be served by a fixed guideway facility. Several TSM measures may be considered in conjunction with a DPM system such as fringe area parking, parking substitution, etc. Section 9 of this manual describes some TSM parking measures with specific reference to the proposals advanced by Los Angeles in their DPM application to UMTA.

- Public Involvement - This section requires that there be full opportunity for timely involvement of the public, local elected officials, and all levels of government in the alternatives analysis process. Formal public meetings are also required in compliance with the environmental impact statement (EIS) process (the relationships between the alternatives analysis process and the EIS will be discussed in the section on alternatives analysis.) Section 4.4.4 discusses specific techniques that can be used to constructively involve the public in the planning process.

4.2.3 Elaboration on the Alternatives Analysis Process*

Alternatives analysis (AA) occurs after an area has developed its long range plan and demonstrated in system planning that detailed consideration of major investments is warranted, and before it can receive UMTA approval to proceed with preliminary engineering on a particular project. The alternatives analysis process is still evolving, and extensive work is underway by UMTA to define more precisely general guidelines for alternatives analysis.

4.2.3.1 System Planning

System planning (originally referred to as "Phase I" alternatives analysis) precedes detailed DPM consideration in that it focusses on the region as a whole and identifies those corridors which may be candidates for major capital investment within the next 15 years (in accordance with the area's long-range plan). Consideration should be given to the types of

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*Some of the issues referred to in this discussion were identified in the sessions and papers issued at the Airlie House Conference, "Seminar on Technical Aspects of Alternatives Analysis." For a more detailed discussion of alternatives analysis, refer to the Overview Paper distributed at this conference.

actions appropriate for the downtown with a cursory appraisal of a DPM option. In this phase, local funding availability and probable state and Federal funding sources should be assessed to determine the extent and magnitude of investments that may be in order.

Sketch planning techniques such as those presented in this document are appropriate for providing a quick, inexpensive yet reliable method for analyzing a large set of broadly defined alternatives and combinations of alternatives in this phase. Baseline alternatives which describe the existing transportation system should be compared against broadly defined future-oriented alternatives, one of which may be a DPM system. The base line alternative makes it possible to assess future conditions. Examples of baseline alternatives include a base year alternative, a null (or "do nothing") alternative, or a TSM alternative. The product of the sketch planning analysis will be an identification of which corridors qualify for further detailed study and which alternatives in each corridor should be subject to a more detailed review. The downtown area should also be considered as a potential site for alternative improvement actions, including possibly a DPM system.

At the completion of system planning, the applicant submits the material produced to UMTA. UMTA reviews this material and, on the basis of this review, decides whether the applicant should proceed with alternatives analysis. The applicant is notified of the decision by UMTA.

4.2.3.2 Alternatives Analysis

The alternatives analysis should proceed concurrently with the preparation of a Draft Environmental Impact Statement (DEIS). The reason for pursuing this as a joint activity is to avoid unnecessary duplication of effort in analyzing issues which are common to both the final phase of the AA and the DEIS. This phase should result in a local decision on an alternative or combination of alternatives, based on the cost effectiveness and environmental impacts analysis produced during this phase for each of the alternatives. Table 4-1 illustrates a prototypical table of contents for the Phase II AA/DEIS.

The Phase II AA and DEIS is prepared jointly by the applicant and a UMTA Review Team. UMTA assistance is provided in accordance with the requirements of the National Environmental Policy Act, which specifies that an EIS be prepared by a "responsible Federal official." Local and Federal responsibilities in this process are detailed in joint FHWA and UMTA environmental regulations, "Environmental Impact and Related Procedures," published in the Federal Register, October 30, 1980.

At the completion of the alternatives analysis, the applicant submits the AA/DEIS to UMTA. After internal review by UMTA, the applicant is notified by letter of the DOT final

TABLE 4-1

ILLUSTRATIVE TABLE OF CONTENTS FOR AN AA/EIS DOCUMENT

I. Summary

Need for Action
Alternatives
Significant Impacts Matrix
Detailed Impacts Matrix

II. Need for Action

Regional Goals and Needs
Description of Existing Transportation System
Description of Existing Environment
Land Use/Population/Employment Forecasts
Citizen Involvement Process

III. Description of Alternatives

Planning History Leading Up to Phase II Analysis
Long Range Plan
Phase I Analysis

Description of Each Alternative By:

Corridor Location
Length of Increment
Technology/Operating Characteristics
Alignment
Grade Separation
Station Location
Capital & Operating Costs
Patronage
Financial Feasibility

IV. Impacts of Each Alternative

Physical
Social
Economic
Transportation

V. Evaluation of Alternatives

Significant Impacts Matrix
Detailed Impacts Matrix

VI. Identification of 4(f) & 106 Issues

VII. Technical Appendices (as needed)

Forecasting Models
Evaluation Methodology

[1] Source: "A More Detailed Discussion of the Alternatives Analysis Process," UMTA, Airlie House Seminar, November 8-10, 1977.

decision. DOT approval would allow the applicant to begin preliminary engineering (PE) on the selected alternative. Table 4-2 summarizes the local and Federal responsibilities for activities which occur in system planning and alternatives analysis.

4.2.4 Devising a DPM Planning Process Consistent with UMTA Guidelines and Requirements

There are three broad phases of the planning process which a locality would go through in the course of planning for a DPM system. These phases specify how and at what point in the process a DPM option evolves and is carried through the subsequent planning stages. These three phases are:

I. Pre-DPM consideration
II. DPM as an alternative
III. DPM as the selected alternative

The emphasis in this section is on Phases II and III since it is during Phase II that a DPM system emerges in the planning and decision making process in more concrete form. Phase I, or Pre-DPM consideration, was discussed previously as a component of the area's long-range planning process, at which point the area's needs and priorities for specific corridors and the downtown area are identified.

Table 4-3 presents a recommended approach for planning and phasing the DPM project in accordance with the three phases specified above. The specific activities, appropriate participants, products to be generated, and required decisions and actions for each phase of the process are shown in this Table.

One of the important features of Table 4-3 is the integration of the alternatives analysis requirements and selected elements from the DPM Project Implementation Guidelines into a format which is appropriate to DPM planning. The objectives in the Pre-DPM Phase (I) are to develop and adapt a long range plan for the regional area with specific consideration of a downtown development plan. At this point it is necessary to look at the interrelationships between downtown needs and regional corridor needs to assess where the priority needs occur and to balance planned activities between the downtown and the regional corridors within the available funding limitations as best as possible. Upon completion of the long range plan, the local area may enter into the Phase I alternatives analysis study after receiving approval from UMTA to enter into this phase of the work, if Federal funding is desired. The intent here is to analyze specific corridors in the area, all of which may include the downtown core, at a sketch planning level of detail in order to identify priority corridors and specific alternatives within these corridors for more detailed study.

TABLE 4-2

ALTERNATIVES ANALYSIS REVIEW PROCEDURES AND PARTICIPANT RESPONSIBILITIES

Action	Participant Involved
1. System planning; Request for AA funding	Applicant
2. Review of system planning documentation; Decision on alternatives analysis	UMTA
3. Notification to applicant on AA	UMTA
4a. Preparation of AA and DEIS	Applicant
b. Guidance on development of AA/DEIS	Federal DOT Joint Review Team
5. Submittal of AA/DEIS	Applicant
6a. Review of AA/DEIS	Joint Review Team
b. Decision on AA/DEIS	UMTA and DOT Executive Staff
7. Notification to applicant on Preliminary Engineering	UMTA
8. Conduct Preliminary Engineering Studies and prepare final EIS (FEIS)	Same procedures as outlined in steps 4-7, applied to preliminary engineering.

SOURCE: UMTA Internal Memo

TABLE 4-3

STRUCTURE AND STAGING OF THE DPM PLANNING PROCESS

PHASE	PHASE COMPONENT	PARTICIPANTS	PRODUCTS	DECISIONS AND ACTIONS
I: Pre DPM	**Long Range Development** • Needs Identification • Specification of objectives	Regional Planning Agency Local public agencies Transit operators Public Interest Groups Organized Downtown Interests	• Areawide needs; identification and statement of objectives • Identification of corridors and activity centers needing further actions • Downtown Development Plan	• Form a Regional Task Force or Inter-agency coordinating committee to develop a grant application to UMTA for planning funds to conduct an alternatives analysis study. • UMTA decision on Phase I Alternatives Analysis
I: Pre DPM	**Phase I Alternatives Analysis (upon receipt of UMTA approval)** • Develop an evaluation methodology to be used in the Phase II AA • Develop a citizens participation process	Task Force Technical Consultants Public Constituency	• Identification of corridors which may warrant a fixed guideway system within the next 15 years. • Prioritization of corridors for further detailed study • Documentation of which alternatives within the priority corridors should be subject to further analysis • Specification of a program for citizens involvement • Specification of an evaluation methodology which includes goals and objectives, evaluation criteria and evaluation measures for conducting the analysis	• Consensus of Task Force and public officials on target corridors and specific alternatives • Commit local resources to Phase II Alternatives Analysis • Submit Phase I Alternatives Analysis reports to UMTA • UMTA decision on Phase II Alternatives Analysis

TABLE 4-3 (continued-2)

STRUCTURE AND STAGING OF THE DPM PLANNING PROCESS

PHASE	PHASE COMPONENT	PARTICIPANTS	PRODUCTS	DECISIONS AND ACTIONS
I: Pre DPM (cont.)			• Assessment of available state and Federal funding sources • Assessment of local sources of matching funds	
II: DPM as an alternative	Phase II Alternatives Analysis • Draft Environmental Impact Statement on broad corridor alternatives	Task Force Technical Consultants UMTA Joint Federal Review Team Public Interest Groups Private Business and Developer Groups	• Design and operational description of each alternative • Specification of the physical, social, economic and transportation impacts of each alternative • Cost effectiveness comparison of each alternative • Draft EIS • Public comments on Phase II AA and DEIS • Refined assessment of available Federal, State and local funding sources	• Consensus by locally elected officials on preferred alternative or combination of alternatives • Commit local resources to preliminary engineering • Submit Phase II Alternatives Analysis/Draft Environmental Impact Statement to UMTA • UMTA Decision on Preliminary Engineering

TABLE 4-3 (continued-3)

STRUCTURE AND STAGING OF THE DPM PLANNING PROCESS

PHASE	PHASE COMPONENT	PARTICIPANTS	PRODUCTS	DECISIONS AND ACTIONS
III:DPM As the selected alternative or element of the selected combination of alternatives	Preliminary Engineering • Draft Environmental Impact Statement on DPM Alternative	Task Force Technical Consultants Downtown Community Groups Chamber of Commerce Other Business Associations Legal Consultant or in-house Legal Expert Transit Labor Unions UMTA	• Specification of design and operational plans for the DPM system (refined from the Phase II AA DPM alternative) • DPM Implementation Plan (integration with downtown and regional transportation network and with downtown development plans) • Draft environmental impact statement • Procurement bid package • Impact evaluation plan • ROW acquisition; compensation to business • Elderly and handicapped accomodation plan • Plan for public and private joint development activities • Preliminary cost monitoring plan • 13 C Labor Agreement	• Private sector commitment to joint development projects with the public sector • Revise downtown plans • Consensus by locally elected officials to final DPM system design • Commit local resources to final engineering • Submit preliminary engineering results to UMTA • UMTA decision on system design and final engineering • Select final engineering consultant

TABLE 4-3 (continued-4)

STRUCTURE AND STAGING OF THE DPM PLANNING PROCESS

PHASE	PHASE COMPONENT	PARTICIPANTS	PRODUCTS	DECISIONS AND ACTIONS
III: DPM As the selected alternative or element of the selected combination of alternatives	System Design/Final Engineering	Task Force Technical Consultants Downtown Community Groups Chamber of Commerce Other Business Associations UMTA	• Cost Monitoring Plan • Management Plan • Design Review Results • Construction Schedule • Operational Safety Plan • Product Assurance Plan • Systems Operating Plan • Security Plan • Support and Maintenance Plan	• Commitment of local matching share to DPM construction and operations from the public and private sector • Commitment of capital grant funds by UMTA • Selection of system contractors and manufacturers • Commitment by private sector to specific joint development plans
III: DPM As the selected alternative or element of the combination of alternatives	DPM Implementation • Construction • Post construction adjustments	Task Force Technical Consultants Downtown Community Groups Chamber of Commerce Other Business Associations Downtown Management Entity for DPM (if appropriate) UMTA	• Monthly Program Status and Progress Reports • Acceptance testing • Ongoing maintenance management and support • Impact evaluation • System promotion	• Initiate changes in structure or operations as required by program status and progress reports • Carry out complementary CBD Development Projects

When the Phase I AA is completed and approval from UMTA is granted to proceed with Phase II AA, the planning phase which formally considers DPM as an alternative begins (i.e., Phase II). The Phase II AA includes the preparation of a DEIS on the corridor alternatives, provides a more in-depth assessment than the Phase I AA of the specific design and operational features of the alternatives being studied, and identifies the level and kinds of impacts which may be associated with each of the alternatives. Taking all of these factors into consideration, a preliminary cost effectiveness analysis comparison of the alternatives is prepared which must then be integrated with the assessment of available funding to carry out the preferred option(s).

The Phase II activities lead into Phase III of the DPM planning process. At this point, the DPM has been selected as a favored alternative or element of a combination of alternatives. Preliminary engineering (PE), the first element of the Phase III tasks, requires approval from UMTA to begin. PE activities focus spcifically on the selected alternative which was identified as a result of the Phase II AA of the corridor alternatives. During this time, the design and operational plan for a DPM system are specified, as is a DPM implementation plan. A DEIS is produced for the DPM or for the combination of alternative components, if that is the selected option. This DEIS differs from the one produced as an element of the Phase II AA, in that it is a very specific treatment of the selected DPM alternative, rather than an assessment of several corridor alternatives. Planning for joint development opportunities between the public and private sector, an important central component of DPM planning, should occur during PE, and can profitably be begun in earlier phases. Other activities to occur during PE include the developing of an elderly and handicapped accommodation system plan, addressing labor issues, acquiring right-of-way, and providing compensation to adversely affected entities where this is required.

The system design and final engineering component of Phase III planning finalizes the plans and activities developed during PE and develops specific schedules for system construction, management, cost monitoring, operations, security, etc.

Finally, during DPM implementation, which is the last element of Phase III planning, system construction takes place, initial impacts are monitored, and last minute changes that appear to be necessary are carried out. Activities subsequent to construction as initial system operations take place are not discussed within the planning process section.

It should be noted that, for each of the phases discussed above, a series of staged approvals by appropriate local public and private officials is required. The concept of obtaining incremental commitments to specific phases of the project by locally elected officials and the private sector appears to be an effective way of proceeding, since it allows these officials to "keep their options open" relative to final project construction, rather than requiring them to commit themselves prior to understanding all of the details and implications of the project.

A major relationship exists between the success of the DPM planning process which has been the subject of this section, and the institutional structure established to carry out the DPM project planning and implementation. Suggested institutional arrangements for conducting these activities are discussed in the following section.

4.3 INSTITUTIONAL ARRANGEMENTS FOR PLANNING DPM SYSTEMS

4.3.1 Approach

This section presents alternative local institutional structures, termed institutional models, which appear to have the greatest potential for successfully managing and conducting the DPM planning process. Experiences of the DPM demonstration cities, in combination with a consideration of institutional arrangements used in other downtown transportation and development projects, serve as the basis for this discussion. Because the current DPM projects were initiated in response to UMTA invitation rather than as an outgrowth of the traditional transportation planning process, any experiences of the demonstration cities which are not applicable to future DPM cities will be noted.

When formulating institutional models that are appropriate for planning a DPM system, it is necessary to remember that the objectives of a DPM system differ from those of traditional transportation projects. As such they require a reconsideration of the existing arrangements for transportation planning at the local level. In some metropolitan areas, the responsibilities and expertise of the agencies currently involved in transportation planning and decision making may be sufficiently broad so that they can continue this same role as the sole planning agencies in DPM planning. However, it is more likely that agencies outside of the traditional transportation arena can contribute positively to the DPM effort.

Prior to discussing some of the insitutional models that may be successful for managing DPM planning responsibilities, a point of qualification should be noted:

- Local areas have the best understanding of what does and does not work in their own situation and, as such, are most often the best judges of the feasibility of any specific institutional arrangement. To accommodate the important element of local discretion in the institutional design process, a model framework incorporating the key factors instrumental for DPM planning is presented. In this way, guidance for local areas on recommended institutional approaches is provided without losing the flexibility for localities to fit their individual needs and arrangements into these model frameworks.

4.3.2 Background Factors Important in Structuring DPM Institutional Arrangements

Two sets of background factors are important components of the DPM institutional design process. The first set represents some observations about DPM planning and its participants which have implications for designing institutional arrangements. While many background factors are important, only those that are especially relevant to DPM planning are noted below:

- A DPM system is likely to be more attractive to downtown business interests and private developers than are more conventional transit projects. As such, the role and opinions of the private sector in planning a DPM system is a very important component of the planning process and should be recognized as such in forming a planning team.

- In many cases, the initial proposal for a DPM system comes from a relatively small group of planners and administrative officials within the city government (supported by a group of downtown business interests),. In most cities such groups already exist and have collaborated in downtown plans and development projects on previous occasions. It may be anticipated that the core group of individuals promoting the DPM project are likely to be strong project advocates rather than impartial evaluators. (While this may not be undesirable, it should be taken into account when assigning responsibilities to the various participants.)

- Because of the experimental nature of DPM systems, the potentially major impacts, and the substantial local costs (particularly those related to on-going operations) it is difficult for the local proponents of DPM projects to generate broad local support in the early stages of planning. Without such support, it is difficult to get sufficient local funding to carry the project as far as the preliminary engineering phase, where the major UMTA funding for the technical work becomes available.

Another set of background factors to consider is not DPM specific. Rather, these factors focus on ways to improve the quality and effectiveness of institutional arrangements in general. While this subject will not be discussed in detail here, three main points which are particularly instructive for DPM planning are cited below:

- The channels of existing working relationships, both among individuals and public and private agencies, which have developed over past projects and plans should be carried forward into any new institutional arrangements.

- The lead planning agency should have direct access to elected decision makers and should be able to gain the attention, respect and trust of these officials.

- Institutional arrangements will be more effective if the agencies with actual political authority also have legal responsibility.*

4.3.3 Initial Steps in Forming DPM Institutional Arrangements

A key aspect in structuring institutions to effectively carry out a set of goals is to anticipate potential problem areas and to preliminarily test and establish the groundwork for institutional arrangements in advance of their formal existence. Some specific recommendations are noted below:

4.3.3.1 Identify and contact the public and private agencies who are potential contributors to the DPM project funding - This will provide insights into how the institutional arrangements should be structured and the potential sources and magnitudes of funds which can be expected.

4.3.3.2 Anticipate in informal testing, future institutional arrangements for joint responsibility of DPM activities among transportation and other agencies - This requires resolution of legal and administrative arrangements and the contribution of planning funds from each agency. Compatible personalities and working relationships at the policy-making and key staff levels are critical for success.

4.3.3.3 Anticipate the expertise and staff needed to carry out the DPM activities, and decide which tasks can be handled in-house and which require outside assistance - On the basis of this, reevaluate whether other agencies should be brought into the process (e.g., Los Angeles suggested that legal assistance was critical to effectively negotiating arrangements with the private sector and in preparing EIS documents). Determine if funding is available for the necessary outside assistance.

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*Operating Multi-Modal Urban Transportation Systems; System Design Concepts, Inc., December 1977.

4.3.3.4 Anticipate joint development arrangements with private developers - Identify specific value capture schemes and benefit assessment techniques including tax increment financing or special tax districts. Section D.2 explores joint development techniques in greater depth. Identify those joint development mechanisms which can be pursued within existing legislation and institutional frameworks, and those schemes that would require new legal and/or institutional authorities.

4.3.3.5 Set up downtown authorities to carry out functions supplementary to DPM activities - Downtown authorities may be needed to control parking rates and manage fringe parking, to administer a taxing district, or to provide maintenance, management activity programming, and promotion for newly created pedestrian areas. The important features of such authorities are that they be responsive to all downtown interests, that they can coordinate and expedite various governmental responsibilities in the DPM area, that they can identify needs and match resources to those needs, and that they can facilitate the required actions on a timely basis.

4.3.3.6 Insure that channels exist for broad community information and participation - As policies and programs develop from general consensus to specific projects and actions, broader public information and participation programs must keep pace with this evolution. The level of public interests in downtown projects varies widely among cities. Interest is usually low in general planning issues and can rise rapidly when actions with specific impacts become eminent. Such changes should be anticipated and public consensus reaffirmed at each stage of the process. A constant flow of information should be supplied through the press. Public awarness of projects, and attitudes toward them, should be tested by surveys, interviews and polls. (Specific mechanisms for setting up channels of communication with the public are discussed in Section 4.4.4.) When citizens and other interest groups are formally included in the DPM planning process, it is important to clearly spell out the roles and powers of these groups to avoid misundertstandings later on.

4.3.4 Model Institutional Arrangements and Participant Roles

The institutional framework presented in this section is a composite model which incorporates features observed in a number of DPM demonstration cities. While it is relatively unusual for all local agencies to agree that a particular institutional structure is the best possible one, and the DPM demonstration cities are no exception,* it appeared to the study team from personal observation and interview results in the DPM cities, and from previous experiences in proposing and analyzing institutional arrangements, that the proposed model is a very functional one. The public and private agencies and organizations included in this model, and the channels of communication and lines of authority established among the participants, insures that the proper mechanisms exist for carrying out and managing the planning and decision-making tasks.

Although the basic framework incorporates the important component features of a functional model, its actual effectiveness depends in large part on the ability for each local area to incorporate their specific needs and arrangements into the framework proposed. Examples of specific arrangements for accomplishing this within the basic institutional model are discussed.

4.3.4.1 The Basic Model Framework

The model represented in Figure 4-1 shows the basic design of the DPM model proposed. It illustrates the various committees which should be included in the institutional plan and the agencies and departments which should comprise these committees. As shown in the model, two alternatives for lead agency responsibility are presented. The first alternative (A) assigns primary responsiblity to a single agency which is responsible for making the final decision on the DPM financing and management at the local level. The second alternative (B) consists of a joint venture of shared responsibilities between either two public agencies or a public agency in combination with a private downtown business and development coalition.

An explanation of the model relative to the functions of each of the committees represented in this model, the reasons for including the specified committeee participants, and the channels of communication and coordination which appear to have the greatest potential for effectively conducting the DPM planning process are discussed in greater detail below based on the individual model components portrayed in Figure 4-1.

Technical Activities - The technical planning activites of the various DPM tasks are carried out jointly by a technical team of agency staff and private consultants, as portrayed in the bottom line of Figure 4-1. The work tasks to be addressed by the technicians and the level of detail at which they are addressed will vary according to the stage of the DPM planning underway (refer to Table 4-3 for a specification of the work tasks

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*An Agency's appraisal of the effectiveness and appropriateness of the institutional arrangements often reflects heavily on the level of involvement that the particular agency has in the process.

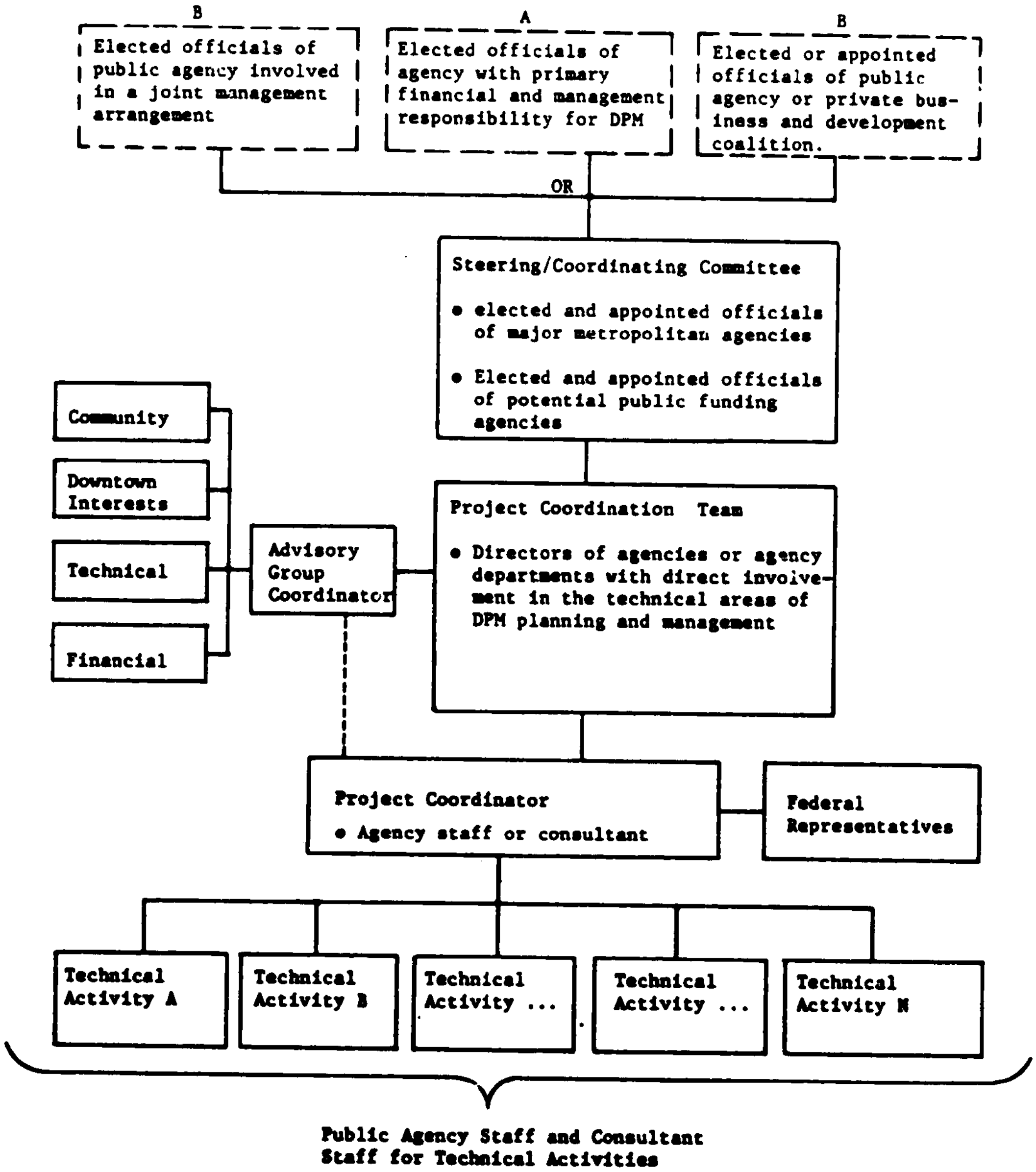

FIGURE 4-1

MODEL FRAMEWORK FOR DPM PLANNING INSTITUTIONAL ARRANGEMENTS

appropriate to each of the stages of the planning process). The appropriate mix of agency staff and outside consultants depends upon the agency staff capabilities, time availability, and financial resources available for DPM activities. The staff from several agencies should be included in the technical team planning the DPM project. A list of suggested public agencies and their respective roles is given below:

- City Planning Department - Integrate the DPM project into center city plans and land use plans, to insure that the DPM project is compatible with the adopted city plans. Provide data on downtown land uses (residences, businesses, etc.), analyze environmental impacts, and organize a public involvement process for the DPM.

- City Engineering (Public Works) Department - Provide input into the DPM design and operational plans, analyze DPM construction feasibility and comptability for given street dimensions; study right-of-way opportunities and problems.

- City Traffic/Transportation/Parking Department - Provide data on traffic conditions and capacities for selected streets in the downtown, analyze the traffic impacts of the DPM both during construction and after operations begin, consider the impacts resulting from closing certain streets to automobile traffic, analyze the downtown parking situation and look at alternative parking management strategies that can complement DPM operations.

- City Economic Development Department/Redevelopment Agency - Provide information on current and projected business and development cities in the downtown, analyze the impact of the DPM on these activities and discuss ways in which the DPM can positively contribute to downtown development and revitalization, contract existing and potential employers and developers to discuss joint development opportunities and the develop specific arrangements, analyze the need to relocate or compensate businesses and residents.

- City-Regional Transit Operator(s) - Design plans for bus/auto intercepts at DPM stations at the periphery of the CBD, analyze the current and future role of bus circulation and distribution in the CBD and the kind of bus service modifications that would be necessary to accommodate the DPM. Analyze both regional and local impact on bus ridership and the optimal interface between the public surface transportation network and the DPM.

Project Coordination - Because several agencies are likely to be involved in the technical analysis, a Project Coordinator should be designated to provide direction in coordinating and monitoring the activities of these separate agencies. One of the more successful mechanisms for accomplishing this coordination is to provide an environment in which selected staff from the separate agencies work together on a day-to-day basis at a common headquarters during the course of the project. This can occur by establishing temporary project offices or by allocating space within the lead agency offices for the temporary assignment of the project coordinator and the technical staff. These arrangements will facilitate communication among the staff, provide easier access to the staff for the Project Coordinator (and vice versa), and encourage interaction among the staff assigned to the seprate work task areas. In Los Angeles, the Community Redevelopment Agency (CRA), the lead agency for that city's DPM project, has taken the approach of providing space within their agency for the temporary assignment of staff from other agencies and for private consultants. Representatives from the City Planning Department, Engineering Department, Traffic Department, and the Southern California Rapid Transit District (the regional transit operator for the area) work together in the CRA offices. Figure 4-2 portrays the organizational arrangements of the CRA transportation department for the DPM project.

The Project Coordinator, in addition to being directly responsible for the technical staff, has two other important functions:

- The Project Coordinator must be directly informed of the Federal rquirements pertaining to the DPM planning process and capital grant procedures. This person must maintain regular contact with the UMTA staff members monitoring the local DPM activities in order to explain the local activities to the UMTA representatives and to feed information and suggestions from the UMTA staff back into the local activities. The Project Coordinator would also be responsible for informing local officials of up-to-date Federal policies and requirements. This two-way channel of communication sensitizes Federal officials to major local issues, and enables the local area to be closely in touch with Federal requirements.

- The Project Coordinator must work in close cooperation with the designated Advisory Group Coordinator so that a mutual exchange of information can occur. The work performed by the agency technicians can inform the directions of the various advisory groups and the concerns expressed by the advisory groups can be addressed by the technicians. The public's perception of a project is often very different from that of the technical staff. Consequently, the concerns identified by advisory groups may often be inadvertantly ignored by the technical staff. Since the ability to deal with the issues identified by public groups will have a direct bearing on the DPM implementation prospects, it

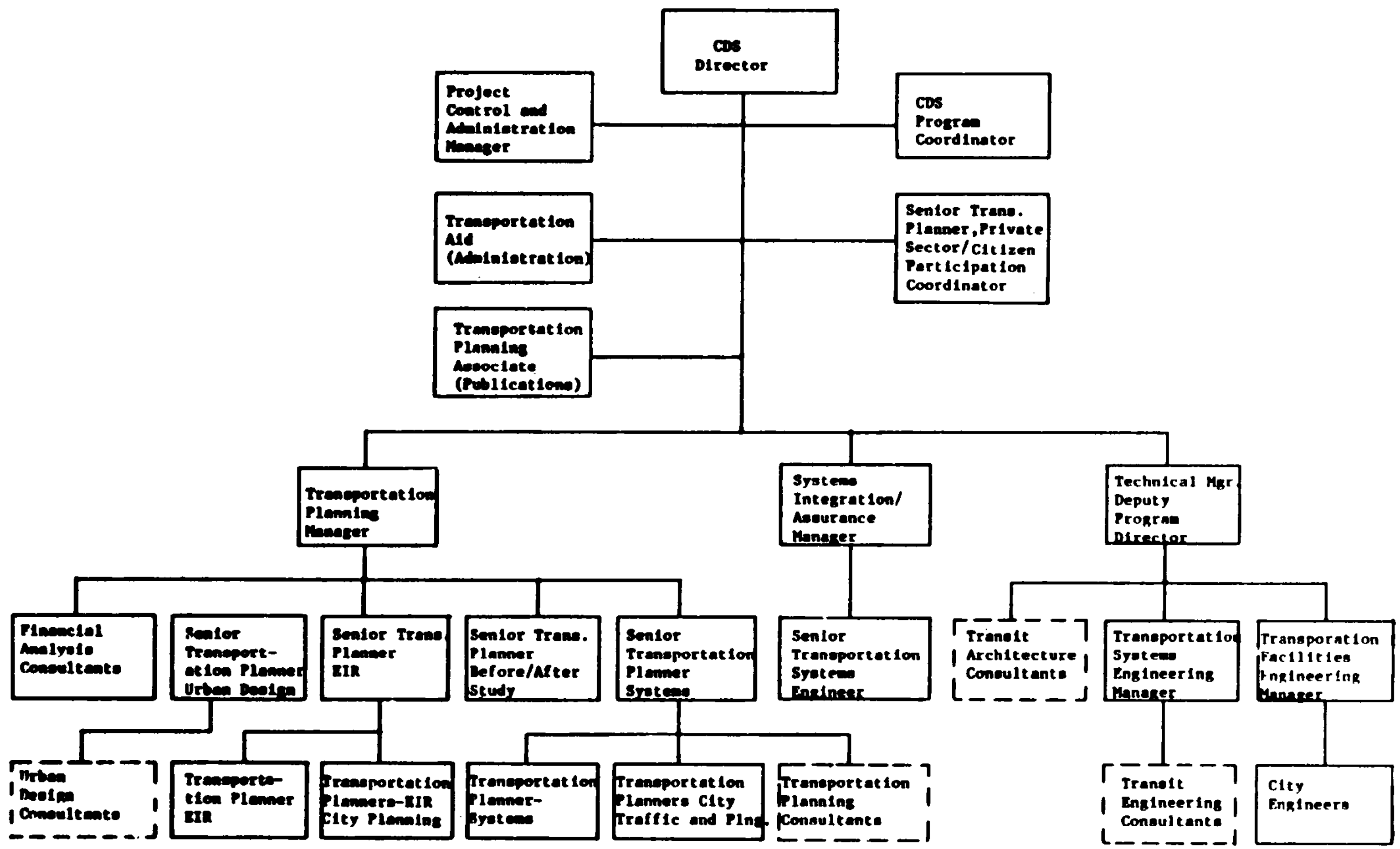

FIGURE 4-2

ORGANIZATION CHART OF THE COMMUNITY REDEVELOPMENT AGENCY TRANSPORTATION DEPARTMENT FOR THE LOS ANGELES DOWNTOWN PEOPLE MOVER PROJECT

is critical that these "outside" concerns are directly incorporated into the planning process. Likewise, an explanation by the technical staff as to why certain concerns may or may not be well founded can reduce the elements of conflict which typically occur between technical staff and public advisory groups. Monthly meetings should be held between the Project Coordinator and advisory group representatives to discuss emerging issues of concern. A progress report should also be presented. In the St. Paul arrangement, the advisory group coordinator and the Project Coordinator each report directly to the Project Coordination Team. While this is essential for centralizing work efforts, informal working relationships between the respective coordinators outside of the forum of the project coordination team should also occur on a regular basis. The management organization for the DPM project in St. Paul is shown in Figure 4-3.

The Role of Advisory Groups - Advisory groups provide an important outside perspective on the DPM activities. Suggestions and opinions expressed by these groups are important to the DPM planning process because the DPM system has the potential to heavily influence private land development and economic development activities, in which the private sector are the lead actors and can provide needed project funding. Also, because the DPM technology is still virtually untested in major urban environments, community groups may have significant reservations about it. Surfacing issues relative to the deployment of this technology can be an important contribution from these groups. In St. Paul, four advisory groups were established within the management structure for the DPM project: a Community Advisory Committee consisted of citizens from throughout the city who were recommended by neighborhood groups and chosen by the Mayor; a Technical Task Force composed of regional public and private tehchnicians chosen by both the Metropolitan Transit Commission, (the regional transit operator) and the Metropolitan Council (the regional planning body); Urban Development Committee which consisted of business interests and existing and potental developers chosen by representatives of twenty organizations and appointed by the Mayor. These three advisory groups were initially set up in St. Paul; later it became apparent that a Final Advisory Committee should also be constituted. This committee was then formed to represent downtown finance, business and labor interests (a group whose support is critical for DPM development).

In Los Angeles, a Community Advisory Panel (CAP) was formed during the initial planning stage of the DPM project. This group consisted of citizens invited to participate by the Mayor. They met on a bi-weekly basis "to discuss, debate and resolve citizen positions on downtown problems in relation to proposed

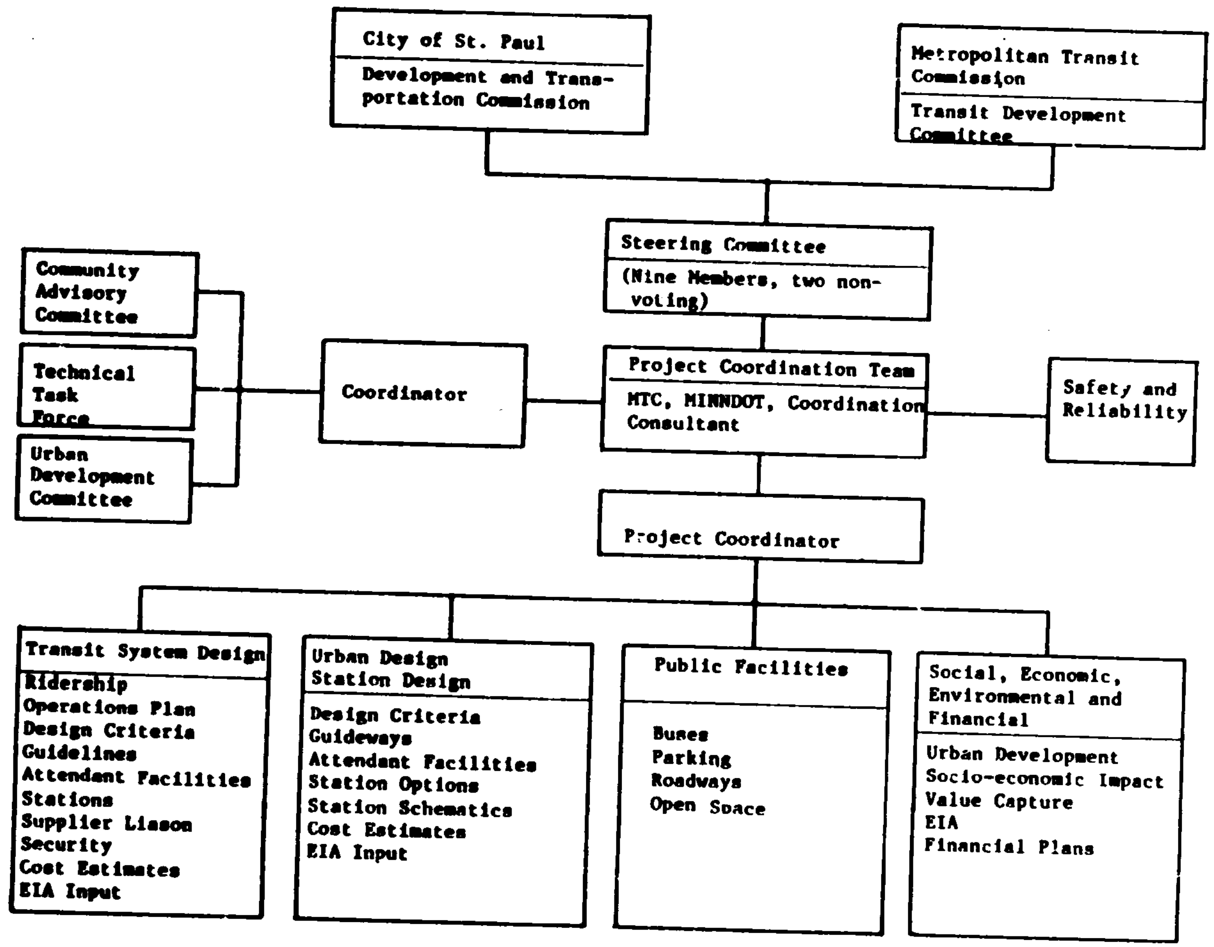

FIGURE 4-3

MANAGEMENT ORGANIZATION FOR THE ST. PAUL DPM transportation systems".* This group was greatly assisted by the Community Redevelopment Agency of the City of Los Angeles (the lead agency in the Los Angeles DPM Program) which provides the CAP with information, a forum for discussion, and access to the DPM decision-making body.

The Advisory Group Coordinator and the Project Coordinator are directly accountable to the Project Coordination Team, which is comprised of directors of agencies or agency departments that are directly involved in the technical areas of DPM planning and management. The agencies to be included here correspond with those which are represented on the technical planning team discussed previously. The function of this team is to direct and monitor the activities of the Project Coordinator and the Advisory Group Coordinator, and, in particular, to insure that both groups are working in consonance. The Project Coordination Team is responsible for ensuring that the technical analysis addresses those issues which are of importance to higher level decision-makers and that its products are presented in a form which can be readily understood by those decision-makers.

The Role of the Steering Committee - The Steering Committee is comprised of elected and appointed decision-makers from major policy making agencies of the city, region, and state. The officials represented on this committee are responsible for setting general policy in contrast to the more technical group of transportation and planning agency directors which comprise the Project Coordination Team. The Steering Committee's function is to provide overall direction to the DPM project -- from its evolution through implementation. This group, because of its diverse perspectives and constituencies, can provide a broad overview of important issues and potential problem areas. This group is also the forum in which the higher level policy issues relative to the DPM project can be debated and conflicts resolved. The St. Paul DPM organization structure includes a steering committee of nine members. Two of the nine members are state legislators who sit on the committee as non-voting members. The following paragraphs describe the composition and objectives of the Steering Committee of the St. Paul DPM project:**

> A key feature of the overall program organization is the Steering Committee which will provide overall direction of the project assisted by appropriate staff. The Steering Committee is designed to provide an interagency forum of top policy makers. It is likely that this forum will be a major point of conflict resolution and coordination for decision-making. The Steering Committee has nine members:
>
> (1) Chairman - President of the St. Paul Council

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*Report of the Citizens Advisory Panel; July 1976.
**People Mover Significance for Development in Downtown St. Paul; Alderson, Stephen R. and Barry L. Engen - Paper presented at AIP Annual Conference, Kansas City, Mo., October 1977.

(2) Mayor of the City of St. Paul
(3) Commissioner of the Minnesota Department of Transportation
(4) Chairman of the Metropolitan Transit Commission
(5) Vice Chairman of the Metropolitan Transit Commission
(6) Chairman of the Metropolitan Council
(7) Chairman of the Transportation Advisory Board
(8) A state senator (non-voting)
(9) A state representative (non-voting)

The Steering Committee is not just a blue ribbon panel for show but is a working group already heavily involved in basic policy. The deliberations and reactions of this group are intended to foster the best possible interagency communication and will heavily influence the direction of the project studies.

Depending upon the local situation, another committee may be appropriate, comprised solely of the elected officials from one agency or a joint partnership of two agencies which will assume primary financial and management responsibility for the DPM project at the local level. This is the body responsible for making the final determination and commitments on the DPM project. The actions of this body should be sensitive to the decisions generated in the Steering Committee, especially if potential funding agencies are on the Steering Committee but are not part of the single-agency decision-making body.

4.3.4.2 More Explicit Model Representations

Within the basic framework presented above, more explicit models targeted to individual goal needs must be devised. Two approaches are suggested in this section, with two recommended variations for each of the approaches presented.

Single Lead Agency - Primary responsibility can be assigned to a single agency if that agency has the diversified capabilities to address the transportation, land use, development, and economic objectives associated with the DPM project(s). This suggests that multipurpose,, as opposed to single purpose agencies are best suited to serve in this capacity. This multipurpose agency must be directly accountable to or governed by a body of elected officials which has the financing capabilities to make commitments on the DPM project. A city general-purpose government, or, as in the case of Los Angeles, a redevelopment agency (which is an agency of the city), are appropriate bodies to assume primary leadership on the project. In contrast, an agency such as a metropolitan planning agency which is without statutory authority, without independent financing capabilities, and does not have its own group of elected officials, does not possess the needed authority or accountability to initiate and carry out actions which are critical to the DPM project. In addition, an agency with regional responsibilities may not be able to justify intensified concentration on a localized project, even though the overall impacts can have regional implications.

Joint Responsibility - Responsibility for the DPM project may be shared among a small number of agencies in order to combine the expertise of the several agencies (to prevent fragmentation, however, joint partnership among more than three agencies is not recommended). In the St. Paul situation, the City of St. Paul and the Metropolitan Transit Commission (MTC) both direct the DPM project. MTC has bonding authority and, as such, is able to provide a share of the local contribution to DPM project funding.

Another possible arrangement for joint management of the DPM project would include the private downtown business and development sector as one party of a joint venture with a multipurpose city government. Given the critical and influential role of the private sector in moving a DPM project toward implementation, it may be reasonable to make this sector a formal partner in the DPM institutional structure. As noted in literature by Sam Bass Warner and Floyd Hunter, the business leadership is more than an interest group placing demands upon the political leaders. It is actually a part of the political leadership which operates through legitimized private policy-making bodies.* An institutional model based on a joint partnership of the private and public sector, to provide the overall direction for a DPM project, has not been tested previously. Legal issues may have to be resolved to make such an arrangement feasible. However, it is suggested that this approach be seriously considered by localities structuring a DPM project.

4.4 PLANNING TECHNIQUES

4.4.1 Techniques for Testing DPM Impacts on Urban Structure and Activity Patterns

Both the major positive and negative impacts of a DPM system are contingent on the way the system interacts with the surrounding physical structures and activity patterns. To assess these impacts, it is first necessary to assess and model the existing urban fabric. The "Urban Ecological Analysis Techniques" presented in Appendix 4-D and the discussion in Section 10 on Urban Design Impacts describe techniques for such assessment. The following will concentrate on the application of

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*Ideas expressed by Sam Bass Warner, The Private City; Floyd Hunter, Community Power Structures.

these techniques at three stages in the DPM planning process: (1) initial testing of DPM appropriateness for the city, (2) choice of DPM routes and general alignments, and (3) detailed design.

4.4.1.1 Initial Testing of DPM Appropriateness for the City

When the idea of a DPM is first considered, it is essential to make a judgement about its appropriateness to a particular environment. The existing structural and activity patterns of downtowns should greatly influence this judgement - such patterns can make it either relatively easy and profitable or very difficult and costly to implement such a system. At the earliest stage, certain indicators can be assessed in a qualitative way, and considered together to suggest where a particular city lies on this spectrum. Table 4-4 summarizes some of the major indicators. Initially, these should be assessed in a simple qualitative way (strongly positive - positive - negative - strongly negative). Physical and activity indicators and key aspects of the Transportation Framework should be mapped with simple sketch techniques (see Sections 4 and 5 of Urban Ecology Analysis Techniques, Appendix 4-D). Dominance of negative indicators is likely to make it difficult and costly to implement DPM. A very strong negative indication in even one category makes a DPM program risky, unless specific measures for reducing such problems are available.

4.4.1.2 Choice of DPM Routes and General Alignments

The indicators listed in Table 4-4 must be tested in more detail in this phase. Sub-section 10.3.5 in Section 10 on Urban Design Impacts describes major impact areas to be anticipated with DPM, and Appendix 4-D on Urban Ecological Analysis describes and illustrates techniques for modelling the existing urban environment and juxtaposing such models on the DPM alternatives. By this stage in the planning process, many of the critical factors will have emerged. Areas with narrow streets, historic, or otherwise sensitive physical fabric elements, as well as opportunities for induced activity and joint development, will have been generally identified. At this stage, the more specific benefits and costs associated with each alternaive must be determined. Detailed urban ecological analysis maps should be prepared at this point: <u>General Context</u> and <u>District Scale</u> maps for the whole downtown area, including all potential routes, and <u>Special Nodes and Fabric Studies</u> for critical points along each alternative under consideration.* Critical points are likely to occur at all stations and guideway segments that pass through or near narrow streets, shopping or other high activity areas, buildings or districts on or eligible for the National Historic Register, public open spaces, areas of potentially high incidence

*See Section 4, Appendix 4-D.

TABLE 4-4

INDICATORS FOR APPROPRIATENESS OF DPM TO A PARTICULAR DOWNTOWN

TYPE INDICATOR	INDICATORS FAVORING DPM	INDICATORS AGAINST DPM
1. Existing Activity Fabric	. Densely structured, distinct activity centers . High intensity mixed use at centers	. Dispersed or low level activity without major centers . High level but evenly distributed, street-oriented activity
2. Existing Physical Fabric	. Predominance of wide streets (90 ft or more R.O.W.) . Wide sidewalks (15 ft or more) . Major developable sites at potential key station points . Open rights of way (through parking lots, median strips) . Predominance of non-sensitive uses at DPM level (2nd or 3rd floor): parking, blank walls, vacancies	. Predominance of narrow streets (60 ft or less R.O.W.) . Narrow sidewalks (12 ft or less) . Tightly built up older building fabric with street oriented architecture . Historic buildings, districts or landmarks (section 106) along potential routes . Public open space along potential routes (section 4f) that may be incompatible with guideway . Predominance of sensitive uses at DPM level: offices with windows, institutions, residential space
3. Planning and Growth Policies	. Expanding downtown economy and active real estate development market . Policies encouraging major new mixed use development at activity centers	. Static or declining downtown economy with limited short range development potential . Policies favoring preservation and only infill-type limited growth

TABLE 4-4 (continued)

TYPE INDICATOR	INDICATORS FAVORING DPM	INDICATORS AGAINST DPM
(cont.)	. Expressed policies, legislative back up and past working relationships favoring city transit authority joint venture	. Lack of working relationship or difficulties between city and transit authority
	. City/private joint development backed by legal framework, financial arrangements and past project experience	. Lack of joint development experience or of necessary working relationships, defeat of past proposals for tax districts, etc.
	. Public funding sources are available to finance: 1) front-end planning; 2) 20% of technical planning work; 3) 20% of construction; 4) long range operation and maintenance	. Public funding not available as local match for federal funds
4. Transportation Policies and Factors	. A pedestrian system focused on activity centers that can be DPM stations - upper level systems that can feed into DPM directly (skyways, or tunnels if DPM below grade)	. Active, street oriented multi-directional pedestrian patterns with an even mix of origins and destinations
	. A fringe parking system that can be served by DPMs available sites, public control of consensus over operation, rate structure, zoning regulations favoring fringe parking	. No major parking sites available at fringe of downtown
	. Transit integration; good regional and metropolitan rail or bus service concentrated on potential DPM stations	. Inexpensive, underutilized parking still available nearer destinations
		. No obvious points of concentration for transit - DPM transfer

of crime, and areas where land owners or tenants are likely to object to DPM. In addition, major opportunity areas (joint development or new activities for under-utilized structures) should be mapped and analyzed. To understand the potential impacts of alternatives at this stage, a number of detailed features of the DPM system must be anticipated. For example, the visual impact of the guideway on a street will vary greatly with its cross sections, material, finishes, noise and vibration characteristics, height, type and spacing of supports, and projected maintenance program. In addition, other design decisions such as spacing two guideways apart to accommodate center stations, transitions among horizonal and vertical alignments, required emergency cross-overs, and other engineering requirements will have a major influence. Since detailed design for the specific project is not available at this stage, such assessments must rely either on elements already developed in other DPM projects or advance prototype studies for such critical features for the project under consideration. The latter approach could prove quite costly and time consuming and would have to be specifically funded during alternatives analysis.

Choosing among alternatives is likely to involve extensive public presentations and discussions. Sub-section 10.3.5 of Section 10 makes some specific recommendations for combining urban ecological analysis with specific participatory techniques. Further recommendations for workshops and public information techniques are made elsewhere in this section.

Two major types of public interest can be expected at this stage to surface in relation to alternative routes: (1) those who feel they would benefit from DPM and will lobby to be included in the routes, and (2) those who see potential harm from it and will lobby to move the route away from their area. The former is likely to include major development sites and commerical complexes; the latter, historic districts, parks, and residential neighborhoods. It is is essential that at this stage all major interests involved in each alternative are contacted and informed - including property owners, tenants, representatives of businesses and institutions, potential users of DPM, and groups concerned with local public expenditures.

4.4.1.3 Detailed Design of DPM Stations and Guideway in Relation to the Urban Ecology of Downtown

Some of the critical issues for this stage of the planning process are:

- Vertical and horizontal alignmment of guideways in relation to specific building and street features
- Quality of the pedestrian environment under the structure

- Access patterns and connections to sidewalks and other pedestrian ways at stations

- Volumes of pedestrians generated at stations and possibly removed from certain street segments

- Detailed physical and functional integration with new buildings or the remodelling of existing structures (see Phasing sections for a discussion of the process for this)

These issues can be examined by superimposing detailed DPM plans, cross sections, and mapped activity volumes on detailed urban ecology maps of each route and its surroundings (see Sections 4 and 5, Appendix 4-D). The problems that can arise at this stage are:

- Architectural relationships to existing structures which are more difficult than originally anticipated, due to unforeseen detailed engineering requirements

- Sub-standard pedestrian environment under the guideway, with insufficient technical flexibility or funds to re-establish the sidewalks as a first class pedestrian facility

- Direct access to and visual surveillance of station platforms from active public areas may be cut off by the choice of particular station schemes (such as a central platform between two tracks)

Urban ecological analysis should be used to anticipate where such problems are most likely to occur while the design is sufficiently flexible to be revised.

4.4.2 Joint Development Techniques

To clarify occasional misunderstanding of these terms, "joint development" will be used here to mean the combination of real estate development by private entities directly related to DPM system implementation and by the public agencies responsible for building and operating it. One of the major objectives of DPM planning in the demonstration cities is to help in catalyzing private development. The success of such projects is critical to the success of DPM and vice-versa. Experience with joint development projects around the country is all very recent and is evolving very rapidly. Both UMTA's policies and the Department of Housing and Urban Development's Urban Development Action Grants (UDAG) favor this approach and almost every city in the country is building or considering such projects for its downtown. A 1973 publication, <u>Transit Station Joint</u>

Development,* gives a good general overview of the subject although more recent case studies should be consulted. St. Paul's Town Square project, begun in June 1978 at the main intersection of two future DPM routes, is probably the most complete and up-to-date example.**

4.4.2.1 Assessing Joint Development Potential

Assessing joint development potential plays a major role at two key points in DPM planning: (1) assessing potential for the downtown as a whole for the initial decision on need and opportunities, and 2) assessing the comparative potential of each alternative route at the time when a choice among these must be made. The summary sheet on "Induced Development" in the Urban Design Impacts section in Section 10 lists critical factors and predictive measures that can be used in making these assessments. Each of the winning entries for the first round of DPM demonstrations has made a statement about DPM related development potential.*** Each argues for a major contribution to this potential by the DPM. A testing of such projections must involve a testing of the quality of the overall market studies and of the analysis of specific sites for their potential for capturing a share of such markets. But such testing will provide only some general baseline information. Actual success will be highly dependent on the entrepreneurial effectiveness of the combined public and private groups in planning, organizing, building, promoting, and managing these projects. Practical techniques for predicting potential at an early stage are limited to examining projects already committed and predicting others on the basis of general planning criteria (site capacity, proximity to DPM station and other transport facilities, locational and environmental attractions, ownership, land assembly and site cost issues, and financing availability). The resulting judgements, as illustrated by Table 4-5 prepared for St. Paul, are simple and quite generalized. Such judgements should be confirmed through a type of "delphi" technique: polling some members of the regional development community to assess the potential of the downtown/DPM complex as a whole and the relative potential of specific sites. Since the likelihood of development is highly dependent on developers' perceptions and intentions, such a poll will yield very useful information. A simple informative prospectus explaining DPM and downtown plans must accompany such a poll to

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*By the National League of Cities and U.S. Conference of Mayors with Skidmore, Owings and Merrill and Development Research Associates, consultants, sponsored jointly be U.S. DOT and U.S. HUD, published by NTIS, Final Report DOT-05-20021.

**For information, contact the DPM project, City of St. Paul or the Oxford Properties Corporation, developers.

***See proposals by Detroit, Houston, Los Angeles and St. Paul.

TABLE 4-5

RATING DEVELOPMENT/DPM POTENTIALS[1]

	Joint Development Possible	Impact on Scale and Timing	Impact on Performance
Committed Projects			
1. Oxford	Yes	Low	High
2. Radisson	Yes	Low	High
3. Arts and Sciences	Maybe	Low	High
4. YMCA - Skyway	No	Low	Low
5. Civil Engineers	No	Low	Low
Probable Projects			
6. Mears Park II	Maybe	Med.	Med.
7. Civic Center	Yes	Med.	High
8. Block C	Yes	High	High
9. Block G	Maybe	Med.	Med.
10. Block 617	Maybe	High	High
11. Capri Apartments	No	Med.	High
12. Miller Rehab	Yes	High	High
13. Rice-Marion II	No	Low	Low
14. Block 553	No	Low	Med.
15. Ramsey Hill	Maybe	High	High
Potential Projects			
1. Block 526	Yes	High	High
2. Block L	Yes	High	High
3. Depot Area	Yes	High	High
4. Block 642	Yes	Med.	High
5. Block CII	Yes	High	High
6. Block GII	Maybe	Med.	Med.
7. Block 608	Maybe	High	High
8. Block 637	Maybe	High	High
9. Block 524	No	Med.	High
10. Block 523	No	Med.	High
11. Block 509	Maybe	Med.	High
12. Block 506	Maybe	High	High
13. Block 628	Yes	High	High
14. Block 620	Maybe	Med.	High
15. Block 621	Maybe	Low	Med.
16. Block 440	Yes	Low	Med.
17. Capitol Mall	Yes	Low	Med.
18. Rice-Marion III	No	Low	Low
19. Block 617	Maybe	High	High
20. Ramsey Hill	Maybe	High	High

[1]From Development Potentials in the DPM Impact Area, paper prepared by the DPM Project Team, St. Paul, 1978.

insure that the respondents understand the nature of proposed improvements.

4.4.2.2 Special Anchor Projects

Because assessment of overall development potential is so uncertain, early public and private commitments to one or two special anchor projects play a very important role. Such commitments are very effective in establishing general faith in the feasibility of joint development. They are also laboratories for developing the required legal, financial, political, and administrative instruments. The "Town Square" project in St. Paul (also referred to as "Oxford/Radisson" and "7th Place Galleria") referenced above is a good example. This project is critical in its location (at the main interchange), in its timing (just preceding DPM), and in its design provisions (creating major public pedestrian spaces to integrate DPM with skyways and street levels, making structural provisions for future DPM installations). One such project can move joint development opportunities much closer to reality. An alternative pattern of anchor projects is the one proposed for Houston. There, project proposals at each end of the DPM shuttle line would create combined transportation terminals and mixed use commercial development.* An exceptionally successful and well integrated example of such development has been built in Nottingham, England. In this case, free bus loops provide the downtown distribution while the two anchor developments at the north and south ends of downtown (Victoria and Board Marsh Centers) combine parking, regional transportation and extensive commercial development. The bus loops and pedestrian systems connect these two focal points.

Steps for joint development have to be designed so that both public and private sectors will maintain a sense of parity of risk and commitment at each stage. The assessment of benefits should be mutually negotiated and agreed upon and form the basis of defining reasonable investments and risks. Specific guidance on this cannot be given here but the just emerging case study experiences of St. Paul and Houston should be useful to other cities. Many of the issues relate directly to phasing and are discussed in the phasing section.

4.4.3 Task Forces, Advisory Groups and Workshops

Earlier discussions on the local planning process and institutional arrangements have identified general requirements and patterns for community participation. The focus here is on techniques that make such participation constructive and creative. Task forces are generally appointed to represent

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*See North and South Terminal projects, Section 5.1, Houston DPM proposal, 1976.

specific interests in planning or reviewing the project. They usually include some technicians but most of the members are not trained in the technical disciplines involved. The task forces may be intended to serve for the life of the project or for specialized issues or phases. If they have political clout (through parent agencies of individual members), they become a de facto policy board for the project. If they do not, they will remain in an avdvisory capacity. At its best, the task force process can be instrumental in building a supportive and gradually broadening constituency for the project, while helping to shape it to the real needs of that constituency. At its worst, however, a task force can be an endless obstacle course of conflict, confrontation, and delay. Generally, two types of ingredients will determine the course of the process:

- Actual relationship between each interest represented and the likely impacts of the project

- Types of interactions, relationships, and procedures, both pre-existing and created during the task force process

A preponderance of non-negotiable conflict in the former area is likely to doom the task force process (and possibly the project as a whole) to failure. However, it is much more likely that most of such conflicts are negotiable on some level.

The candid assessment of true interests and of the potential negotiating fields for a task force are essential at an early stage. For example, the representatives of residential neighborhoods may be committed to opposing any major public expenditures for downtown and claim that money should instead be spent in the neighborhoods. Such representatives are unlikely to be persuaded by any variation of design scheme, alternative route, or operating plan for DPM. They should, however, be very amenable to considering the way future tax revenues from the revitalized downtown may help provide relief from residential property tax. This example provides one of the first guidelines for a well managed task force process:

- Establish true interests and priorities of each of the members (and their organizations) at the earliest stage and find points of common concern and negotiation

This can best be accomplished in a series of intensive workshops at the commencement of the task force process. During these sessions the members should get well acquainted with each other's personalities and interests, with conditions and plans in the downtown, and the general features of the DPM concept. The emphasis should be on very active participation by the members. Sessions should be structured formally enough to elicit active participation by everyone. This may involve filling out and sharing questionnaires, drawing maps of individual concerns, or having each member make a brief statement before more general discussion. It is important to record and formally review the results of each phase of discussion by identifying and displaying statements of issues, objectives, agreements, and disagreements. Such summaries should be continually updated and kept on display to the group.*

This type of beginning is in contrast with the usual practice where task forces begin by listening to lengthy professional presentations and then react when issues of concern arise. The difference in products and quality of a process that begins with concerted creative effort and one that begins with only reactions to the creative efforts of others should not be underestimated.

As the DPM plans evolve, special intensive workshop sessions may be required to address particular decisions and negotiating areas. Examples may be the impacts of an alternative route through an historic area, options for DPM operating and fare policies, or the balance of incentives, benefit taxes and public controls to be offered private developers. Each such area requires learning considerable technical information and identifying realistic tradeoffs to make decisions.

It is critical that the required technical information is provided in a form that is an easily accessible working tool for lay task force members and not as undigested technical papers. Preparing such background information in the forms of summary handouts and displays is an important responsibility for the technical team.** One effective technique for both providing technical background and for keeping the records of previous decisions of the group accessible is to establish an "information room" where such displays permanently cover the walls and where all task force meetings are to be held. Such a room, combined with a store front planning and information office (see next section) can also double as an effective facility for other public information programs.

4.4.4 Public Information Techniques

At distinct points in the DPM planning process, public advertisements and hearings are legally required. These occur with each application for Federal funds (for alternatives analysis, preliminary and final engineering, and for

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*The Harvard Square Planning Workshops were a successful application of these techniques. See Harvard Square Case Study, Appendix 4-D. Also, Heder, L., M. Francis and V. Karen, _Harvard Square Planning Workbook_, MIT Laboratory of Architecture and Planning, 1974, and Heder, L. and M. Francis, "Quality of Life Assessment," section in _Methodology of Social Impact Assessment_, K. Finsterbush and C.P. Wolf, editors; Dowden, Hitchinson & Ross, 1976.

**See _Harvard Square Planning Workbook_.

construction) and with all environmental impact studies. But a public information program designed to build a supportive constituency and to avoid confrontations at the formal phases must go considerably beyond these statutory requirements. The useful elements of a public information program are:

- Communications from task force members on a continuous basis to the interest groups they represent (neighborhhod association, Chamber of Commerce, downtown institutions, etc.) - see preceeding section for discussion

- Media coverage

- Surveys, polls, and interviews

- Store front planning office

One useful public information tool is a concise, well illustrated brochure on "What is DPM? What Can It do for Downtown?" Such a brochure geared to a broad non-technical audience, and to media release and use, should be widely distributed. A slide tape or film supplementing the brochure for television and public presentation, would also be valuable. Although information of this type is in the form of sales documents from individual system suppliers, these cannot be expected to give a comprehensive and impartial treatment to all available systems or to objectively illustrate downtown opportunities and constraints related to DPM.

It could be anticipated that public interest in the DPM projects will increase and possibly shift emphasis as the plans evolve from the initial general efforts to detailed design and construction. A public information program should include monitoring the current level of interest and responding to the questions most appropriate to the decisions of the current phase. At the same time, general and seemingly harmless decisions at an early stage may lead to controversial consequences at a later date. The public cannot be expected to anticipate these consequences (for example, the impacts on utility relocation costs or effects on an historic structure of the choice of a general route alignment). To forge a meaningful public consensus at each stage, the technical team should identify and publicize in advance such potentially critical aspects of early decisions. The following are some techniques that have proved useful for public information.

4.4.4.1 Media Communications

It is important that the planning team provides the local newspapers and radio and television stations with a continuous flow of information and that such information is well publicized at each development stage. Often, planning issues only receive publicity when they turn into a confrontation, and then the effect of the media coverage is to exacerbate the confrontation. In order to alleviate this problem it helps to understand that most of the choices for media publicity are made on the basis of perceived audience interest. Most media managers perceive confrontation as interesting and regular press releases about planning projects as less so. To achieve a more balanced coverage the technical team must be somewhat ingeneous in making its messages interesting to the media through illustrations, concise vivid descriptions or special presentations.

The print media can provide a good vehicle for feedback. Letters to the editor following publicity give some indication of public reactions. In many cities, newspapers have been willing to print special tear-out questionnaires and polls which can thus reach a very broad audience. If newspapers are used for polling, it is important that all the papers in an area are involved, as they often cater to quite different segments of the population.

4.4.4.2 Surveys, Polls and Questionnaries

Surveys, polls, and questionnaries should be used to get a feel for public attitudes at each critical decision point. They should always be accompanied by appropriate levels of background information on DPM and the downtown and on the specific issues in question. Issues tested through such surveys at successive stages may be:

- What should be the future of downtown? What development and transportation policy options are preferred?
- What is the general reaction to DPM, to its predicted costs and benefits? How accurately and how favorably is it perceived? What is the level of public willingness to pay for such improvements either out of taxes or at the fare box?
- What are preferences among potential alternative routes (link these to personal travel and use patterns)?
- What are the preferences among the available design prototypes? What are the key issues affecting patron convenience and comfort?
- What are the reactions to the first operating segment? What adjustments in operations are needed? What future additions?

4.4.4.3 Store Front Planning Offices

Store-front planning offices have been successfully used in a number of downtowns to combine public information with planning workshops and also to house an on-site management/promotional entity for already completed downtown facilities.* A store-front office can take the city officials and technical personnel out of remote offices and locate them in the actual environment they are manipulating. It can remove barriers between business people and city officials and raise mutual trust and respect through daily contact. It can make the planners more aware of the daily operating and management issues of the downtown. The store-front office should have an evolving, permanent display reflecting both the existing conditions (urban ecology) of the downtown and the status of planning and development programs. The displays should include models and renderings to illustrate the implication of the plans. They should provide concise summary information to take away (e.g., in the form of brochures) and an in-depth technical library for perusal on the premises.

The office should have acknowledgable professional staff accessible to the public to answer questions and obtain back-up information. Both financing such an office and gaining credibility for it could improve if it is set up as a joint project of the city and a private group such as the Chamber of Commerce or a downtown development corporation. The office should be located in one of the busiest pedestrian areas, should appear open and accessible, and should aggressively advertise itself to the public passing by.

4.4.5 Phasing of DPM Development

The planning and implementation of a DPM system in a dense downtown area requires careful coordination with the complex set of existing features and planned developments. The condition of most downtowns is dynamic, and the constant change involves both decline of older areas and massive efforts of revitalization and new development. Both the current activities and the changes that are occurring have associated time cycles and time requirements. If a DPM system is to successfully contribute to the synergy of a downtown, the staging of its development must be sensitive to the existing condition of the downtown area and must be carefully meshed with the timing of other downtown developments. Because of the lack of completed DPM projects, the discussion of the impacts of phasing must be based on the currently evolving designs and project impacts of the planned DPM demonstration projects.

4.4.5.1 Phasing of Development Projects and the DPM System

New buildings or new uses of old buildings can contribute to the success of a DPM system in a number of ways:

- Providing additional ridership

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*The Downtown Mall Office in Memphis is a successful example combining most of these functions.

- Allowing integration of stations and guideways into the downtown physical and activity fabric

- Creating activity, thereby adding attraction and safety at DPM stations

- Providing revenue, through value capture schemes, to finance DPM operations

The extent to which each of these contributions is critical to the success of the DPM system determines the requirement for completing such developments prior to or concurrently with the DPM. Some of the projections for the St. Paul project can illustrate the point:

Ridership - Fifty two to fifty five percent of riders are estimated to come from intra-downtown trips and it is projected that a 20 percent growth in office or retail activity could result in a 33 percent increase in such trips.* Actual new development plans in St. Paul anticipate up to a 20 percent increase in new construction or major rehabilitation in the downtown area by 1990. The impact on ridership is significant but gradual and does not require precise coordination of phasing.

Guideway and Station Integration - This issue requires much more precise coordination in critical areas. The Town Square project at the junction of the two DPM lines in St. Paul is already under construction and supports for DPM guideways have been incorporated into the Galleria design. The stations were moved to the outside edges of the project to allow some flexibility in their final design and construction. Somewhat better integration could probably have been achieved if DPM designs and commitments had been further advanced but the solution devised does not apear to create critical problems.

An alternative route segment through the Rice Park historical district is currently under consideration. The urban designers on the team perceive benefits in both the improved accessibility to the district and the excitement of the DPM riders exposed to this interesting area. Aside from cost considerations, the feasibility of this scheme depends on physical integration of the guideway with a number of development projects. Without such integration, the visual impact of the guideway would be unacceptable. The phasing problem here is that commitments to very specific physical configurations of new development must be secured before this route alignment can be selected for detailed engineering.

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*Memorandum to Richard Wolsfeld from Barton-Aschman Associates on Ridership Estimates (for specific alternative schemes), June 23, 1978 - range reflects variation among alternatives.

Activity, Attraction and Safety - Construction of a DPM system in a redevelopment area always presents the risk of operating stations where the lack of activity represents a safety hazard due to the high probability of crime. No part of the St. Paul route proposal seems so impacted by a projected lack of activity to represent a major risk problem. The 7th Place Galleria will contribute an exciting and active space at the main junction and could have a catalytic effect similar to that of the I.D.S. Center in Minneapolis that connects the skyway system and Nicollet Mall. In other cities where depletion of downtown activities and local crime rates are more serious, the opening of DPM stations on desolate sites may pose a real threat to the system and its patrons.

Value Capture Revenue - While all of the demonstration cities have anticipated value capture revenue in their operating funding, none seem to be relying on immediate income from the induced developments.* Thus, this is more of a middle range (5 to 10 years) concern rather than one directly affecting the DPM implementation schedule.

Generalizing from these experiences, it can be recommended that localities classify joint development projects as:

Critical anchor projects - Projects such as the St. Paul 7th Place or the Houston North and South Terminal projects that should require full planning and design coordination with the DPM system and should be in operation at the time that the system opens.

Existing buildings or projects already in implementation that must be physically adapted to accommodate DPM guideways or stations. Such modifications may involve integrating circulation systems, adapting space use patterns or protection from adverse DPM impacts. Such adaptive measures must be planned and performed prior to or concurrently with the DPM project.

Provisions for probable future projects along DPM lines. Such provisions should include ensuring developable site configurations and providing for future direct pedestrian connections to stations. Public capital expenditures for such provisions should be kept low until actual developer commitments are made.

Future DPM extensions of major existing or new developments. If developments already exist (such as a major university or medical center outside of the first phase route), then such extensions should be carefully planned and feasible routes identified. If the developments are planned, DPM extensions

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*Value capture revenue projections have only been made in very general terms.

should be planned on a comparable schedule. Any plans for extension will clearly be contingent upon first phase success.

A general point to consider here is that lead time for a major mixed use project is likely to be similar to that required for the DPM. However, most private development projects must prove their feasiblity before they can finance detailed planning. DPM on the other hand requires considerable detailed planning and impact studies before commitment to proceed. Thus, critical anchor projects, in order to proceed on a coordinated schedule, must be proved feasible prior to assurance of DPM, i.e., they must be strong enough to work even if DPM does not occur or becomes delayed.

4.4.5.2 Phasing DPM and Integration with Other Transportation Systems

A major part of the DPM patronage is expected to come from transfers from autos and regional transit. In the case of St. Paul, 45-48 percent of the total DPM trips are predicted from these sources. Fifteen to nineteen percent of the trips would be transferring from autos; 25-30 percent would transfer from regional transit. Roughly half of each category is expected to be destined directly to work places, the other half to a variety of non-work destinations (business, shopping, recreation, etc.).*

These major components of DPM ridership are likely to be highly sensitive to the level of coordination that exists between the DPM system and these other transportation facilities and their operations. The following describes some of the factors that are likely to critically affect the actual ridership generated by these sources.

<u>Auto transfers</u> are expected to occur when travellers park in peripheral "intercept" or "fringe" parking areas and then transfer to ride the DPM to their final downtown destination. In practice, such travel patterns have proved difficult to encourage in primarily auto-oriented, medium-sized downtowns. The difficulties arise from two sources:

- A competing, relatively inexpensive parking supply closer to the destinations
- Competitive convenience and time of simply walking from parking lots to destinations

The first prerequisite to capturing auto transfers is making available the peripheral parking facilities. Land acquisition and construction for these is usually costly and can require

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*From memorandum, "St. Paul DPM Ridership Estimates for Alternatives 4, 5, 6 and 7 for the Year 1990" by Barton-Aschman Associates, June 23, 1978 - the ranges given cover the figures for the different alternatives.

major subsidies (up to 75 percent of cost) to allow pricing low enough to attract customers.

In many medium sized downtowns (including St. Paul) there is no real parking shortage in or near the downtown. The complaints about parking are more concerned with price and convenience (which by the market forces tend to exist in a direct trade-off relationship). To make DPM-related fringe parking really effective as an "intercept", it may be necessary not only to keep the price of fringe parking artificially low, but to raise the cost of core parking higher than its present cost through taxing or a parking authority empowered to prescribe rates.

In addition, walk trips from fringe parking lots to DPM stations must be made exceptionally convenient and attractive to be preferred to walking directly to the destinations. This can be accomplished through the design of both parking facilities and of the stations. Walks should be minimum in length, direct, clearly signed, weather protected, well lit, safe, and perceived as safe. These design criteria should be emphasized because they are presently largely ignored in most major parking facilities.

The measures described above will be necesary to capture any significant portion of park-n-riders. Thus, at least the significant majority of them must be in place concurrently with the opening of DPM. This requires developing well in advance:

- Land resource for fringe parking
- Funding mechanism for subsidizing fringe parking facilities
- Legal and organizational structure for controlling downtown core parking areas
- DPM plans and operations to accommodate fringe parking service requirements

It is desirable to consider these plan elements during the alternatives analysis phase and develop and negotiate them in detail during preliminary engineering.

There are other measures related to traffic management and auto restriction that will contribute to a more pedestrian-oriented downtown and can reinforce the DPM system. If such measures were implemented on a large scale throughout the core area (as they have been in Munich, Nottingham, Bremen, Gothenburg and many other European cities), they could have a very significant effect on DPM ridership and success. However, no major U.S. city and certainly none of the present DPM demonstration sites are considering auto restrictions anywhere near this scale. The more modest plans for single street pedestrianization, while contributing generally to the attraction of downtown, are likely to have little direct effect on the DPM.

Therefore, the phasing of such projects (such as the 7th Street Mall in St. Paul) is not critical to the DPM project.

Transit transfers are expected to occur from regional feeder lines. The plan prepared in St. Paul for DPM/Bus integration* does not provide an analysis of the types of transfer trips that would be expected to transer. It should be assumed that the majority of these trips (close to 30 percent of total ridership of DPM) do not terminate close enough to their destination for the passengers to prefer walking. It may be expected that the number of transit/DPM transfers will vary greatly among different localities. Major factors causing the variation are:

- The pattern of major transit stops and terminals in relation to final destinations
- The pattern of DPM routes and stations with respect to both of the above

The importance of phasing coordination of DPM with other transit elements will vary directly with the expectations for transit/DPM transfer. In a case such as St. Paul, expectations are high and the coordination becomes essential.

People are generally reluctant to transfer, particularly among different modes that, in the case of DPM, probably occur on different physical elevations. To overcome this reluctance and compete successfully against walk trips to the final destinations, the integration of DPM and transit must:

- Provide combined stations with no significant walking distance between loading areas
- Provide coordinated operations taking into account both schedules and capacities
- Make both physical and schedule relationships very clear through signing and other publicity

Meeting these criteria may require some physical and operational adjustments in the present transit patterns. These adjustments must be planned and funded in anticipation of actual completion concurrently with the corresponding segment of DPM if significant transit to DPM transfer is to be realized.

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*By the Metropolitan Transit Commission, June 5, 1978.

APPENDICES

to

CHAPTER 4

Appendix 4 -A: UMTA DPM Project Implementation Guidelines

Appendix 4 -B: Required Submittals to UMTA for the First Round DPM Cities

Appendix 4 -C: Sample Evaluation Measures for Alternatives Analysis

Appendix 4 -D: Urban Ecological Analysis Techniques

APPENDIX 4-A

UMTA DPM Project Implementation Guidelines

INTERFACES BETWEEN PROJECT ELEMENTS, ASSOCIATED ACTIVITIES AND PROJECT PARTICIPANTS[1]

Phase	Element	Associated Activities	Participants
I	Award of capital grant for preliminary engineering		• UMTA
I	Preliminary Engineering	• Establish route layout, system envelope and interface definition • Establish property acquisition and renewal requirements • Establish soil boring and analysis requirements • Determine utility relocation requirements • Determine traffic and roadway alterations • Estimate system costs • Develop implementation schedules	• Grantee

[1]Adapted from the UMTA DPM Project Implementation Guidelines

Phase	Element	Associated Activities	Participants
I	- Submission of EIA	• UMTA generation of EIS from EIA	• Grantee and UMTA
I	- Impact study baseline	• Pre-installation survey of site conditions	• Grantee
I	- Procurement bid package	• Establish system requirements/performance specifications • Develop product acceptance criteria • Develop supplier qualification criteria • Establish manufacturing controls • Specify design and testing approval requirements	• Grantee
I	Submission of preliminary engineering results	• UMTA review of preliminary engineering results	• Grantee & UMTA
I	Project implementation go ahead	• Selection of one or more sites for implementation (Phase II)	• UMTA
II	System Manufacturer selection	• Release approved RFP • Hold bidders conference • Obtain RFP responses (proposals); Submit copy to UMTA • Evaluate proposal	• Grantee

Phase	Element	Associated Activities	Participants
II	- Manufacturer technological qualification	• Review of selected manufacturer's design and equipment status • Determination of product improvement requirements • Establishment of test requirements for certification • Inclusion of product improvement requirements into supplier's contract	• UMTA and Grantee
II	- Award of contract to system Manufacturer	• Contract negotiation • UMTA third-party concurrence • Contract award	• UMTA, Grantee, and System Manufacturer
II	Start of final A&E design	• Turn-key responsibility	• System Manufacturer
II	Product improvement	• Propose product improvements	• System Manufacturer
		• Design review & concurrence	• UMTA and Grantee
		• Prototype fabrication	• System Manufacturer
		• Design verification testing	• UMTA, Grantee, System Manufacturer
		• System Manufacturer certification	• UMTA, Grantee
II	Property acquisition	• Family and business relocation • Utility relocation	• Grantee

Phase	Element	Associated Activities	Participants
II	**Completion of final A&E designs**	• Final A&E designs	• System Manufacturer
		• Review of final designs	• UMTA and Grantee
		• Approval/rejection of final designs	
II	**Construction Sub-contractor awards**	• Construction bid package preparation	• System Manufacturer
		• Contract negotiation	• System Manufacturer
		• Construction Sub-contractor selection	• System Manufacturer
		• Guideway construction	• Sub-contractor
		• Station construction maintenance and storage facility construction	• Sub-contractor
		• Other fixed facility construction	• Sub-contractor
		• On-site design modifications	• System Manufacturer and Sub-contractor
II	**Vehicle and system component fabrication**	• Quality assurance monitoring	• Grantee
		• Design verification testing	• System Manufacturer
		• Software testing & verification	• System Manufacturer
		• Verification documentation	• System Manufacturer

Phase	Element	Associated Activities	Participants
II	**Project monitoring**	• Schedule monitoring	• UMTA, Grantee, System Manufacturer
		• Cost monitoring	• UMTA, Grantee, System Manufacturer
II	**Project reporting**	• Schedule and cost visibility	• Grantee, UMTA
		• Exception reports	
		• Quarterly (at least) project reviews	
		• Minutes of project reviews	• Grantee
II	**System integration and shakedown**	• Equipment installation	• System Manufacturer
		• Software installation	• System Manufacturer
		• Acceptance Test Program	• System Manufacturer
		• Shakedown Testing	• System Manufacturer, Grantee, UMTA
		• Acceptance Testing	• Grantee, UMTA, System Manufacturer
II	**Employee training**	• Operating personnel training	• System Manufacturer, Grantee
		• Maintenance personnel training	• System Manufacturer, Grantee

Phase	Element	Associated Activities	Participants
II	**Revenue operation**	• Operations plan	• Grantee
		• Daily system start-up and shut-down	• Grantee/operator
		• Daily vehicle diagnostics and maintenance	• Grantee/operator
		• Daily revenue collection	• Grantee/operator
		• Anomaly management	• Grantee/operator
		• Security surveillance	• Grantee/operator
		• Daily maintenance of way and other fixed facilities	• Grantee/operator
		• System administration	• Grantee/operator
		• Safety management	• Grantee/operator
		• Operations data collection	• Grantee/operator
II	**Impact analysis**	• Post-installation site conditions survey	• Grantee
		• Socio-economic benefits study	• Grantee
II	**Project documentation**	• System operating characteristics	• Grantee/UMTA
		• Final report	

APPENDIX 4-B

REQUIRED SUBMITTALS TO UMTA FOR THE FIRST ROUND DPM CITIES[1]

PHASE I SUBMITTALS

- Project Implementation Plan;
- Drawings, Designs, System Analyses and trade-off study results;
- System Requirements/Performance Specifications;
- Product Acceptance and Supplier Qualification Criteria;
- Environmental Impact Analysis;
- Procurement Bid Package;
- Baseline Survey for Impact Evaluation;
- Elderly and Handicapped Accommodation Plan; and
- Patron Security Plan.

PHASE II SUBMITTALS[2]

- Cost Monitoring Plan,
- Management Plan,
- Design Review Results,
- Technical Compliance Review Report,
- Glossary
- System Construction Schedule,
- Work Breakdown Schedule,
- Program Status Reviews,
- Monthly Progress Reports,
- Product Improvement Verification Plan,
- Operational Safety Plan (Red Cover),
- Product Assurance Plan,

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[1] Source: DPM Project Implementation Guidelines; UMTA

[2] The Phase II submittals are to be the product of the grantee and the system manufacturer

PHASE II SUBMITTALS (cont'd)

- Failure Assessment Plan,
- Quality Assurance Plan,
- Reliability Program Plan,
- Configuration Management Plan,
- Logistics Support and Maintenance Plan,
- Final System A&E and design drawings and Functional Block Diagram,
- Systems Operating Plan,
- System Safety Program Plan,
- Operational Security Program,
- Acceptance Test Program Plan,
- Gross Hazards Analysis,
- Spare Parts Provisioning Plan,
- Operating and Maintenance Training Program Plan,
- Operations Manual,
- Training Manual,
- Maintenance Manual,
- Software Documentation,
- Systems Description Manuals (Command & Communications, Station, Vehicle),
- Impact Analysis, and
- Project Documentation (Final Report).

APPENDIX 4-C

Sample Evaluation Measures for Alternatives Analysis

RELATION OF CRITERIA TO VARIABLES

Evaluation Criteria	Dependent Variable Package
Surface Traffic Mobility	Traffic Congestion Delay
Safety	Safety Index Accident Cost
Land Use and Urban Design	Impact on Existing Land Use Opportunity Created Compatibility with CDMP
Community Disruption/Displacements	Residential Displacements Commercial Displacements Special (e.g., church) Displacements
Environmental/Ecological Considerations	Noise Impact Air Quality Neighborhood Disruption Visual Intrusion Vegetation Disruption
Accessibility	Number of People Within 2.5 Miles of Rapid Transit Line Percentage of Work Trips Within 15-20 Minutes (Access Plus Egress Time)
Level of Service	Total Daily Transit Trips Total Daily Transit Trips by Mode Maximum Link Daily Transit Ridership Maximum Link Peak Hour, Peak Direction Transit Ridership Average Transit Travel Time Average Number of Transfers Per Transit Trip
Energy	Propulsion Savings Due to Auto Diversion Losses Due to Train-Auto Delay

APPENDIX 4-D

URBAN ECOLOGICAL ANALYSIS TECHNIQUES

Introduction

In the practice of urban design and evaluation we have found that while it was generally accepted that the physical environment profoundly affects all activities in the city, there was a lack of techniques for describing and analyzing these relationships.*

The term "Urban Ecological Analysis" draws analogy to studies of organisms and their habitat in the "natural"environment. The analysis juxtaposes the physical structures in the city (streets, buildings, open spaces) to the activities taking place within them (auto traffic, pedestrian movement, public transportation, retailing, land development, offices, housing, etc.). The descriptions are more specific and detailed than conventional land use and transportation mapping. The analysis facilitates judgements about:

- the appropriate fit between activity and environment (i.e. is the sidewalk sufficient for pedestrian traffic and is pedestrian traffic adequate to support a particular type of shopping?)
- the balance or competition between different activities as contained by the environment (i.e. will the number of people at a bus stop add to the liveliness of the street or constrain an already overcrowded sidewalk?)
- special ecological niches required for certain activities (such as bus stops getting free evening surveillance from adjacent all night cafeteria)
- environmental capacity (such as the number of buses that can run on a pedestrian/transit way before the pedestrian environment becomes severely impacted)

These judgements can then be used to guide decisions about transportation projects such as traffic management, parking policies, pedestrianization, exclusive transitways, conventional fixed rail transit or downtown "people movers". They can also guide decisions on incentives and controls for private development in or near existing urban centers.

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*The development of the "Urban Ecological Techniques" began in 1973 in the MIT Laboratory of Architecture and Planning. The techniques were first applied in the Harvard Square Urban Ecology Study at MIT under the direction of Lajos Heder with assistance from Mark Francis and Victor Karen. The firm of Moore-Heder, using the same team, has applied the techniques to a study of Auto Restricted Zones.

The techniques provide a comprehensive framework for decisions about the built-up urban environment. They also facilitate communication and review by government decision makers, community groups, and other interests. The mapping systems rely on analysis of correlations and on the display of data, analysis and designers' judgment in a comparable format.

The techniques discussed in the following are conceived to be useable by any city planning department or consulting firm. They mostly rely on accepted techniques of data gathering and mapping. In some areas where traditional techniques have ignored important phenomena, we developed new techniques (mostly in the area of activity mapping and in the detailed node studies) but these can be easily applied by all practitioners. It is very likely that more innovative techniques will be needed and developed in future studies and the framework of an Urban Ecological Analysis will be able to accept these.

The remainder of this paper contains the following sections:

1. The urban ecology analysis approach
2. Elements and applications
3. Level of effort for urban ecological analysis projects
4. Scales and areas of analysis
5. Special mapping and analysis techniques
6. Applications for transportation issues
7. Three case studies: Harvard Square, Downtown Boston, and Downtown Memphis

1. THE URBAN ECOLOGICAL ANALYSIS APPROACH

The life of a built-up urban area is governed by ecological rules as much as is that of a salt marsh or a sand dune. Activities and their environment interact in complex but by no means random ways. The rules of interaction are sometimes known and measurable, sometimes known but not quantifiable and sometimes unknown or subject to disagreement.

The urban ecological approach does not claim that all the rules will become measurable or even adequately described. It seeks to develop a tool for the continuing and cumulative discovery of these phenomena within a particular place. The issues posed in the introduction - appropriate fit, balance, ecological niches for activities and environmental capactiy - will not yield to mechanical criteria of evaluation. They can, however, be related to causal factors displayed and distributed spatially and subjected to the judgements of analysts, designers, and the lay community in an open and trans rent way.

The ecological approach is particularly appropriate and necessary in the democratic, greatly de-centralized political structure of U.S.cities. Unlike in some historic examples of European city design where strong central authority could control the planning and shaping of cities, in a U.S. city many diverse interests must agree before any major environmental action can be implemented. At present these agreements are often governed by short range political expediency. But in the longer run, only those cities will prosper that succeed in building a political constituency around sound ecological principles of development. In general, this means understanding the way the parts of an urban system can work together for maximizing the energy of the whole system. In practice, it means the need for each special interest group to negotiate a sound compromise between its self interest and the needs of the system as a whole. The urban ecology model can provide the objective basis of these negotiations. It can also progressively incorporate the resulting decisions, policies and implementation projects.

The concepts applied in urban ecological analysis have a number of antecedents:

1. Overlay map analysis in regional land planning was pioneered by Ian McHarg [1] and since then applied by many practitioners of landscape architecture and regional planning. These analyses map land features such as soils, slope, vegetation, etc. They overlay maps of interrelated phenomena and determine the "suitability" (i.e. minimum constraints) and "capability" (i.e. maximum supporting factors) for regional transportation facilities and land development.

1. Ian McHarg, Design with Nature, Doubleday/ Natural History Press, 1971.

2. Studies in the perception of the city - Kevin Lynch's work[1] was the first in defining the elements of city perception (node, path, edge, district) and combining subjective interview/mapping with analytical studies.

3. Behavior settings - detailed interaction of environmental and behavioral patterns have been studied by Robert Bechtel.[2]

4. Detailed urban structure and activity mapping has been researched by Stanford Anderson at the MIT Department of Architecture.[3]

Urban ecological analysis evolved out of conventional planning studies and from incorporating concepts from the above sources. As a technique, it continues to evolve with each application. The elements of the technique are summarized in the following section. Its potential contributions can be summarized as follows:

1. Clarify the community to its members: promote understanding of the way physical and activity elements interact with each other, illustrate problems, opportunities and trade-offs. At present much serious confusion persists among professional and administrative officials as well as the general public in relation to these issues which often leads to unnecessary conflict. When there are no common understandings and ground rules, everyone is naturally wary. A transparent, understandable and well published model of how things work can greatly help a community in managing its present and planning its future.

2. Serve as the basis of policy decisions on transportation, development control, public investment or management. In the Harvard Square case study, each community group first participated in an analysis and then developed policy recommendations. Because these recommendations were based on a thorough ecological understanding, the differences between different groups' policies could be rationally negotiated and incorporated into an overall Harvard Square Policy Plan.

3. Serve as a basis for plans including area wide development plans, transportation improvement plans or specific development sites. A thorough understanding and clear display of the ecological structure of the area can increase the chance for relevant innovative solutions, for finding the areas of greatest benefit and minimum negative impact and for discovering previously overlooked resources.[4]

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1. Kevin Lynch, Image of the City, MIT Press, 1961.
2.

3. Thresholds I and II - working papers prepared by Professor Stanford Anderson as reports for the Grunsfeld Foundation (unpublished).
4. See the Boston Auto Restricted Zone Pedestrian Study among the case studies. Note the way the anlysis lead to the planning of pedestrian improvements and shuttle bus routes.

4. Serve as a basis for environmental impact assessment by disaggregating and spatially identifying particular impact types and by showing the interaction among several impact types at a particular site. The analysis will provide clear and detailed assessment of the amount and location of impacts that exceed established acceptable levels. It will also indicate locations where a synergetic action of existing conditions and one or more impacts is likely to take place.

The following sections give some technical descriptions, guidelines and illustrative examples for performing urban ecological analysis. These should assist in setting up the analysis for particular places and projects. It must be born in mind, however, that the essence of the urban ecological approach is increased sensitivity and responsiveness to the specific nature of a place. Thus no method can be mechanically applied without a close scrutiny of the local situation and a careful selection and adaptation of the appropriate aspects of the technique.

2. ELEMENTS AND APPLICATIONS

Base maps and overlaid or juxtaposed inventory information are the central elements of Urban Ecological Analysis. The base maps show the physical structures. The inventory maps show conditions, activity generators, activity flows, trends over time, stated plans and policies and community attitudes. Usually three different scales of mapping are appropriate, dealing respectively with context, district and node level information. The scales and areas for mapping are described in more specific detail in Section 4.

Photographic studies supplementing the maps are useful both as general illustrations and as specific analytical tools. Photo analysis can reveal physical effects such as scale relationship between buildings and streets, shadows cast, continuity of street frontage and architectural vocabulary and relationships. It can also be applied for activity analysis to indicate level of sidewalk crowding[1] and auto/pedestrian conflicts.

Cross-sections of buildings and streets can provide indication of scale and density. They can also be overlaid with information about conditions, activity generators and activity flows. Cross-section studies are particularly necessary for dense city areas with multi-level circulation such as subways, elevated people movers, pedestrian skyways or basement arcades.

General "Resources, Problems and Opportunities" analysis maps can be obtained by emphatically diagramming these elements on the basis of the inventory (see Memphis case study). Such maps can form a hypothesis for further, more rigorous analysis.

Simple indicator or threshold maps can show the patterns made by these elements. For instance a map of all pedestrian entrances (see Boston case study) on a district scale map indicates the streets with primary pedestrian orientation. Conversely, a map of all curb-cuts can show the vehicular orientation of streets. Such maps can also indicate threshold effects such as all buildings above a certain rating for historic value or all stores with floor rents above $15/s.f. The patterns obtained can show clustering of certain phenomena and the relationsips between them and some planning actions or impacts. Other factors of interest for such threshold maps may be traffic congestion levels, building deterioration, incidence of crime and vandalism, traffic accidents and pedestrian volumes both at the high and low limits.

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1. See pedestrian "level of service" studies in Pedestrian Planning and Design by John J. Fruin, Ph D. MAUDEP, 1971, p.76.

Correlation analysis can be performed when the spatial coincidence of two or more factors has a significant effect. For example, in the Harvard Square analysis, we identified stores where low inside pedestrian counts corresponded to high counts outside on the sidewalk and high space rents. We expected this to indicate potential business difficulties. In fact, three out of the five stores thus identified went out of business within two years. Such correlations may also be tested between low lighting and maintenance levels and lack of storefront activity (for incidence of crime and vandalism); number of people on the streets in cars and number of pedestrians (for need to reallocate street right-of-way - see Boston case study); new transit guideway proposals, narrow streets and location of historic buildings (for potential adverse architectural impacts of a transit alternative). The correlations can be mechanically read from the superimposition of maps, but their significance and value must be determined by outside analysis.

"Suitability" and "Capability" maps have been widely used in regional land planning and can be adapted for Urban Ecological Analysis. The former eliminates areas rendered unsuitable for a given purpose by recognized constraints and indicates a pattern of most suitable (i.e. least constrained) locations. For example, in studying potential locations for an elevated transit line, one may map all narrow streets, historic or architecturally sensitive buildings, second floor activities that may suffer from the presence of the guideway and street activities that may be hurt by the imposition of an overhead structure. If each of these factors is mapped on a transparent sheet and overlaid with all the others the darkest total color will show the greatest combined constraints while the lightest shows areas "most suitable."

Capability is defined by the presence of positive factors and can be built up through the overlay mapping of positive elements. For the above example this may include access points to major activities, parking locations and transit interchange points. The darkest combined areas would then show the "most capability."

An overly mechanical application of this technique can however be probematical since the interaction of different factors is not necessarily analogous to the additive accumulation of shades of color. Particular combinations of factors may become critical (such as lack of surveillance in a high crime area) while others may aggregate in a more tolerable way. Thus, while the overlay mapping will point out significant patterns, these must be closely examined for the particulars of their effects.

Activity Interaction Matrices In the Harvard Square case study, we developed a series of matrices to rate the interaction of activities with their envrionment and each other. The matrices identify activities that can benefit from one another, ones that are likely to be displaced by a stronger "species" of activity competing for its space. We also identify the effects of transportation changes and of additional development on each activity set. The matrices and the maps complement each other and point out that often a relatively subtle balance rather than unlimited growth or elimination of elements is required.

Alternatives analysis can be performed by superimposing alternative proposals for transportation or development projects over the basic urban ecological analysis maps. The proposals must be represented both by their physical description and their activity generation. For a transit proposal this would include guideway configuration in plan and section but also ridership projections to each station point. For a development proposal added employment, retail volume, pedestrian and auto traffic, parking needs and provisions and real estate tax contributions should be represented. These factors can be combined with their existing counterparts at their particular location. The combined effects then can be tested against both beneficial and negative thresholds at each location (i.e.reaching critical mass of social and economic activity for a lively shopping street vs. reaching unacceptable levels of pedestrian/auto conflict). The benefits and problems of each alternative can then be clearly displayed and evaluated for both total impact and impact on critical local conditions.

Environmental Impact Analysis would follow basically similar procedures to those described for alternatives analysis. Particular impact issues (such as effects on the elderly and handicapped or air pollution hot spots) can be mapped in specific detail for both existing conditions and for the proposals under analysis.

Value maps are an essential tool for collecting and recording value judgements by the general community as well as by special interest and professional groups. The Harvard Square case study shows techniques of aggregating individual use patterns as well as expressed "liking " and "disliking" of particular areas. Value maps can also be prepared by workshop groups in response to the presentation of urban ecological base analysis. For example: Where is the high level of traffic congestion seen to be the greatest problem? Which areas experiencing physical deterioration have the greatest functional or symbolic value and should therefore have the highest priorities for revitalization? Among alternative proposals having different impacts in different areas which ones should be considered more critical? This type of value testing can occur in workshops, questionaires or interviews. Each participant can make a base map with sketch coding. These maps can then be summarized by planners and displayed back to the community.

The urban ecology analysis encourages cycles of such value testing followed by further analysis of areas considered critical by the community. It also encourages the use of the analytical maps as teaching tools to better inform the community of the specific cause and effect relationships among its own resources.

A special case of value mapping is a type of "Delphi" technique that involves the polling of professionals to identify and locate particular types of values. This way groups of real estate brokers can map development potential, groups of policemen can identify areas conducive to crime and groups of architects can map districts of special architectural value.

3. THE LEVEL OF EFFORT FOR URBAN ECOLOGICAL ANALYSIS PROJECTS

There is a potentially endless complexity of information about the city fabric that could be collected, mapped and analysed. Limitations of time, money and ability to process the information set constraints. This poses two challenges for structuring any particular project of urban ecological analysis:

1. The selection of the most relevant, highest priority aspects for detailed study and
2. The creation of a cumulative system which enables the specialized pieces gained over any particular study to join up into a more comprehensive urban ecology model of the area.

The criteria that determine the level of effort justified in a study should be

1. Complexity of the urban fabric
2. The extent of the proposed action and its sphere of influence
3. The sensitivity of the urban fabric to the particular impacts of the project
4. Community values vested in the existing structural and activity pattern.

It is evident that in order to make judgements about these criteria one must have already begun the analysis. In most complex analyses a series of iterations are required. The findings of each cycle must be exposed to judgements on the above criteria in order to determine whether further detailed study is needed.

For the initial effort the following guidelines may be useful:

1. Complexity of the urban fabric tends to increase with density, the number of different uses (living, shopping, work, etc.) in close proximity, the age of the area, the variety of its social and economic groups, the complications of its street and building patterns, the amount of traffic flow, pedestrian activity and the level of congestion. Other, more particularly local factors such as rivers and steep topography, strongly established local traditions, work and living patterns can also add to complexity and should be reviewed.

2. The extent of proposed actions and their sphere of influence. A hypothetical judgement must be made about this and tested by going beyond its limits in a few sample cases.

   For instance, in an assessment of BART's impacts in San Francisco, it was stated that the environmental effects are limited to "strips of land a few hundred feet wide along BART trackways."[1] An analysis based on this hypothesis should start by testing a few key areas where intuitive inspection suggests possible wider impacts (such as major intersecting streets, station areas, etc.). If these wider impacts prove trivial, then detailed study could proceed within the linear corridor as suggested. If some of these areas show extended impacts, then an inventory of all such conditions and an extension of study boundaries to include them will be required.

The sphere of influence must also be estimated on the basis of the activity generating potential (i.e. number of people, parking and traffic generation, ridership estimates for transit facilities, etc.). The generated activity must then be juxtaposed to the already existing activity level. The impact should be tested against two types of critera: 1) % increase in the activity and 2) increases in areas already near some environmental threshold such as adding pedestrians to already crowded sidewalks or creating a barrier next to an already isolated neighborhood.

3. The sensitivity of the urban fabric is a function of how easily the balance of its elements can be upset. This is not necessarily a function of density or complexity. For instance, we found that changes in volume and type of pedestrian activity are much more likely to change the social environment of a neighborhood shopping center than of a busy downtown district.[2]

The presence of activities functioning near their maximum environmental threshold is a good indicator of potential sensitivity. But these thresholds can be complex and difficult to establish. In a luxury residential area, even a small intrusive element can drive away clients with great freedom of choice. In a shopping area some businesses may thrive on increased foot traffic while others may suffer if they cannot expand their services or pay increased rents.[3] Because of the complexity of these judgements, questions of sensitivity should be tested in several iterations, particularly in relation to elements of high community value (see below).

In general,sensitivity tends to be high for: purely residential areas, areas already near or above acceptable thresholds for traffic, noise or air pollution, historic areas, areas of special social or ethnic cohesion and areas with special natural features such as parks and waterfronts.

4. Community values vested in the urban fabric are to some extent evident from past actions and reactions. For instance, a proposal that would have caused the removal of some large sycamore trees along the river

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1 The Evironmental Impacts of BART - Interim Service Findings - Intensive Summary, p. 12 by the Metropolitan Transportation Commission, July, 1976.

2. Harvard Square Urban Ecology Study and Boston Auto Restricted Zone Study, see case study examples.

3. This was found to be the case in the Harvard Square study.

in Cambridge created such a furor of protest a decade ago that these trees are still treated as sacred objects by all local politicians. Strong community interest is a correct (as well as politically necessary) indicator of the need for detailed ecological study. In the Harvard Square project, an often expressed interest in the "balanced diversity" of the area caused us to perform a detailed study of activity settings and their interactions and we did in fact find an unusual level of sensitivity there.

By contrast, in downtown Tucson the relatively low level of activities in combination with the prevailing sentiment that most of these activities should be changed rather than preserved made a fine grained detailed study of the activity patterns unnecessary.

It can be anticipated that community valuation of an area will increase with the extent to which the area "works" for its users and with the length of time they have been associated with it. Such factors could be surveyed and analysed, but people should also be asked directly through interview and survey techniques and open public forums. Aggregated maps of individual concerns [1] can then be used to identify areas where detailed study is warranted by community interest.

Thus the level of effort required cannot be pre-judged until some assessment is made of all of the above factors. A basic set of urban ecological descriptions as described in the previous section is a necessary tool for deciding what special analysis is needed in each case. If this set does not yet exist any major project proposal for the downtown area should justify its preparation prior to further specialized studies.

Each major special purpose study can add to building up a comprehensive descriptive and analytical Urban Ecology model of the area. If the initial steps are taken carefully, the level of effort required can decrease with each subsequent special purpose study. The following sections on mapping and analysis technique provide some recommendations for gathering, mapping and managing the information in ways that can maximize its cumulative benefits.

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1 See Neighborhood "Use", "Likes", and "Dislikes" maps in Harvard Square case study.

4. SCALES AND AREAS OF ANALYSIS

Different projects will require different levels of detail and emphasis of analysis. On the other hand if a city wants to insure that the analyses conducted for individual projects accumulate into a comprehensive urban ecological model, some uniform decisions about format, scale and graphic techniques must be made.

For most analyses one or all of three distinct scales are likely to be appropriate. These three are related to:

1. The general context
2. District scale structure and activities
3. Special node and fabric studies

1. The general context usually requires simple diagramatic maps on a number of scales. Facts about regional demography, transportation network, generalized land use and geography can be recorded on a regional map. Standard road maps of a metropolitan area provide a reasonable base for this. The more immediate context of major structural features, land uses and activity generators surrounding a district under study also needs to be established. This information can be mapped diagramatically or over base maps ranging in scale from 400 to 1000 feet to an inch. [1] It is desirable to establish one such base map scale appropriate to represent the immediate context of a particular area and use it consistently for inventory and analytical maps. These maps will typically show information aggregated by districts and related to major roads and transportation corridors. The base maps only need to show basic street and block patterns and major landmarks. Aerial photographs at the same scale are a useful supplement to give a sense of the scale, density, and character of the surrounding developments.

2. District scale structure and activities maps form the core of an Urban Ecological Analysis in most cases such as selection among detailed transit route alternatives or setting guidelines for development programs. This scale is appropriate for the study of the details of the street network and related activities which would be required for pedestrianization or traffic management decisions.

   The maps for these studies should be drawn at scales of 1"=100' or 1"=200'. Base maps at these scales should show city structure including:

   - streets and sidewalks(to accurate width)
   - contours of at least 5' intervals
   - building outlines with an indication of height

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1 Drawing scales are given here as recommended for original graphics and displays. The maps at these scales can be reduced to 8½ x 11" report size and still be legible.

- property lines
- major building and service entrances
- curb cuts and open lots
- all fixed transporation: rail lines, transit routes and stations, expressways and ramps, parking garages and lots
- all public open spaces
- identify major locally recognized landmarks.

A basic set of district scale analysis should also include (at the same scale):

Conditions: ownership, age and maintenance level of structures, vacancy/occupancy, floor rents, land values.

Activity Generators: Employment (by block or building), retail (with floor area), tourist attractions (with visitor volumes), residential areas (with block-by-block totals), transit stops (with boarding counts), parking lots and garages (with total capacity for each).

Activity Flows: pedestrian volumes and traffic counts on all streets (at peak and off peak hours), parking utilization, retail volume.

Trends: generalized maps of conditions and activities 5 and/or 10 years previously.

Plans and Policies: projected public improvements and private development with description of ingredients, size, traffic, parking and pedestrian generation and time schedules for implementation.

Community Attitudes: perceived problem areas and opportunities, areas used by particular groups, areas "liked" and "disliked", areas feared because of crime, areas of great symbolic value.

The most frequent subjects for such detailed district scale mapping are the downtowns and commercial sub-centers. In small to medium size cities such active centers are usually small enough and clearly enough defined that they can each fit on a simple district scale map.[1] In large cities such districts are contiguous and functionally overlapped and a mosiac of separate maps has to be used. The separation between component maps can create some problems which are discussed in the following section on mapping techniques.

3. Special node and fabric studies are required for two reasons: 1) detailed attention to a particuarly sensitive area[2] and 2) a test of the more detailed conditions of a typical section of the city which can be extrapolated to other similar conditions.

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1. We found this to be true for Memphis, Providence and Tucson but had to make a more arbitrary definition of the Boston downtown study area.
2. See Harvard Square case study.

The structural base maps for this scale include a description of both the public rights of way and the adjacent private spaces (see figure). They work well at a scale of 1" = 40' which allows a detailed presentation of the envrionment and activities and still can include several blocks on one map.

At this scale the three dimensional nature of the environment should be represented. Maps should be prepared for other than ground levels that have major continuity. This includes mezzanines and second levels, especially if skywalks or elevated people movers exist or are planned, and undergroung levels, especially if they connect pedestrian areas or subways. Cross sections of buildings and streets can be coded similarly to the plans to represent the vertical distribution of activities. Photographs can also be used as a base for diagramatic coding to represent analytical information (building condition, architectural value, distribution of uses, etc.).

5. SPECIAL MAPPING AND ANALYSIS TECHNIQUES

In this section we provide a few technical suggestions for mapping and analysis procedures that are not commonly employed in planning practice.

District scale structural maps usually exist in some form in most cities, but some of the required information needs to be added. In small to medium sized cities we found that in a few days of field surveying we could map all entrances, curb cuts and correct any obsolescence on the maps. If building outlines and curb-lines are lacking altogether, they often have to be added from aerial photogrametrics, Sanborn maps or assessor's maps and this can be more time consuming. The effort required in preparing a good set of base maps however, is quickly returned by the efficiency of mapping other information over such maps and by the ability to accumulate such information from one study ot the next.

If several component maps are required for a district they should overlap considerably so that no area is permanently relegated to the edge of a map. A computer mapping system that could print out basemaps and other mapped information within any chosen set of boundaries would be ideal but to our knowledge at this time no such system is practical and workable at the required level of physical detail.

Detailed base maps showing structures, street space, and interiors of publicly accessible buildings are not usually available. Such maps should be prepared only for areas where the district scale analysis indicates special complexity. Likely candidates are primary shopping streets, the vicinity of transit stations and major new developments that are closely tied into the existing fabric. Building configurations at this scale can usually be traced from assessor's maps. Building frontages and accessible interior spaces can be mapped by a careful visual survey - actual measurements are not usually necessary. We mapped the interiors in Harvard Square in great detail but found this to be superfluous for the type of analyses we actually conducted. A more schematic approach used in the auto restricted zone studies was much faster and quite adequate. We used student interns for most of this mapping.

Activity maps We found traffic flow and parking location maps generally available. Parking utilization patterns are usually not well observed but can be simply surveyed and mapped. Open lot parking utilization can be very effectively recorded on aerial photography at specified times of day.

Few cities have good pedestrian data available. We have made two types of counts: hourly flow and pedestrian density. The former can be determined by counting across specified cordons at midblock across sidewalks and at the corners. Ten or fifteen minute counts can be extrapolated to hours at off-peak times but this should not be done for the sharply peaking activities of lunch hour and the 9am and 5pm rush.

Pedestrian densities can be obtained by counting the number of people within a unit area of space (i.e. 10' x 50' of sidewalk) at a given time and obtaining a per square foot density. The value of this technique is that a comparable density figure can be obtained for inside spaces. This type of count can give an accurate description of the level of pedestrian activity at a given time and can be related to retail potential. It can also show "level of service" or congestion of pedestrian areas. Pedestrian counts for a particular map should be obtained for comparable times of day and week, should be similar weather conditions, should avoid special events (such as football games in Harvard Square) and should be identified by these conditions.

Value maps can be drawn by individual community members during workshops or interviews on 8½" x 11" reduced basemaps. Coding should be clearly established beforehand to insure comparability. These maps can then be summarized by planners on larger basemaps that show the weighting by the number of respondents who made particular judgements for each location (see Harvard Square case study). "Cognitive maps" asking individuals to map an area on blank paper without prearranged code proved to be very revealing and excellent individual communication tools but difficult to analytically summarize.

Format and handling of maps is a very important issue. We found several cities that had collected and mapped extensive information that was somehow inaccessible.[1] Large display panels usually need to be prepared in color for clarity. A very good use for such maps is to set then up covering the walls of a conference room or of a community planning center in a storefront and use them as the on-going context for discussions related to the area. This way all participants in these discussions will gradually become familiar with the material and develop their own common urban ecological language to discuss their community. This type of on-going information context is particularly important for task forces, policy groups, or other planning groups that meet regularly over a long period of time. We have found that when such information is not constantly displayed and updated with latest findings and decisions, people have a much greater tendency to backtrack and lose sight of the context of their discussions.

Reproducible 8½" x 11" size black and white reductions of the major maps should be prepared with simplified coding to allow wider access to the information.

1. The most dramatic example was an exhaustive survey of the downtown by the "Interface: Providence" group that was in the process of being put on computer cards but never completed and was thus mostly unavailable for the study we conducted there.

6. APPLICATION TO TRANSPORTATION ISSUES

Several examples in the previous sections have already indicated the potential usefulness of the analysis techniques for transportation planning and impact assessment. In general terms the primary effects of transporattion decisions on the ecology of urban centers include:

1. Changing accessibility and therefore activity generation both directly, by delivering fewer or more people, and indirectly through inducing other developments.

2. Changing activity patterns and environmental conditions on the streets by increasing or decreasing auto traffic, goods movement, bus volumes, parking and pedestrian circulation.

3. Changing the physical and spatial structure by the addition of fixed guideways, roadways or parking facilities.

4. Altering land resources by both occupying land and by either improving or cutting off direct access to parcels.

The effect of a transportation proposal (or several alternatives) can be mapped in all of these categories, superimposed on the maps of existing conditions and examined for positive and detrimental effects for each sub-area, block or street.

Urban Ecological Analysis can also play a basic role in the devleopment of detailed transportation plans. The technique will provide the base for district wide traffic management plans, and for adding new fixed guideway transit. It can also be used for detailed decisions on the configuration of rapid transit stations and the specific location and design of bus stops.

1. District Wide Traffic Management in downtown or dense residential neighborhoods must respond to the often conflicting claims on the public streets by autos, transit and delivery vehicles, pedestrians and bicycles. The vocabulary of improvements may include traffic diversion, auto restricted zones and pedestrian streets, exclusive busways, parking restrictions, special hours for service vehicles. It is essential that the networks created by these elements not only work as transportation systems but are compatible and complimentary with the urban fabric surrounding them.

   In order to insure the appropriate use of streets and the appropriate allocation of space within the street, we developed a system of classification for street character based on urban ecological factors. The factors considered include street width, adjacent building masses and frontages, pedestrian and vehicular entrances opening on to the street, present pedestrian, auto and service volumes, symbolic and visual role of the street in the city fabric. The summary characterization of a street may be: primary pedestrian/shopping street; secondary pedestrian/shopping street; auto distributor street; auto and service access street; transit/pedestrian way. The resulting street classification should be the best possible fit between the street's natural role in the fabric and requirements of the various networks for access, continuity and capacity.[1]

The street characterization and classification approach was applied for the five auto restricted zone demonstration plans (Boston, Burlington, Memphis, Providence and Tucson).[2] The ecological analysis identified streets that were both "suitable" (i.e., not constrained by traffic demand or access factors) and "capable" (i.e., had appropriate activities and generators) to become fully pedestrianized, those that were appropriate for pedestrian/transitways and those that could carry the bypass traffic.

2. Fixed Guideway Transit location and design can involve both generation and displacement of activities. It may greatly effect the streetscape if on or above ground level. It can create the incentive for new growth or revival but it can also become a barrier between districts and activities. "Suitability" and "capability" maps of a district can provide a general pattern useful during the conceptualization of alternative routes, technologies, vertical alignment and station location. Later stage alternative route analysis and impact evaluation requires a more detailed juxtaposition of physical configuration and activity generated by the proposal to the existing conditions. If the guideway is on grade interaction with traffic patterns, pedestrian crossing, shopping and neighborhood social patterns is likely to be critical. Elevated guideways including Downtown People Movers are likely to impact streetscape and architectual character including light, shade, noise, views and microclimate. These impacts can be specified for all locations, examined for critical interaction with existing conditions at each place.

3. Station Location and Configuration can be designed and evaluated in juxtaposition to the detailed "node" scale analysis. Specific maps to check are: architectural evaluation, pedestrian density, pedestrian/vehicular conflicts, existing retail analysis (type, intensity, floor rent) and evening activity (for potential visibility of station for security). We found that the Harvard Square study suggested a series of criteria for the redesign of the subway station which was planned for reconstruction. Initial prevailing opinion was that it would be advantageous to the major retail shops in Brattle Square (one block from the present station entrances) to have station access closer to them. We then examined closer the relationship between the gradation of pedestrian volumes (heaviest near the subway, moderate in Brattle Square) and the type of retail they supported. We found that the location near the station was optimal for

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1. Such street classification was adopted as public policy by Portland,OR for downtown (Portland City Council, 1975) and city wide (1977).

2. See Moore-Heder: Opportunities for Downtown Improvement, Moore-Heder/ Minuteman Press, Cambridge, Mass., 1977.

news stands and other impulse-item stores but the more expensive apparel, boutique and furniture stores were much better off slightly removed from the greatest crowds. Thus we recommended that the main entrance of the station should remain in its present location.

The following case studies further illustrate the use of urban ecological analysis for determining the appropriate pattern of transportation improvements: traffic re-routing in Harvard Sqaure, pedestrian and shuttle bus service in Boston and integration of bus service into the downtown environment in Memphis.

HARVARD SQUARE URBAN ECOLOGY STUDY

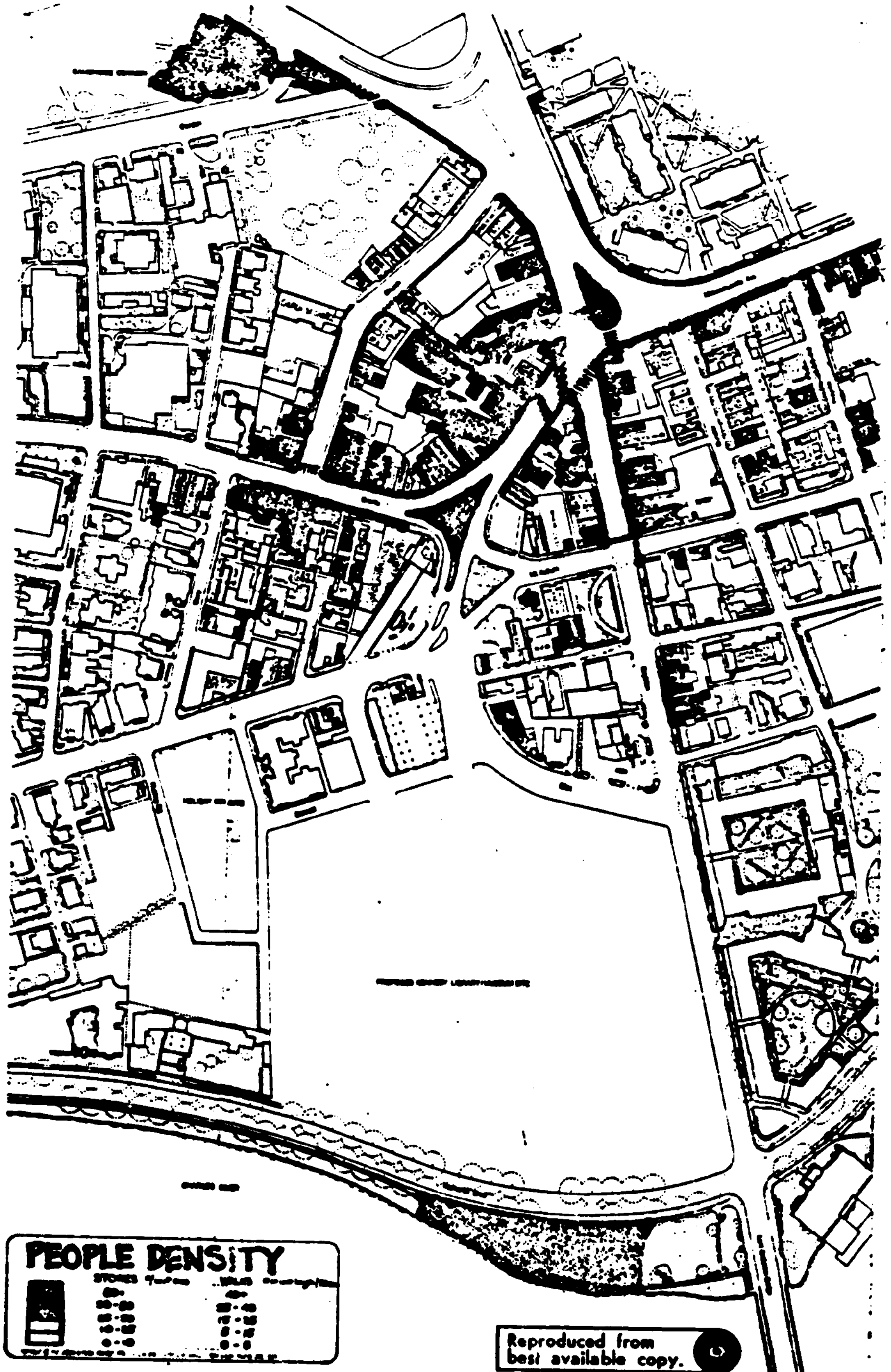
The purpose of this work was to assist local community organizations in setting environmental goals and policies for Harvard Square. The area is dense and compact with an extraordinary variety of environments and activities. Balancing the activities and maintaining the diversity of the environment had been articulated as the general objectives. Besides using existing planning information, the study team prepared a detailed basemap showing the ground level of public and private spaces and made a detailed record of activities. The information was introduced in community workshops and resulted in group analysis and policy plans for public space development and controls on private development.

The illustrations include analyses by the consultant team:

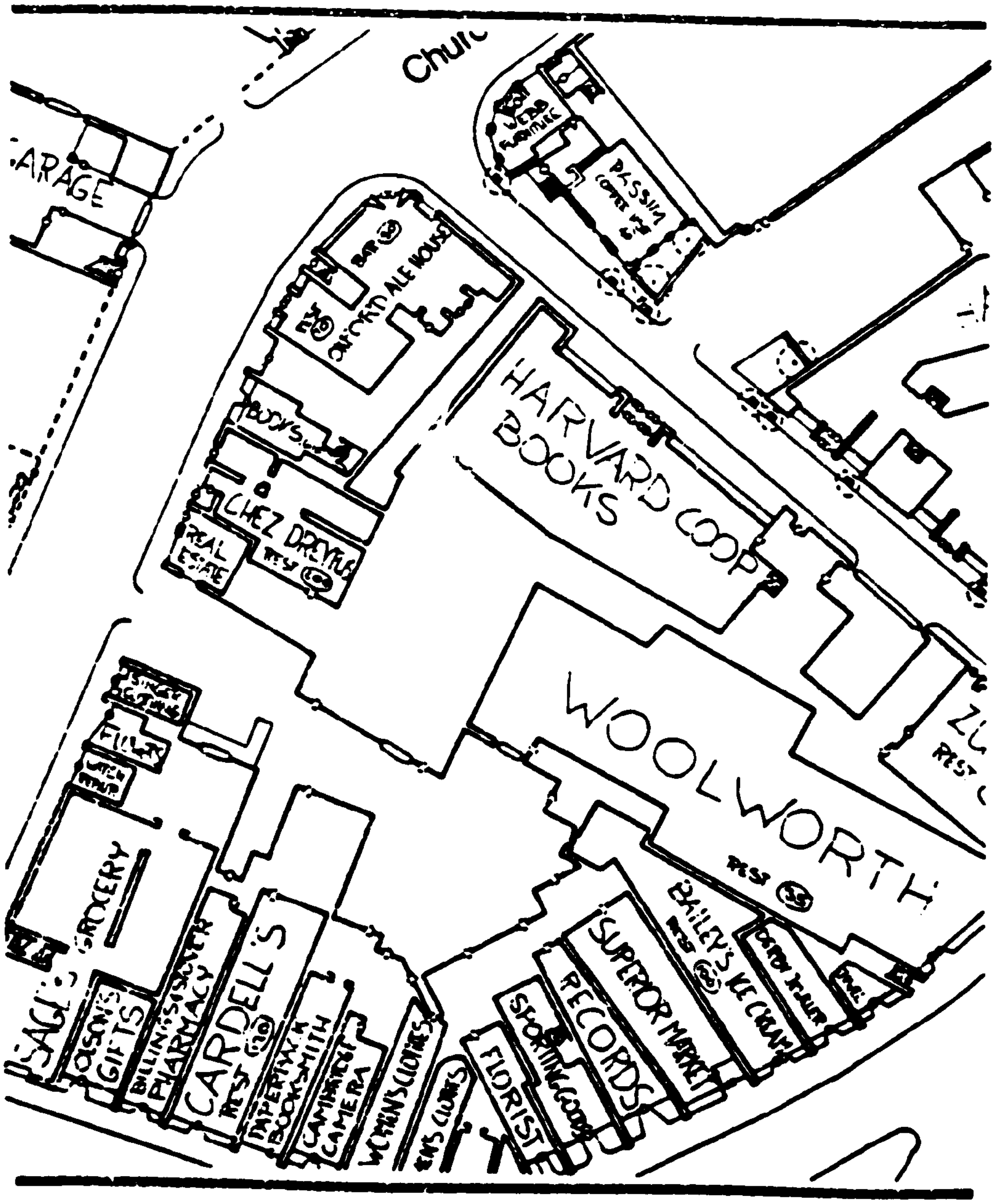
- o Pedestrian Density based on actual counts of pedestrians on a Saturday afternoon on sidewalks and in stores
- o Detail of Basemap prepared by the consultants on the basis of detailed studies
- o Activity Settings -- a summary analysis based on pedestrian volumes, types of retail and observed activities
- o City Center -- the details of one activity setting
- o Matrix of Interaction among activities
- o Public Right of Way -- detailed use analysis
- o Development Capabilities rating likelihood of private development based on ownership, building use, land utilization, etc.

And maps generated in the community workshops:

- o User Summary Map aggregating primary use patterns
- o Areas Liked and
- o Areas Disliked -- maps aggregating the participants' attitudes
- o Policy Recommendations -- examples of plans generated in the workshops at the conclusion of analysis and discussion

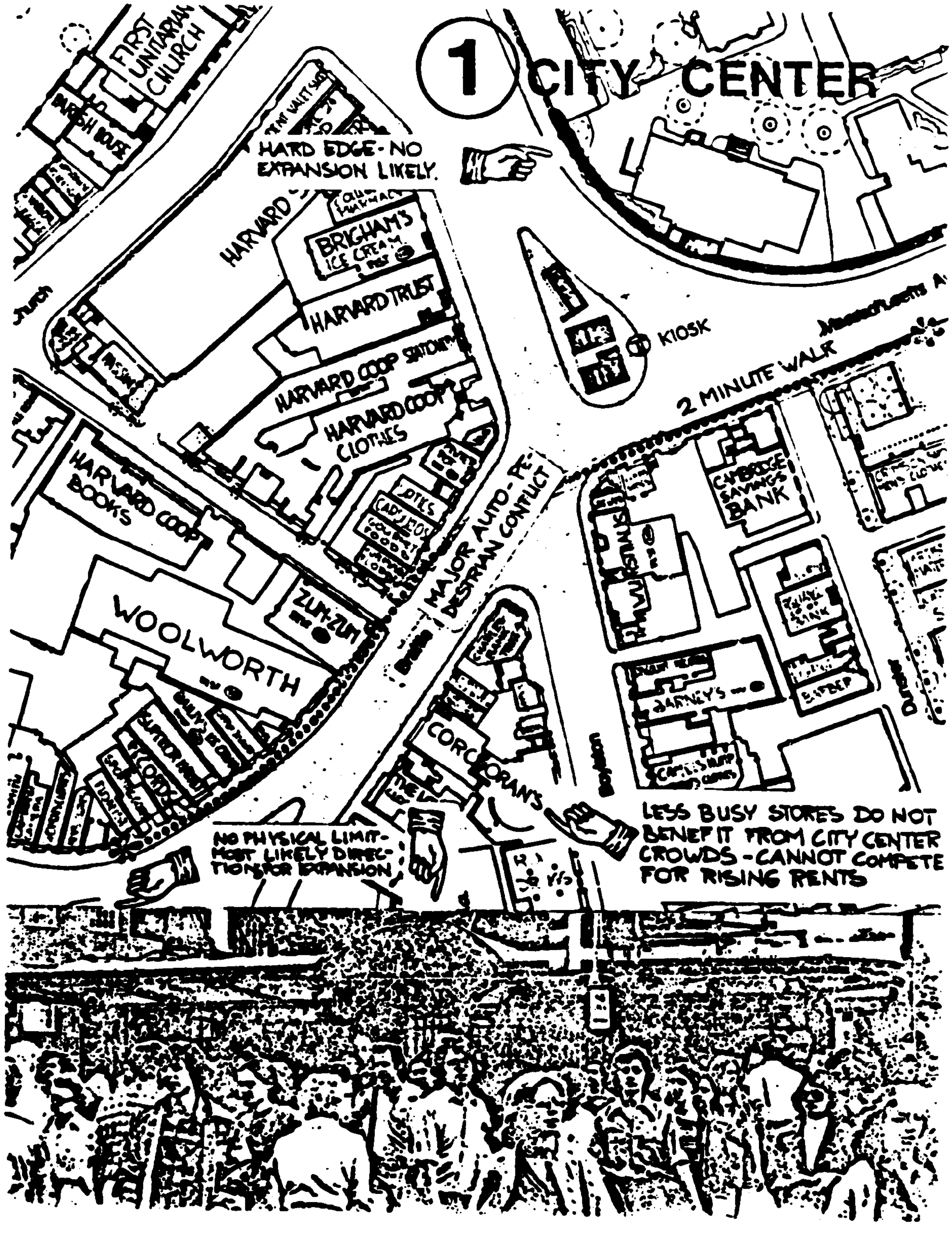


PEOPLE DENSITY
HARVARD SQUARE URBAN ECOLOGY STUDY



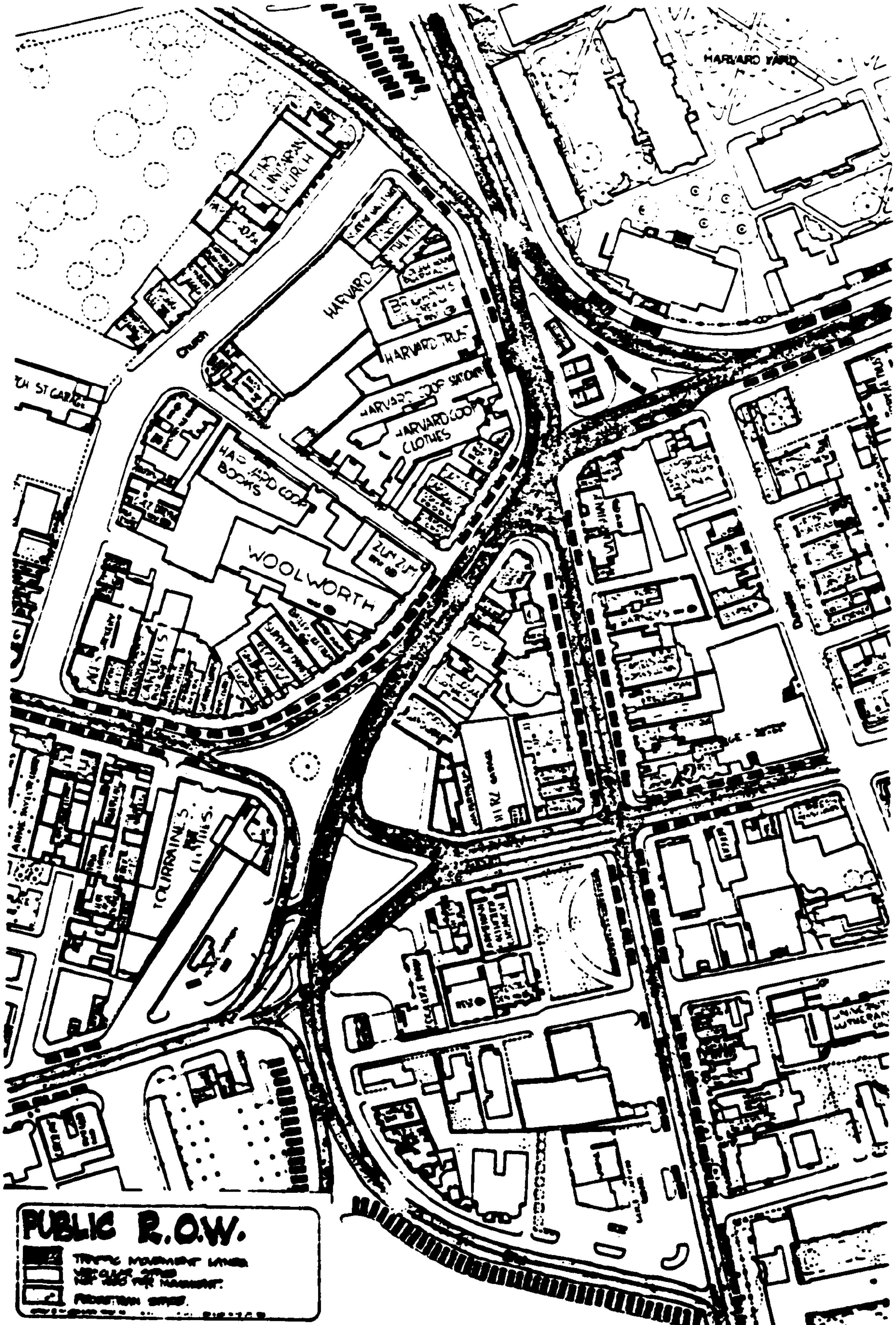
DETAIL OF HARVARD SQUARE BASE MAP


9
10
2
4
3
2
12
8
6
ACTIVITY SETS.
HARVARD SQUARE URBAN ECOLOGY STUDY

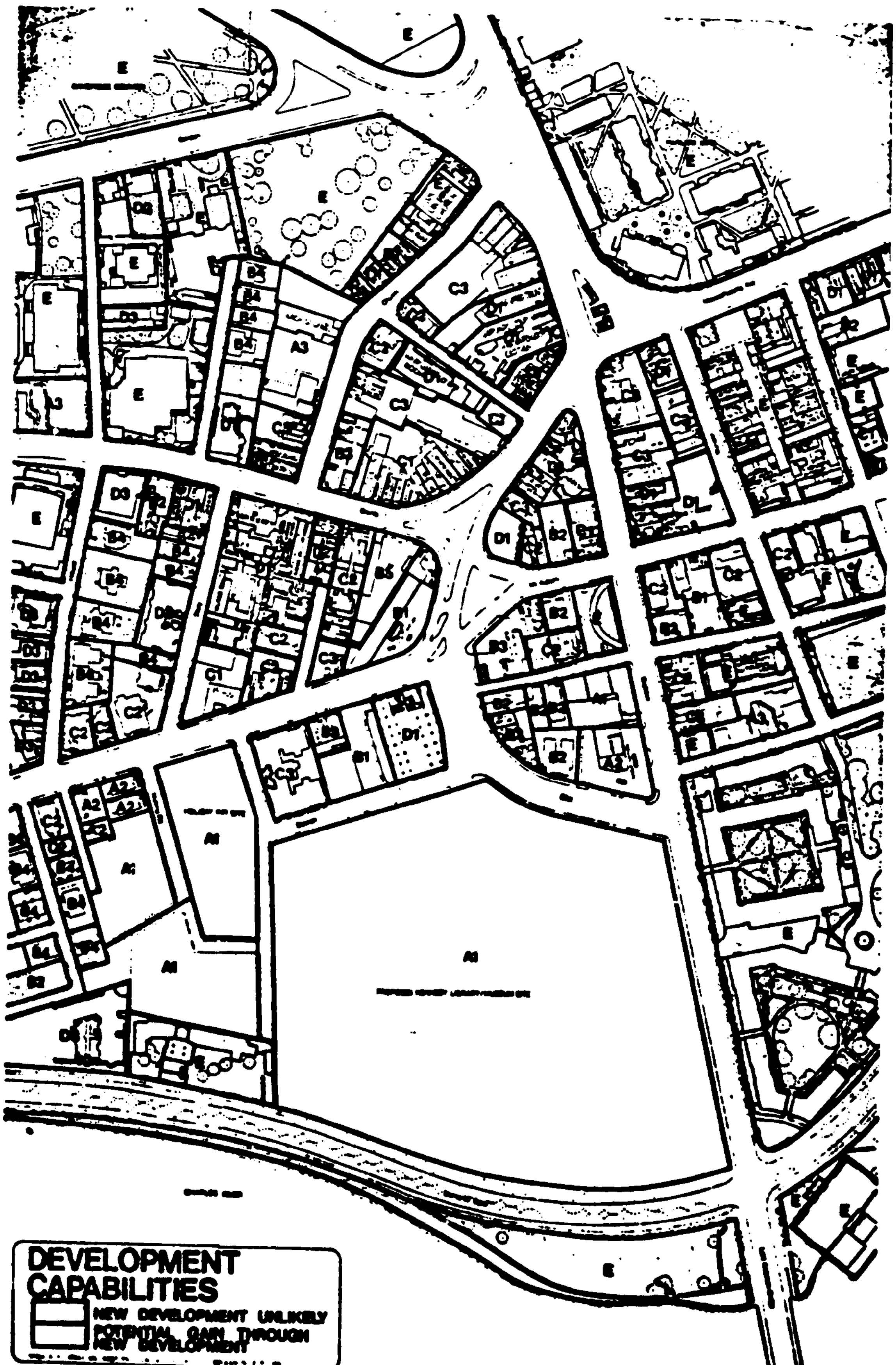

1 CITY CENTER
FIRST UNITARIAN CHURCH
PARISH HOUSE
HARD EDGE-NO EXPANSION LIKELY.
HARVARD
BRIGHAM'S ICE CREAM
HARVARD TRUST
HARVARD COOP STATIONERY
HARVARD COOP CLOTHES
KIOSK
2 MINUTE WALK
CAMBRIDGE SAVINGS BANK
HARVARD COOP BOOKS
WOOLWORTH
ZUM-ZUM
MAJOR AUTO-PEDESTRIAN CONFLICT
CORCORAN'S
BARNEY'S
LESS BUSY STORES DO NOT BENEFIT FROM CITY CENTER CROWDS - CANNOT COMPETE FOR RISING RENTS
NO PHYSICAL LIMIT-MOST LIKELY DIRECTIONS FOR EXPANSION

ACTIVITY SETS CONCERN FOR PUBLIC RIGHT OF WAY USE BY PEDESTRIAN V. AUTOS	PRIMARY NEED FOR AUTO ACCESS AND SERVICE	INSUFFICIENT PEDESTRIAN SPACE, CROWDING CONFLICT W/CARS	EXISTENCE OF ACTIVITY SET THREATENED BY CONGESTION, NOISE, POLLUTIO	PRIMARY NEED FOR ON-STREET PARKING	PARTICULAR CONFLICTS
(1) CITY CENTER	*	*		THIS IS AN INEFFICIENT USE OF PUBLIC SPACE (see map) - WHERE SHOULD IT CONTINUE?	Competition for space by through & local traffic and pedestrians
(2) TOWN SQUARE		*	*		Crowding and pressure reduce use by older; quieter groups
(3) SPECIAL SHOPPING	*	*	*		Many customers need car access, some shop may leave due to problems
(4) STUDENT-PUBLIC		*			Crowded sidewalks and crossings along Mass. Ave.
(5) SOCIAL NICHES		*			Traffic noises and fumes reduce amenity
(6) PUBLIC OPEN SPACE		*	*		Access, noise and pollution problems
(7) TOURIST AREA		*			Disorientation and discomfort of visitors
(8) PRIVATE OFFICE	*				Need for short term parking for clients
(9) SEMI-PUBLIC INSTITUTION	*				Need for short term parking
(10) HARVARD UNIVERSITY					
(11) RESIDENTIAL NEIGHBORHOOD	*		*		Spill-over of commercial traffic and parking
(12) AMBIGUOUS AREAS					Currently absorb most off-street parking in the square

HARVARD SQUARE URBAN ECOLOGY STUDY **S5**

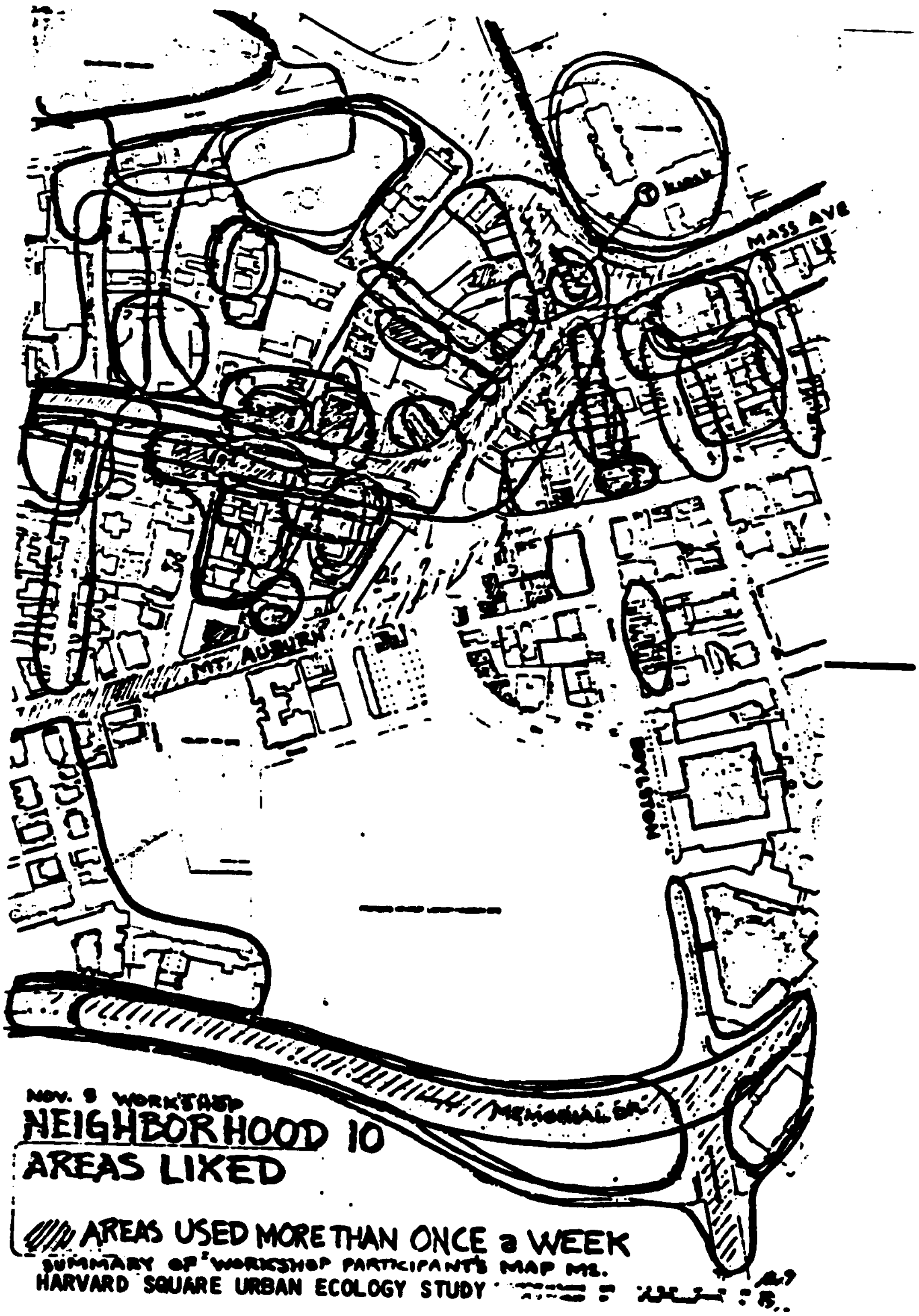


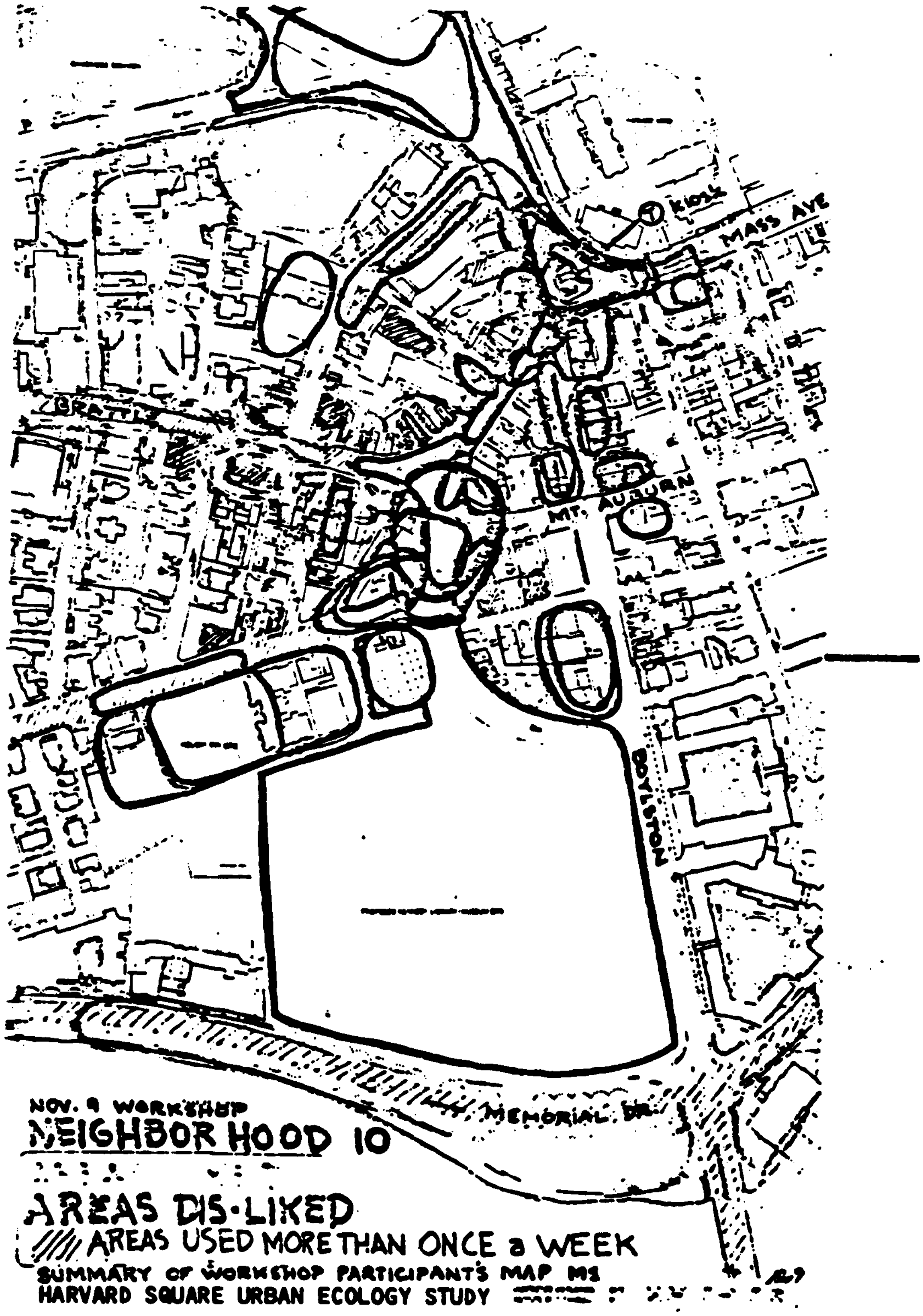
HARVARD SQUARE URBAN ECOLOGY STUDY

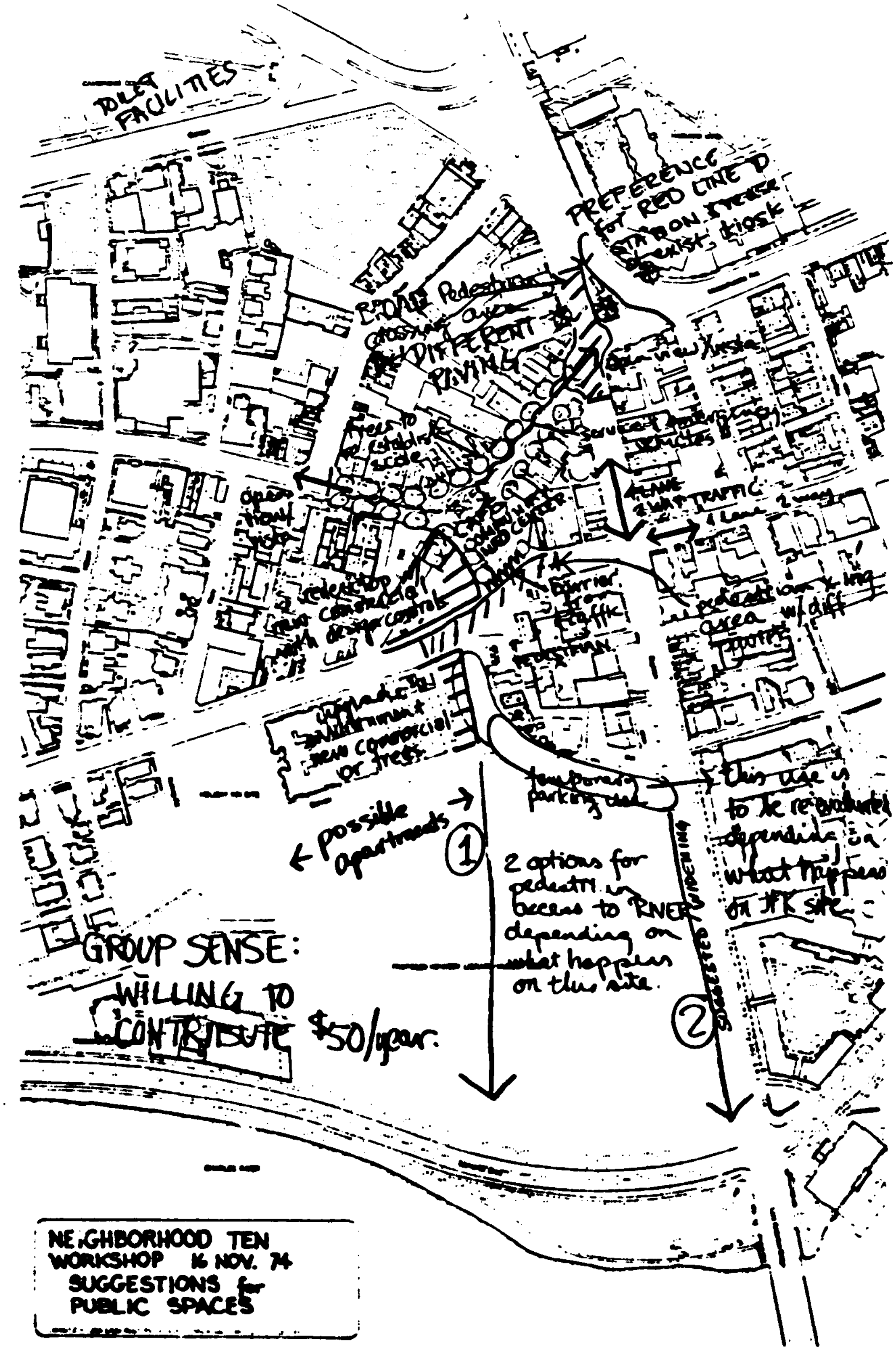


HARVARD SQUARE URBAN ECOLOGY STUDY

HARVARD SQUARE URBAN ECOLOGY STUDY


MASS AVE
MT. AUBURN
BOYLSTON
MEMORIAL DR.
NOV. 8 WORKSHOP
NEIGHBORHOOD 10
AREAS LIKED
AREAS USED MORE THAN ONCE a WEEK
SUMMARY OF WORKSHOP PARTICIPANT'S MAP MS.
HARVARD SQUARE URBAN ECOLOGY STUDY


KIOSK
MASS AVE
BRATTLE
MT. AUBURN
BOYLSTON
MEMORIAL DR.
NOV. 9 WORKSHOP
NEIGHBORHOOD 10
AREAS DIS-LIKED
AREAS USED MORE THAN ONCE a WEEK
SUMMARY OF WORKSHOP PARTICIPANT'S MAP MS
HARVARD SQUARE URBAN ECOLOGY STUDY

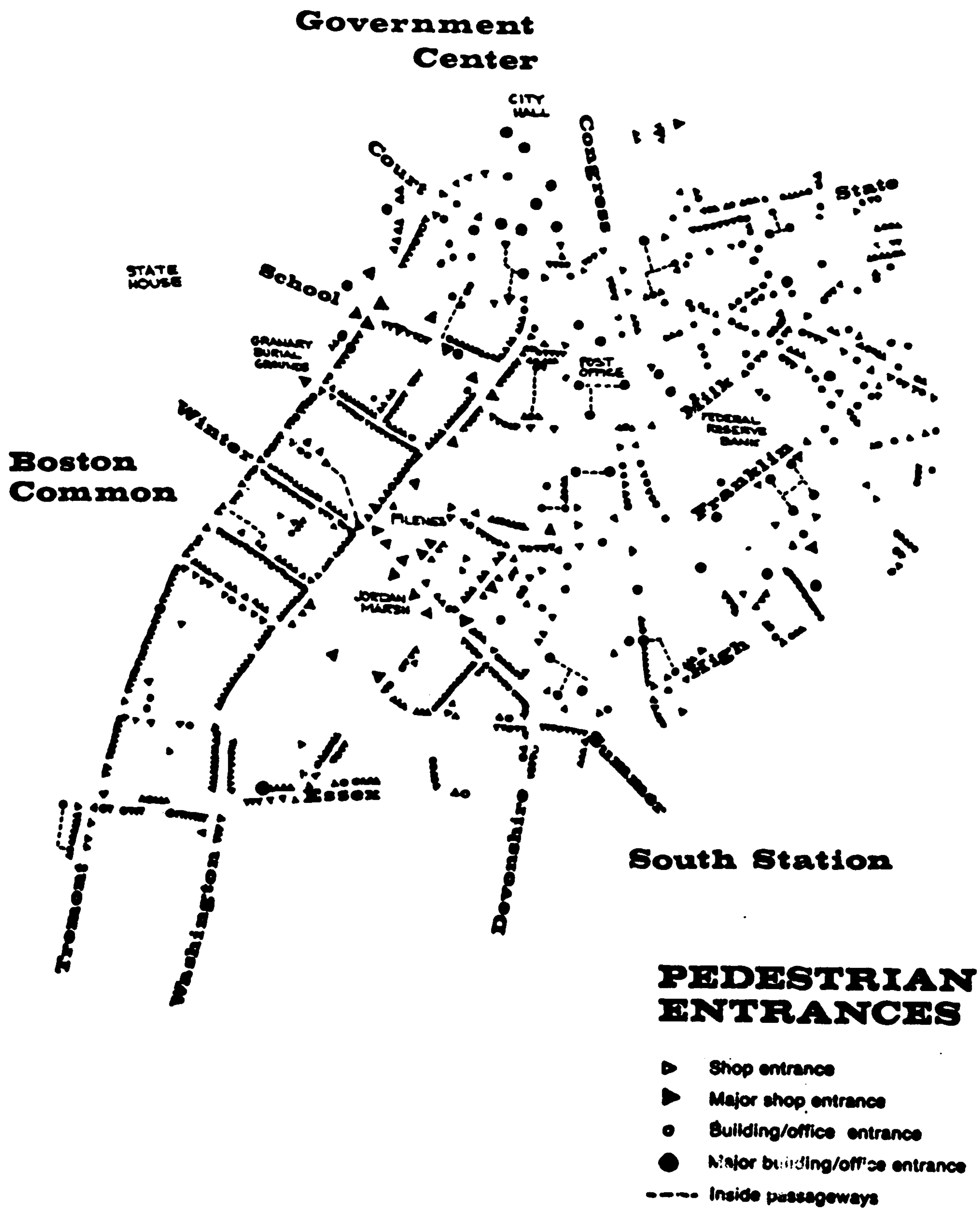

TOILET FACILITIES
PREFERENCE for RED LINE
DIFFERENT PAVING
barrier from traffic
PEDESTRIAN
temporary parking use
this use is to be re-evaluated depending on what happens on JFK site
← possible apartments
2 options for pedestrian access to RIVER depending on what happens on this site.
SUGGESTED WIDENING
GROUP SENSE:
WILLING TO CONTRIBUTE $50/year.
NEIGHBORHOOD TEN
WORKSHOP 16 NOV. 74
SUGGESTIONS for
PUBLIC SPACES

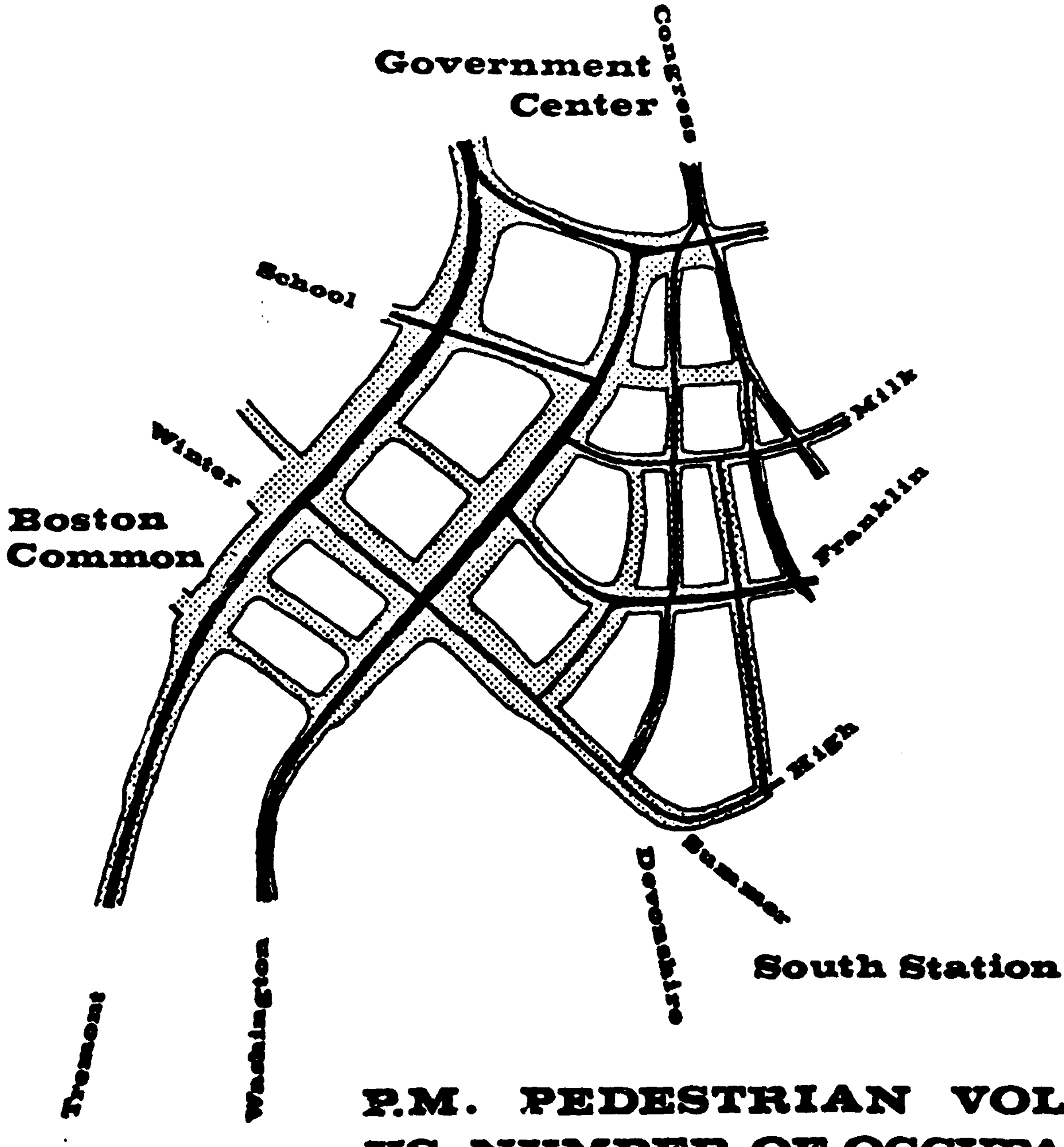
BOSTON AUTO RESTRICTED ZONE STUDY -- Pedestrian Potential Analysis

As part of the ARZ study Moore-Heder conducted an analysis of current conditions of and potential improvements to the pedestrian environement of downtown Boston. The resulting conclusions about pedestrian potential were then balanced against other claims on the streets (traffic, transit, etc.) in designing the ARZ demonstration plan.

The illustrations include:

- Pedestrian Entrance Map that characterizes the downtown streets by the frequency and size of building and shop entrances served
- Comparative Pedestrian and Auto Occupant Volumes showing activities competing for the street space
- Pedestrian Conflicts -- showing detailed analysis of pedestrian conditions along streets identified as critical by area-wide analysis
- Photo Observation of pedestrian conflicts
- Pedestrian Potential -- aggregate analysis map showing potential benefits of pedestrian improvements


Government Center
CITY HALL
Court
Congress
State
STATE HOUSE
School
GRANARY BURIAL GROUND
POST OFFICE
Milk
FEDERAL RESERVE BANK
Winter
Boston Common
Franklin
FILENES
JORDAN MARSH
High
Essex
Summer
South Station
Tremont
Washington
Devonshire
PEDESTRIAN ENTRANCES
Shop entrance
Major shop entrance
Building/office entrance
Major building/office entrance
Inside passageways



P.M. PEDESTRIAN VOLUMES VS. NUMBER OF OCCUPANTS IN CARS

1/4 inch equals 5000 people — PM number of occupants in cars — PM pedestrian volumes

SOURCE: B.R.A.

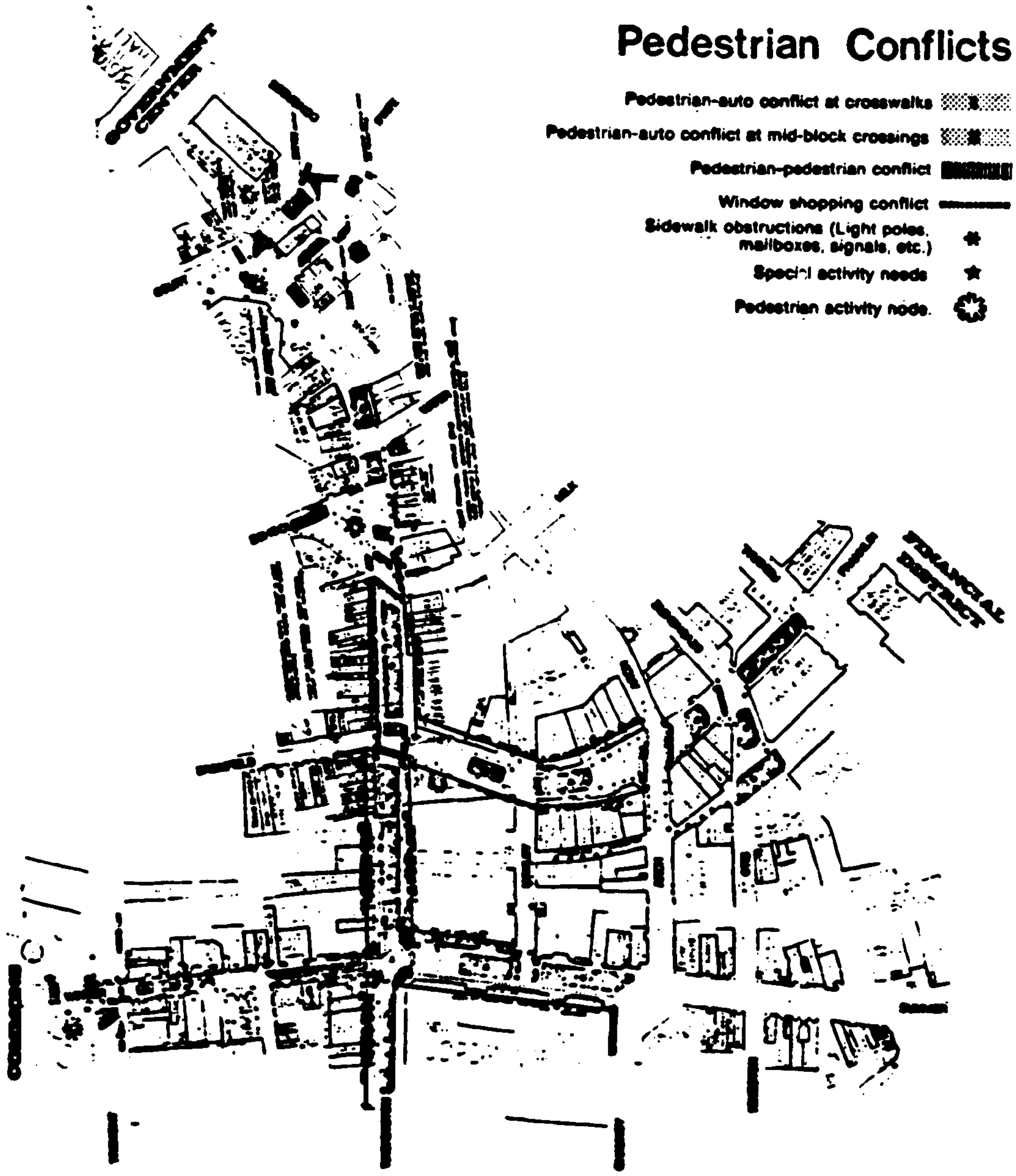
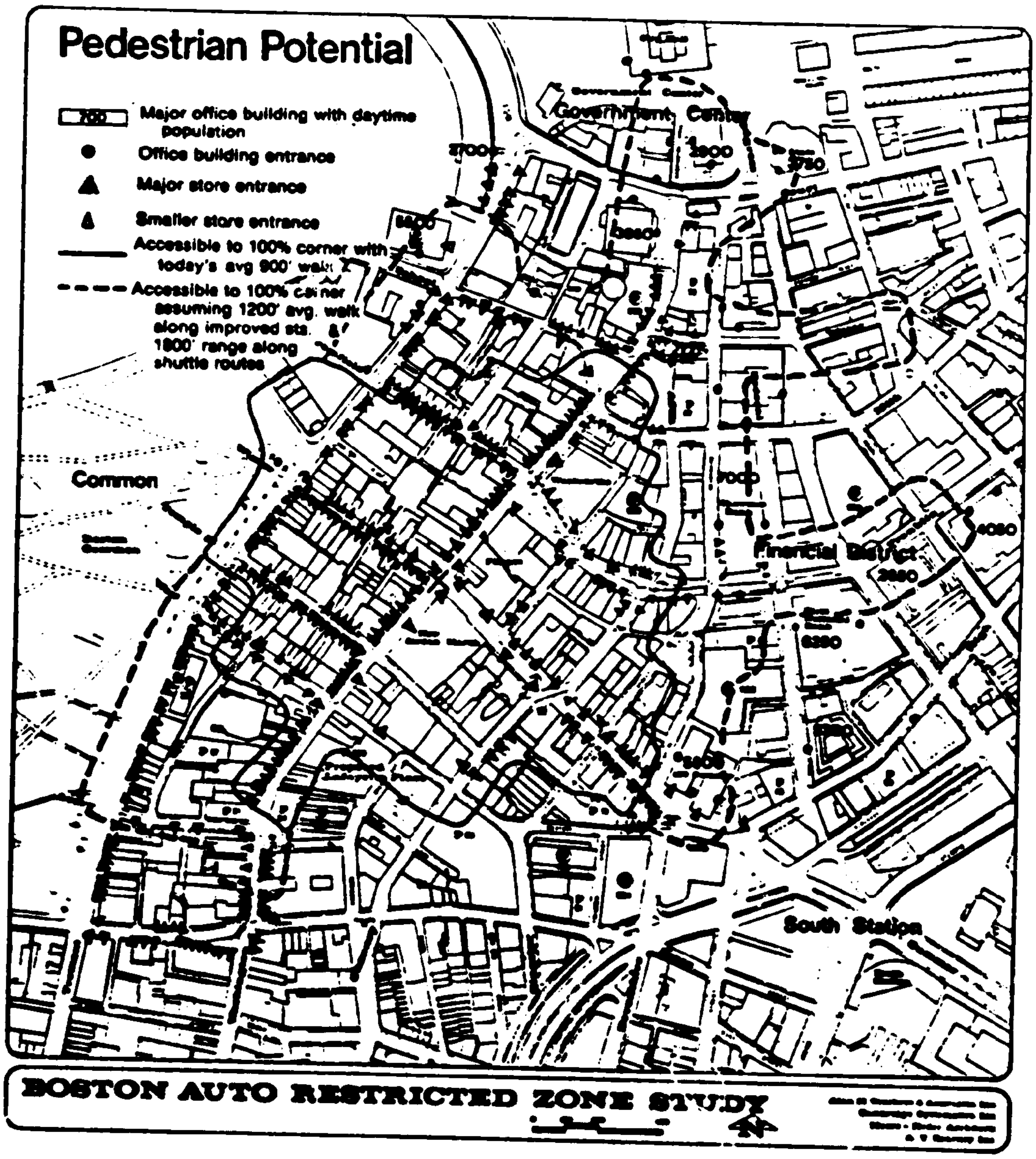

Pedestrian Conflicts
Pedestrian-auto conflict at crosswalks
Pedestrian-auto conflict at mid-block crossings
Pedestrian-pedestrian conflict
Window shopping conflict
Sidewalk obstructions (Light poles, mailboxes, signals, etc.)
Special activity needs
Pedestrian activity node.

PHOTO 19: Inadequate Space Provision for Newspaper Vendor on Washington Street

PHOTO 20: Lack of Sidewalk Space on Winter Street - creates congested environment for both window shopping and pedestrian movement

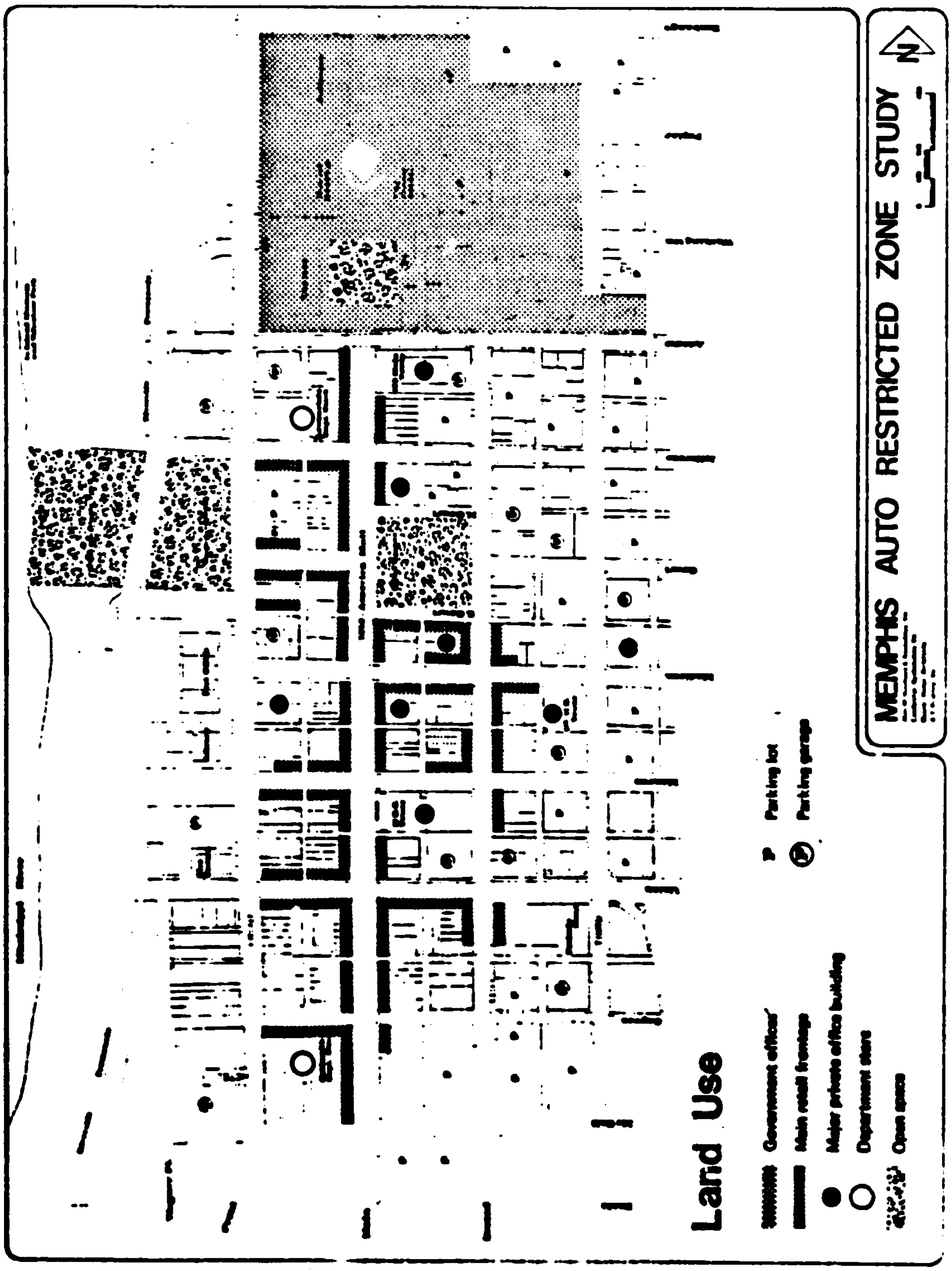

Pedestrian Potential
Major office building with daytime population
Office building entrance
Major store entrance
Smaller store entrance
Accessible to 100% corner with today's avg 900' walk
Accessible to 100% corner assuming 1200' avg. walk along improved sts. & 1800' range along shuttle routes
Government Center
Common
Financial District
South Station
BOSTON AUTO RESTRICTED ZONE STUDY

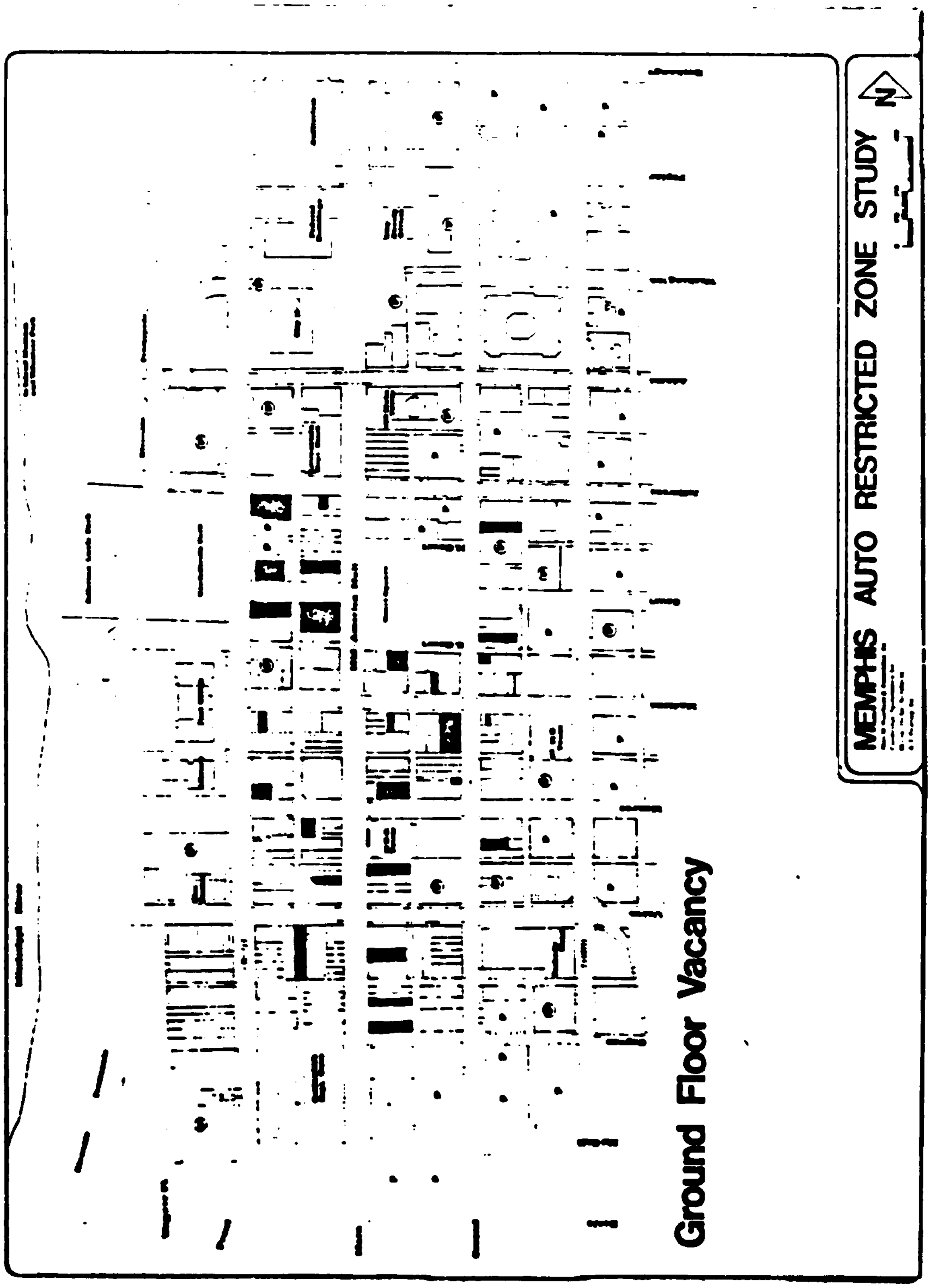
MEMPHIS AUTO RESTRICTED ZONE STUDY -- Mall Impacts and Potential Bus Stop Improvements

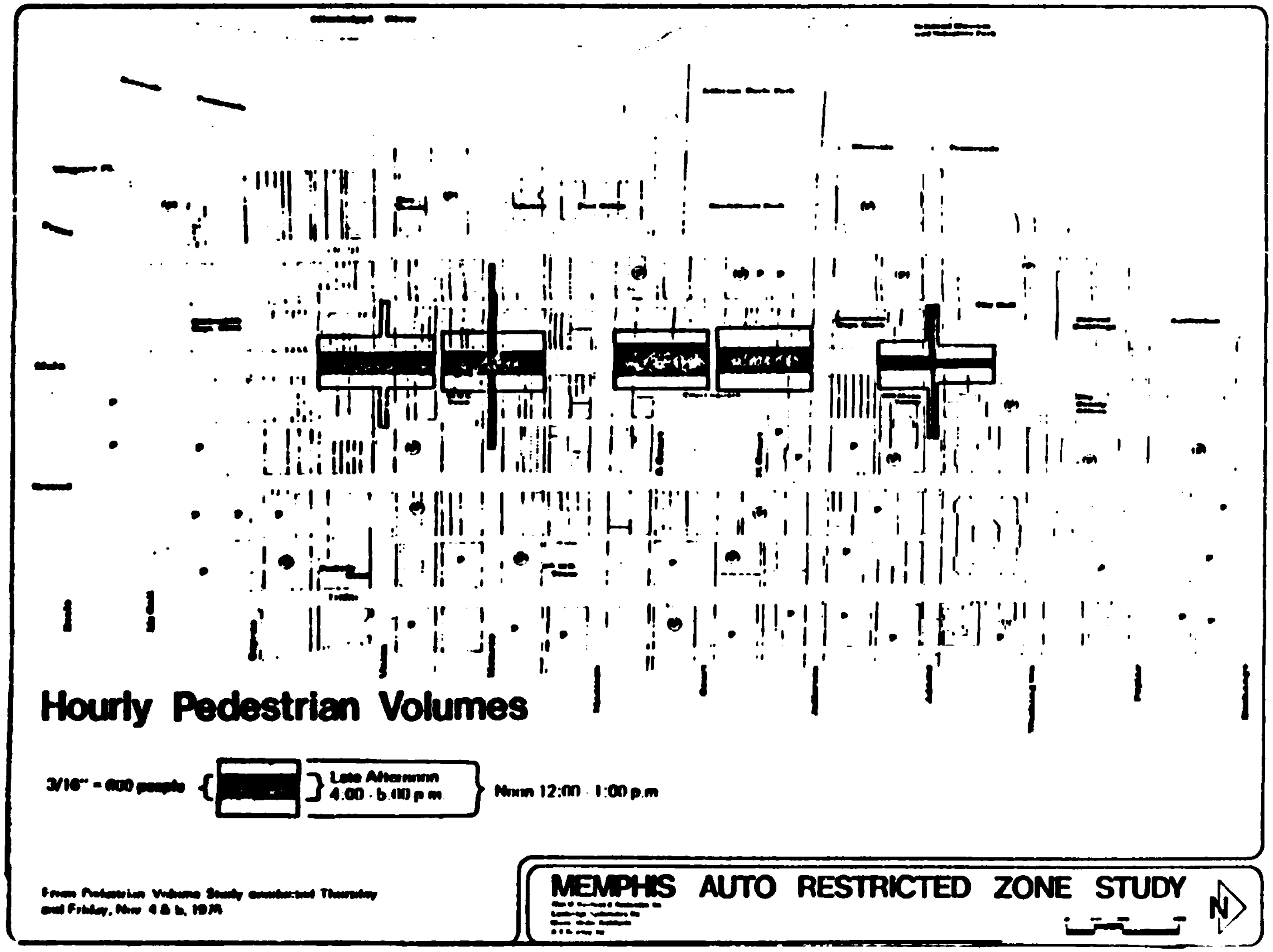
As part of the ARZ study we analyzed the recently completed pedestrian mall in Memphis to test its impact on retail and pedestrian activity. Looking at the city fabric just beyond the mall revealed that the bus stops concentrated along the two parallel streets had become isolated from the other pedestrian activities and functioned in a crowded and uncomfortable atmosphere. A count of passenger accumulations at major stops and a study of the adjacent building fabric led to specific design recommendations for improvement.

The illustrations include:

- Land Use Map of mall district
- Ground Floor Vacancies among shops
- Pedestrian Volumes on the mall
- Problems and Resources -- aggregated analysis diagram showing the relationship between the mall and elements of the surrounding environment
- Photographic Analysis of bus related pedestrian conditions
- Design Recommendations for major bus stop


MEMPHIS AUTO RESTRICTED ZONE STUDY
Land Use
Government offices
Main retail frontage
Major private office building
Department store
Open space
Parking lot
Parking garage


MEMPHIS AUTO RESTRICTED ZONE STUDY
Ground Floor Vacancy


Hourly Pedestrian Volumes
3/16" = 600 people
Late Afternoon 4:00 - 6:00 p.m
Noon 12:00 - 1:00 p.m
MEMPHIS AUTO RESTRICTED ZONE STUDY
N

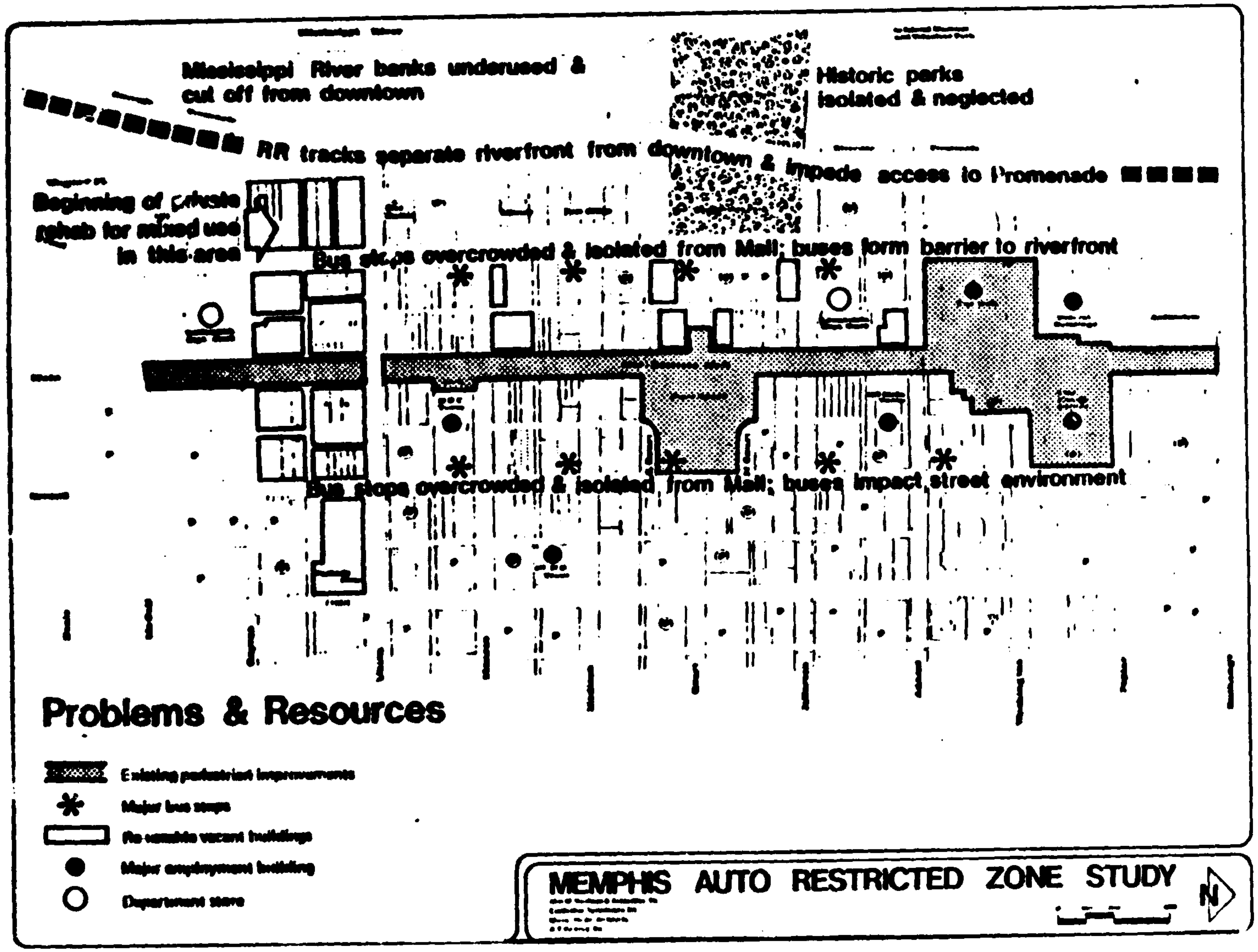

Mississippi River banks underused & cut off from downtown
Historic parks isolated & neglected
RR tracks separate riverfront from downtown & impede access to Promenade
Beginning of private rehab for mixed use in this area
Bus stops overcrowded & isolated from Mall; buses form barrier to riverfront
Bus stops overcrowded & isolated from Mall; buses impact street environment
Problems & Resources
Existing pedestrian improvements
Major bus stops
Re-usable vacant buildings
Major employment building
Department store
MEMPHIS AUTO RESTRICTED ZONE STUDY
N

PHOTO 11: Transit Shelter Blocking Sidewalk

PHOTO 12: Buses Queuing on Front Street

DOWNTOWN MEMPHIS

Up to 60 or 70 passengers accumulate at major downtown bus stops. While bus traffic is heavy on front and second streets, headways for each bus route average ca 20 minutes at peak hour and longer at off peak. The bus shelters provided are inadequate for downtown use. Waiting passengers are exposed to weather, bus fumes and noise and conflicts created by crowding.

TYPICAL EXISTING CONDITION:
Buses by narrow sidewalks create canyon effect, reverberating sound and trapping fumes where people wait

Prefab shelter adequate for 8 or 10 block most of sidewalk

Remaining 10 to 60 waiting passenger wait against wall without weather protection, blocking rest of sidewalk

RECOMMENDED STANDARDS FOR DOWNTOWN BUS ARCADE DESIGN

Lease space in building or parking lot adjacent to major stops – rebuild as waiting space open to sidewalk – provide other activity such as transit office and vendors for surveillance – provide closure after hours

- Provide adequate ventilation, mechanically added if necessary
- Lights and radiant heat
- Closed circuit T.V. for monitoring buses
- Rolling screen for night closure
- Mall type shelter extended over sidewalk at bus loading points
- Clear for other pedestrians using sidewalk
- 10 to 15 outside seats
- property line
- Rebuild floor at sidewalk level if necessary
- Encourage vendors, shops, restaurants to open onto Bus Arcade
- Provide public toilets where possible

Location:
On Second at Madison and Jefferson
On Front at Court

Auto Restricted Zone Design Pattern Moore-Heder 1976

5. SYSTEM DESIGN ALTERNATIVES

This section describes generally system design alternatives and discusses their implications on system cost and usage. It should be used as an introduction to the analytical ridership, cost, revenue, and impact estimation procedures presented in subsequent sections.

5.1 PHYSICAL DESIGN CONSIDERATIONS

5.1.1 Network Configuration

The downtown circulation system network configuration should be designed primarily on the basis of the land use pattern it will serve. There are essentially three possibilities: the linear or shuttle, the loop, or the grid pattern. If the key land uses are essentially strung out in a line, a linear system is likely to be most appropriate. Vehicles on this system would operate in shuttle-like fashion. If the land uses form a ring, a loop system could be suitable. In such a case, a further choice would be required between a single or double loop; in the former all vehicles would travel in only a clockwise or counter-clockwise direction, while in the latter vehicles could travel in both directions. The trade-off between these two are lower costs in the former and shorter average travel times in the latter. A large number of stops in the loop would tend to favor the double loop. The third basic network configuration is more complex and is spread over a large area. Here the problem of separating two lines from one another emerges, along with the requirement for passengers to transfer between one line and another.

5.1.2 Interfaces with the Existing System

In the case of a DPM system, there are three approaches to interfacing with the regional freeway or street network:

- Design the DPM route to serve existing parking lots and garages. This approach may generate significant ridership from regional auto trips but does little to reduce auto use and storage requirements within the DPM service area.

- Design the system to serve under-utilized parking locations on the fringe of the CBD. If the DPM service successfully diverts parking from the CBD to the fringe lots, additional ridership will be generated and the CBD environment will be improved.

- Construct parking facilities on the fringe of the CBD at a location which is well-served by the DPM. This option accomplishes the same objectives as above but increases the supply of parking in the CBD.

Interfacing with the regional transit system can likewise be accomplished by either planning for stations at points on regional transit routes or by construction of one or two transfer stations into which many regional transit lines are routed. This system design not only facilitates the distribution of regional travel in the CBD (which generates DPM ridership and boosts regional trip service levels), but also results in a reduction in the cost of providing regional transit by eliminating operation on the congested CBD streets.

In the interface with both the regional transit system and parking facilities, the transfer conditions are a very critical element. Changing modes introduces additional travel time in the form of waiting and walking time. As will be discussed in detail in a later section, time spent out of a vehicle is generally more onerous than time spent in a vehicle. Thus, transfer facilities must be planned carefully to minimize access and wait times.

5.1.3 Guideways

The most significant design decisions for guideways are their elevation and site location, which will determine the degree to which the guideway creates negative impacts, including visual intrusion, physical disruption, and air and noise pollution. A guideway over public rights-of-way will be visually intrusive, necessarily creating shadows and obstructing lines of sight. The degree of visual intrusion of any particular guideway system is subjective, varying by observer and site specific conditions. However, it is possible to compare the physical dimensions of guideway cross-sections to gain some comparative evaluations. For most proposed DPM systems the outside width of the guideway ranges from about 8 to 12 feet and heights vary from about 2 to 6 feet, exclusive of the vertical members. Of course, for double-track systems, the guideway will be bulkier. Additional bulk will also be necessary if sidings are needed for off-line systems. Aside from the bulkiness of the guideway, the placement of the support structures is also critical. Located at the building line, the guideway may become less visually objectionable but may create a barrier on sidewalks, reducing the effective width for walking. Alternatively, support structures could be profitably placed in existing parking lanes if a deliberate policy of reduced on-street parking is established. The impact of support structures may be particularly large if underground utility relocation and building underpinning is involved. The impact of the support structures is also directly related to the frequency of their occurrence along the line; the shorter the span, the more numerous the supports. This guideway characteristic, a function of guideway weight, generally varies from 50 to 150 feet for DPM systems.

The visual and physical intrusion problem of guideways can be reduced by placing the vehicle right-of-way at grade or below. Placement of the DPM underground may be prohibitively expensive; typical per mile costs for rapid transit lines exceed $40 million. However, placement at grade on wide streets dedicated to pedestrians may be a realistic alternative. A traffic signal preferential system could be designed if DPM headways are not too close to prevent cross traffic, or the DPM might be grade separated only at intersections with major traffic flows. By creating a DPM at grade level, the barrier to use because of stairs or escalators is removed.

Other guideway design characteristics that cannot be ignored include clearances, turning radii, and grades. Clearances will have to be sufficient to avoid conflict with tall ground vehicles, hanging traffic signals and perhaps utility wires or poles. DPM systems with vehicles "hanging off" the guideway will require still taller support structures. Turning radii will have to be kept small enough to negotiate right angles at corners while simultaneously avoiding the misplacement of the support structures on the intersection below. Yet the turning radii can only be as small as the vehicle capability allows. Most proposed systems have turning radii of 30 feet or more. Guideways must also be planned with the climbing capability of the vehicle in mind. Some DPM systems can negotiate grades of only 2 percent; others have demonstrated climbing abilities on grades as high as 10 percent.

5.1.4 Station Design

The design features of stations are tied closely to the decisions made about guideway location and elevation. Station size, however, is more closely related to the demand for the system and not to the particular hardware chosen. For example, station bulk is largely a function of platform space requirement for waiting passengers. For a given demand volume, higher frequency of service and larger vehicles would reduce the platform space required by minimizing the number of passengers on the platform at any one time. For a DPM system with off-line stations, it may be possible to be more flexible in the arrangement of platform space, but more total space might be required because of longer waiting times and the extra trackage at stations for off-line stations. If the demand at a station were excessive, it might become difficult to fit a station within the public right-of-way at all.

Stations located within buildings offer a number of advantages, the most obvious being the removal of the station's bulk and support structures from the public rights-of-way. Platforms, fare collection areas, stairways, escalators, and elevators can be removed from the street and incorporated into the buildings. One can visualize shops and services for the DPM user located in a second floor lobby of a new office building. Advantages include added revenues for rent of retail space in the building and shorter walking distances for DPM users working in the building. However, problems of construction plus security, institutional barriers involving building codes and insurance all may be difficult to deal with. Obviously, newly constructed buildings can be better coordinated to create such schemes than older buildings adapted for that purpose. In fact, it is questionable whether "retrofit" of buildings for DPM stations is practical. Much may depend on the minimization of the combined guideway and vehicle cross-section to allow for threading the DPM through existing structures.

Another way of removing the obstrusiveness of stations is to place them on vacant sites, perhaps those previously used as parking lots but phased out as part of an overall policy of auto restrictions in the CBD.

The examination of the relationship between the arrival rate of passengers at a station or on a station platform and the rate of acceptance of those passengers by station escalators, stairways, fare collection systems, or DPM vehicles is susceptible to detailed analysis by simulation methods. It is possible to determine, for various demand flow rates, what elements of a station design are inadequate when placed under stress. For example, one can ask if queues at escalators become excessive if some escalators malfunction, or does crowding on platforms become dangerous if a DPM vehicle arrives later or not at all? Using known rates of acceptance of vehicles, escalators, and stairways, the limits of demand for a given station design can be determined. Detailed methods for simulation of station design and operation will be outlined in Section 11.

Station design features must also provide for the handicapped and elderly. This includes features such as ramps and elevators which provide access to loading platforms from points within and outside of the station.

5.1.5 Line Haul Capacity

The line-haul capacity of a DPM system is the number of passengers that can be accommodated in vehicles at a given level of comfort at the maximum load point on the system in a specified unit of time. The appropriate capacity will be determined by the upper limit of estimated demand at a point in time and space. To select the proper capacity, therefore, requires knowledge of the size and shape of the demand on the system in both geographic and temporal terms. The three physical characteristics that determine line-haul passenger capacity are: (1) the passenger capacity per vehicle, (2) the number of vehicles per train, and (3) the number of trains that can pass a point in a given unit of time. Again, a price may have to be paid for improvement in each of these areas. To increase the capacity of a vehicle, for example, a larger vehicle may be required, which may translate into higher vehicle costs, and more expensive, larger, and more visually obstrusive guideways. A close relationship exists between vehicle size (measured by vehicle floorspace) and passenger capacity for existing systems. Generally, each additional passenger requires from 4 to 5 more square feet of floorspace. To provide sufficient capacity, seats in the vehicle may have to be limited or omitted entirely, although such an action may not be much of a deterrent for the short trips for which DPM systems are intended. The increase in capacity by joining vehicles in train-like fashion is not possible with all existing DPM hardware. In addition, multi-car trains may require additional employees for surveillance purposes and for alteration of the train consist. The third method of increasing capacity, reduction of headways, again raises the issue of the high cost of sophisticated control equipment, in addition to the higher costs associated with greater operating and maintenance costs of additional vehicle-miles and vehicle-hours of travel. The capacity may also be affected adversely by long dwell times as vehicles back up waiting to enter a station. This may result if demand at particular stations is high and train length and vehicle door widths do not allow for rapid boarding. Simulation techniques will be useful here when potential problem areas are identified (see Section 11).

One-way hourly capacities of up to 36,000 passengers are theoretically possible for existing DPM-like systems, but volumes of only about 8,000 passengers have been experienced. The cost of not providing sufficient capacity should also be addressed. The incremental costs of larger vehicle size, larger train length or increased frequency to handle a very short peak period over a short segment of the system may be avoided if sufficient holding capacity at stations (platforms, stairways, escalators) exists to handle any accumulated passengers. However, such a strategy builds in congestion and may deter added patronage. It also leaves little margin for error if demand estimates are low.

5.1.6 Control Technology

As alluded to earlier, the choice between an on-line and off-line system has many design implications affecting station and guideway design and the type of control system used. An on-line system is the more familiar -- vehicles (or trains) follow one another, proceeding from station to station even if no one chooses to get on or off. In an off-line system, vehicles by-pass stations and only respond to either rider-actuated signals, as in an elevator, or to a central control system. The former works best if demand is so low as to make numerous station stops with no riders getting on or off wasteful to the few riders it is serving. The latter may be called for if specific point-to-point volumes are so great that intervening stops would waste excess time for those being served. The additional price paid for such service is a more complex control system and the accompanying likelihood of higher initial and maintenance costs, unreliability, and larger, bulkier stations because more platform frontage is required to serve individualized demand. Off-line systems will require more vehicles for a given level of demand. On-line systems can get by with larger, but fewer, vehicles. Clearly, complex trade-offs are involved, which are functions of the origin-destination patterns from station to station, station spacing, total passenger travel time, station space availability, and the relative cost and reliability of the two types of systems.

5.2 OPERATIONS DESIGN CONSIDERATIONS

5.2.1 Service Frequency

The choice of service frequency, or, conversely, of headways, is an important one involving many trade-offs. Increasing service frequency may be an effective means for attracting passengers because of the reduced waiting time it achieves. Unfortunately, it is difficult to know the precise impact because available evidence suggests a wide range of sensitivity to waiting time. It is possible then that reduction of headways may prove costly with relatively little return. In a DPM system that carries passengers for a relatively short distance, headways will have to be small to begin with to prevent waiting times from becoming a major component of total travel time and a source of irritation to the passenger. Reduction of average waiting times from say, one minute to thirty seconds by increasing service frequency from 30 to 60 vehicles an hour, may double many of the components of operating and capital costs. The added vehicle miles travelled may translate into added vehicle and guideway maintenance costs, greater required fleet size, more sophisticated, potentially unreliable, and costly control equipment and, unless the vehicles are automated, much higher labor costs for vehicle operation. In addition, headways are constrained by dwell time, the time vehicles spend in the station, loading and unloading.

It will also be necessary to make the distinction between peak and offpeak period frequency. In peak periods it may be necessary to increase the frequency, not for the purpose of attracting additional passengers, but to provide sufficient capacity for those passengers already attracted to the system. Provision of peak hour capacity will likely be the parameter that determines a number of operating and system characteristics, including service frequency, fleet requirements and vehicle size. This capacity may be highly taxed by large surges of demand at line-haul interfaces. A careful examination of the trade-offs between added passengers attracted and added costs is clearly in order. Demonstrated headways on DPM-like systems range from 15 seconds to 5 minutes.

5.2.2 Operating Speeds

Like service frequency, increased operating speed can attract added passengers, in this case because of lower in-vehicle travel times. Limited evidence suggests that a 50 percent reduction in travel time in vehicles would attract 10 to 20 percent more passengers. However, higher speed comes at a price. Of the four parameters that determine operating speed, two (maximum cruise speed and acceleration/deceleration rates), require a more powerful and costly vehicle. In addition, acceleration rates are constrained by the comfort to the passenger --above 3 miles per hour per second a standing passenger will be knocked down. Higher operating speeds may also be achieved by employing fewer stations for a given length of route, but the poorer access this implies may dissuade more potential passengers than the higher speed attracts. Fewer stations may also serve to concentrate passenger loadings at fewer stations, raising the dwell time of vehicles in stations (the fourth determining factor of operating speed), consequently lowering operating speed. Yet higher speeds hold the intriguing possibility of reduced costs and increased labor productivity because more vehicle-miles may be produced per employee while attracting more passengers.

In sum, the selection of operating speed involves the optimization of demand and costs in a very complex way with no unique solution applicable for all DPM systems. The distribution of potential demand, the characteristics of available vehicle hardware, and the relative costs of stations, guideways, vehicles and labor all must be investigated for each proposed system. This is particularly important considering the wide range of operating speeds claimed (8 to 30 mph) for both currently operating and proposed systems.

5.2.3 Service Span

The service span is another system characteristic that must be carefully considered because it can affect both the demand for the system and the cost of meeting that demand. Decisions are required regarding early morning, late evening, and weekend service. Such decisions relate to the original objectives of the DPM; a mostly commuter-related facility may not require a weekend service nor a late evening weekday service, but a DPM intended to serve the retail sector may be vital on Saturdays or weekday evenings. Whatever choices are made, the increase in demand that results from additional service must be weighed against the added costs incurred, costs that are related to the vehicle-miles and vehicle-hours consumed by the system.

5.2.4 Fares and Subsidies

The decisions to be made concerning fares for a DPM system are numerous. Will a flat fare be charged or will fares vary as a function of time of day, day of week, or distance travelled? Will transfers be free? How will discounts be given for senior citizen or other groups? Will DPM fares be integrated with rapid transit system fares or with auto parking fees? How will fares be collected? Will cash, tokens, or credit cards be used? Should there be a subscription system or some other sort of prepayment plan? What will the fare levels be? Will there be a fare at all? Will revenues from fares be expected to cover operating costs? If not, through what subsidy mechanism will costs be covered? Some of these questions warrant further discussion here.

In principle, a fare that does not vary by time of day or distance travelled may be inequitable. The peak period traveller costs the system more because of the additional capital costs required to serve him. Yet with the same fare at all times, he pays no more. Meanwhile, the offpeak user directly or indirectly pays the additional cost. Because offpeak travel demand is generally more sensitive to price than peak travel, a flat fare also tends to reduce total ridership. Similarly, with a fare that does not vary by distance, a passenger travelling farther gets more service per mile travelled, requiring additional expenditures. In practice, however, there are valid reasons to keep a flat fare, especially if ridership patterns are not particularly peaked or trip lengths particularly long. With DPM both these conditions may be true particularly the latter. In addition, the implementation of a fare graduated by time or distance is likely to involve more sophisticated and costly fare collection designs such as the system on BART and the Washington Metro that automatically deduct the proper graduated cost of the trip from a coded card when the passenger leaves the system.

There are few, if any, public transit systems that still meet their full costs through passenger revenues. Public transit has now been recognized as a public service whose costs may be borne from general revenues. This view may be especially relevant for a DPM, a system thought of as an urban development venture capable of generating benefits well beyond its costs. To be resolved is the question of the appropriate portion of costs that should be borne by the user. One extreme is none -- free transit. This would no doubt maximize use, although how many more riders would be attracted over a modest fare remains a valid analytical question. Without a fare the costs of fare collection would evaporate. However, additional costs for additional service may result if the system attracts many more passengers.

The choice of revenue sources to cover the deficit is an important issue. The possibilities include sales taxes on downtown retail businesses, added property taxes in the downtown, income taxes, value capture techniques, regional property taxes, or auto-related taxes, i.e., tolls, parking registration, or gasoline. The decision as to how much fare and how much subsidy and from where, remains to be addressed as part of the analytical process, and finally, as part of the political decision-making process. Further discussion of fare alternatives and other revenue sources is presented in Section 9.

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6. AGGREGATE ANALYSIS OF SYSTEM FEASIBILITY

This section discusses factors which influence downtown circulator travel demand, describes a method for estimating potential patronage, and illustrates how the results will vary depending on the characteristics of the downtown and of the circulator system. For illustration, a DPM is considered. The demand estimation technique presented is called an aggregate one because it starts with overall measures of downtown size, such as total employment or floorspace, and does not require site-specific data on trips. This is in contrast to more detailed disaggregate demand estimation techniques, such as those presented in Section 7, which start from the bottom up and require detailed data for several categories of zone-to-zone trips and transportation network characteristics.

Because the aggregate method relies on travel demand and transportation system characteristics typical, on the average, of various size downtowns in North America, it is obviously less precise than the site-specific disaggregate method. Its basic advantage is that it can allow a quick assessment of potential patronage for various configurations of DPM systems in any city, without first engaging in the collection of local data on travel and transportation performance. Exercising the aggregate estimation "model", even prior to its application to any particular downtown, is instructive for observing how the estimates of demand vary with downtown size, with other downtown characteristics, and with characteristics of DPM systems, such as fares, service frequency, and speed. The demand estimates developed here are intended to be matched with the operating and capital costs of supplying a given level of service. Such an exercise will assist in properly scaling a DPM system to a downtown of particular size and configuration.

6.1 FRAMEWORK FOR AGGREGATE ANALYSIS

6.1.1 Definition of Potential Markets

The potential market for downtown people movers consists of several rather distinct segments. To begin with, there is: (a) travel that has one end of the trip outside the Central Business District and one end within the CBD (regional CBD travel), and (b) travel with both ends of the trip within the CBD (internal CBD travel). In the former case, the DPM will function as a distributor from other modes. In the latter case, it will act as a circulator and will most likely be the only vehicle mode used on a given trip. In the first case, the DPM will usually replace portions of both auto and transit trips. In the second, it will replace some auto and transit trips, as well as portions of trips on foot. To the extent that it attains tangible reductions in travel time and inconvenience, it will also induce new travel, primarily in the internal trip category.

6.1.2 Regional CBD Travel by Transit and Auto

The amount of regional CBD travel diverted to a DPM will clearly depend on how much regional CBD travel there is in the first place. This, in turn, is a function of the amount and type of activity found in the CBD -- the more activity, the more travel. The scale of activity can be estimated most readily with two measures -- employment and floorspace. Most central cities have collected these data from time to time, but there remains a number of difficulties in their use, stemming largely from the lack of any central collection mechanism for all cities to assure uniformity.

The most fundamental inconsistency is the definition of the CBD itself. Some CBDs are defined very narrowly, including only a few blocks of the highest intensity activities; others encompass a number of square miles, including a substantial area of residential activity. Figure 6-1 is given here to permit adjustments for CBDs of differing CBD definitions. It shows the percent of activity, measured either in employment, floorspace or trip destinations, that are found in successively larger portions of a CBD. For example, the figure indicates that for 7 of 9 of the CBD curves shown, 50 percent of a CBD's area (the X-axis) tends to contain from 73 to 83 percent of the CBD's activities. Only Houston and Milwaukee diverge significantly from this pattern with the former being more concentrated, the latter, less dense. The curves were constructed by starting with the densest area of the CBD and successively adding less and less dense areas. These curves can also be used to estimate the relative amount of activities in particular sections of the CBD containing DPM stations.

Aside from the matter of consistent areas, comparisons of CBD activities also suffer because data is seldom collected on a regular basis, requiring comparisons to be made for data of different years. In fact, much of the available data is derived from the comprehensive origin-destination studies, some dating back twenty years or more.

Lastly, there are specific definitive problems with respect to both employment and floorspace. Employment may mean the number of jobs held in the CBD, the number of job-holders (somewhat lower because some workers hold more than one job), or the number working in the CBD on an average day, deducting for vacations and other absences. Employment data may be inflated if all employees of a firm with a CBD address are counted, regardless of whether they actually work in the CBD. Floorspace data likewise suffers from inconsistencies. In some cases, residential floorspace is included; in others only office and retail floorspace is counted, but not other non-residential uses. The mix of the types of floorspace is important because different types of floorspace will generate trips at varying rates. Some floorspace data may be based on the outside or gross dimensions of buildings, others only on the net or inside rentable area, perhaps 15 percent smaller. Floorspace data may also

CBD	Area (sq.miles)	Activities	Percent of Activities in 50 Percent of Area
Houston	1.21	138,110 jobs	93
Norfolk	1.03	24,816 jobs	90
Portland	1.03	59,990 jobs	83
Philadelphia	2.40	396,585 trip dest	82
Los Angeles	1.86	60.0 msf floorspace	81
Boston	3.35	290,626 jobs	78
Pittsburgh	0.48	98,739 jobs	76
Chicago	1.08	296,500 jobs	74
Memphis	0.28	9.0 msf floorspace	73
Milwaukee	1.4 (est.)	35.2 msf floorspace	64

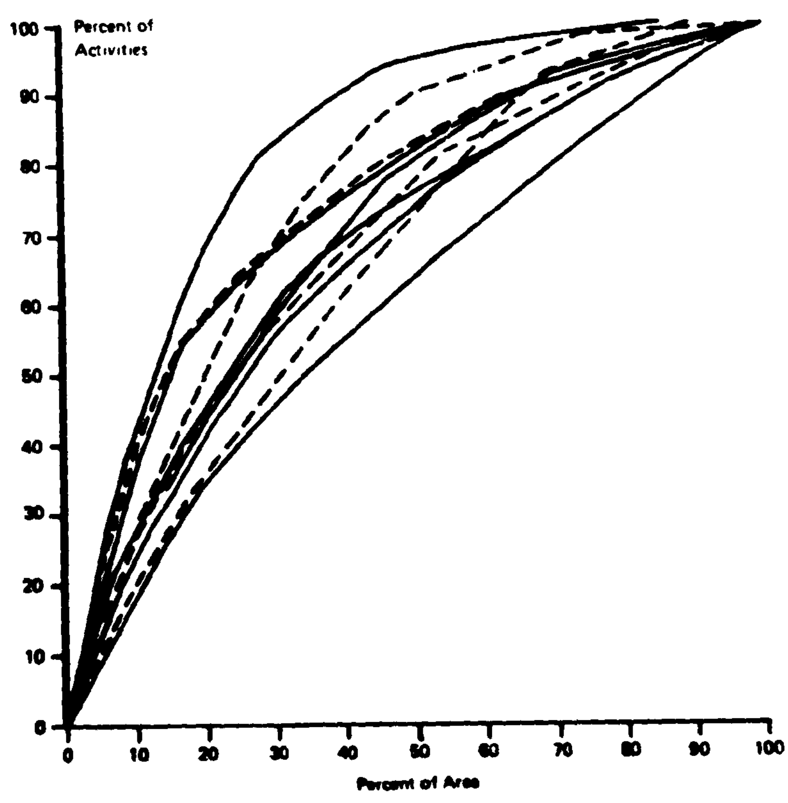


FIGURE 6-1

CENTRAL BUSINESS DISTRICTS ACTIVITY CONCENTRATION

overestimate activities if high vacancy rates exist. Despite the difficulties of measurement, the amount and type of floorspace is a key determinant of downtown travel, both regional travel to and from the CBD, and internal travel within the CBD.

Regional CBD travel will be separated in this analysis into transit and auto travel. This step is necessary since trips by transit are likely to be diverted to a DPM for different reasons than trips by automobile. For example, transit users are more likely to use the DPM if their present transit system delivers them only to the CBD fringe. This is of little consequence to auto users. Conversely, auto users will weigh heavily the relative costs of parking in the center of the CBD as compared to parking at fringe areas served by the DPM. Transit users will find such factors irrelevant to their choice of mode.

6.1.3 Internal CBD Travel

As with external travel to and from the CBD, internal travel within the CBD is a function of the amount of CBD activities. Unfortunately, because a majority of internal CBD trips are "walk-only" trips, i.e., not made using a vehicle mode (VM), they are not recorded by traditional origin-destination interview surveys. In addition, the VM trips internal to the CBD are often undercounted because the interviewee may not be the member of the household making the trip. This may be particularly true for trips by transit.

To close this gap, a number of direct counts of tripmaking at selected sites have been compiled in recent years. Of greatest significance in these counts is the wide variation in trip generation rates by type of land use. Daily two-way person trip ends (trips in and out) per 1000 square feet of gross floorspace among non-residential land uses (of most concern in CBDs) show that industrial floorspace generates about 7, offices generate from 11 to 22 with a decided cluster around 15, while retail establishments generate from 40 to 100 trips per 1000 square feet in suburban locations and still higher rates in central city settings. These wide variations in trip generation rates suggest the importance of separating CBD floorspace by use categories. Examination of such data suggests a weak but discernible pattern. CBDs with more total floorspace tend to contain a greater proportion of office floorspace, rising generally from 40 percent up to 50 percent; retail floorspace tends to be 20 percent or more of total floorspace in CBDs of about 10 million square feet, falling to 10 percent or so for the higher activity CBDs.

If the total number of trip ends generated by all types of land use within a CBD can be estimated using the known mix of floorspace and representative trip generation rates, and if the total number of trips between points outside the CBD and points within the CBD is known (as discussed in Section 6.1.2 above), then the internal CBD trip ends can be estimated by taking the difference between the two.

To consider the diversion of internal CBD trips to a DPM, it is necessary to know how many of them are currently "walk-only" trips, how many are vehicle mode, and among the VM trips, how many are by transit and how many are by auto. The users of each of these three modes are faced with a different set of time, cost, comfort, and convenience characteristics as alternatives to the DPM, and each may place different values on those characteristics.

To estimate the split between "walk-only" (hereafter denoted as walk trips) and VM trips one must rely on limited survey data. In midtown Manhattan, 26 percent of all trips entering and leaving each of two office buildings were walk trips. At the Museum of Modern Art, the split was similar, with 27 percent being walk and at the NYU Bobst Library, with many intra-campus trips, 34 percent. Two retail establishments in Manhattan, but outside the CBD, averaged about 70 percent walk-only. By weighting assumed splits between walk and VM trips for each land use by the number of trips in each land use, an estimate of the overall split between the two can be made.

For an estimate of the further separation of the internal VM trips between transit and auto, one must rely on origin-destination survey data, despite its shortcomings. Including taxi trips as a transit mode, an appropriate categorization in this context, it is found that for five CBDs for which data was readily available, namely Dallas, Denver, Houston, Kansas City, and Indianapolis, the proportion of internal CBD vehicle mode trips made by transit falls below 10 percent. These are all cities with a traditionally high automobile orientation. Atlanta and Detroit have a slightly higher proportion of internal VM trips recorded in the transit column, about one-sixth, while Baltimore's share is close to one-third. The transit oriented CBD of New Orleans and the rapid transit-served CBDs of Boston, Philadelphia, and Chicago indicate that from one-half to six-tenths of the internal VM trips are made by transit. All these splits may be somewhat on the low side for transit because of possible bias in the origin-destination surveys.

Although the available data is meager, it is possible to construct, as will be shown later, an internally consistent estimate of internal CBD trips, distinguishing among walking, transit and auto travel wholly contained within the CBD.

6.1.4 Diversion of Regional CBD Transit Travel to DPM

How many transit users can be diverted to a DPM will depend in large measure on the configuration of the existing transit system. The DPM will offer an attractive alternative if the line-haul system, be it bus or fixed rail, does not penetrate the CBD. If the system already penetrates the CBD, transfer to a DPM will not be very attractive for most travellers. Should the existing system be truncated at a DPM station on the CBD fringe, then obviously a substantial number of transit users would be attracted. Adjustment of an existing transit system in such a manner may be justified if existing service is by bus, if it is slower than the projected DPM, and if the visual, noise, and air quality impact of buses in the core is deemed unacceptable.

The number of transit users delivered to a DPM station, whether in the center of the CBD or its fringe, who actually choose the DPM will depend on the proportion that perceive this choice to be of lower "price" in time, cost, comfort, and convenience. That share is, in turn, a function of: (1) the distribution of the trip ends of the transit users within the CBD relative to the location of DPM stations, and (2) the characteristics of the DPM that influence the "price" the potential user perceives.

The more spread the distribution of trip ends in the CBD, the smaller the proportion of users likely to find a given configuration of a DPM of value to them. However, if CBD activities are located in a few dense clusters, a DPM system is more likely to catch a large share of the potential transit users. Figure 6-1 gave a convenient way of measuring this relative compactness or spread of CBD activities.

A second set of factors affecting the diversion to DPMs is the relative time, cost, comfort, and convenience that a DPM ride offers. The total "price" of using the DPM includes the discomfort of transferring between vehicles (line-haul transit and DPM), including the time involved climbing or descending and stairs or riding escalators, the time and discomfort waiting for the DPM vehicle, the time spent on the vehicle, the time and discomfort of transferring between the vehicle and the street level, the time and discomfort of walking between the DPM station and the final destination, and finally the money cost of the DPM. The alternative of not using the DPM may be to walk the entire distance between the intercepting DPM station and the traveller's trip end or to choose some other vehicle, including local bus or taxi. In the former case, the total price includes only the walk itself. In the latter case, it includes all the same elements of the DPM trip, save perhaps the ascent and descent to and from the DPM.

It is clear then that how the DPM is designed and operated will directly influence the amount of time spent by individuals for each of the elements of their trip. In the case of transfers, station design, especially with respect to elevation change, will impact the "price". The time spent waiting for the DPM is a direct function of the frequency of service for DPM systems on fixed headways; for headways of less than 12 minutes, it has been shown that passengers will arrive at random, meaning that waiting time will average one-half the vehicle headway. For example, if vehicles arrive two minutes apart, the average wait will be one minute. For demand-responsive DPM systems, analagous to an elevator system in a building, waiting time is less easily determined, depending on a complex combination of vehicles in use, demand levels, system length, and the availability of off-line stopping locations at a station.

The time spent inside the vehicle depends on the length of the trip and the operating speed. The operating speed between stations is equal to the maximum speed the vehicle can attain reduced by the delays due to accelerating and decelerating and by the dwell time at stations. The maximum acceleration and deceleration rates are limited by passenger comfort --above rates of about 3 mph per second, a standing passenger can be easily knocked off his feet. Dwell time depends on vehicle design and the volume of passengers entering and leaving vehicles at a station -- 10 to 15 seconds is a minimum when volume is low.

The time and distance spent walking to and from DPM stations are a function of the number of stations and the distribution of activities surrounding them. If activities are clustered tightly around a station, average walking distances will be shorter and the attractiveness of the DPM will be greater, but this activity distribution may be more difficult to generalize quantitatively than the overall CBD activity distribution described earlier in Figure 6-1.

Given a distribution of activities and the characteristics of the DPM system, the relative weight the traveller places on each of the elements of his trip must be established. This has been the subject of much research. It has been found the time spent on each of the elements of a trip (walking, waiting, The time spent in transferring, and riding), are not valued equally by the traveller. vehicles is typically found to be the least burdensome and time spent walking the most burdensome. The logic of this finding is inescapable. Time spent in a vehicle (often seated in comfort) gives the rider a sense that his time is not being wasted, unlike waiting or transferring. Time spent walking includes not only the value of time but the physical exertion involved. Precisely what relative values should be used is less clear. Differing methods of estimating these values in money terms, with differing groups of travelers (by purpose, by time of day, or by income) in different settings produce different results, as illustrated by the summary of in-vehicle and out-of-vehicle values of time given in Section 2.

A further look at the values found for each of elements of the trip are in order. For the cost of transfer between transit vehicles, one study suggests that commuters place a value equivalent to about 4 minutes on the transfer, exclusive of the time spent transferring. Evidence gathered at parallel escalators and stairways suggests that commuters are willing to spend considerable time waiting at escalator queues rather than climbing stairways -- 50 percent will wait as much as one minute to avoid a 20 foot climb, attesting to the high cost placed on stair-climbing. Informal observation suggests that sizable but smaller proportions of transit users will even spend time waiting at down escalators rather than descending parallel stairways.

Waiting for the DPM vehicles is also likely to have an impact greater than the absolute amount of time involved. In a benchmark mode choice analysis, excess time, i.e., time not in the vehicle, was shown to be valued at about twice the in-vehicle time. Similarly, the price placed on walking is also significantly greater than the time alone. In one examination, a conservative value for the avoidance of walking is placed at a minimum of 10 cents per 1000 feet (in 1971 prices), which translates, in 1977 prices, to about 3.5 cents per minute allowing for walking speeds of 230 feet per minute. Also suggested are considerably higher values placed on the avoidance of walking by auto users.

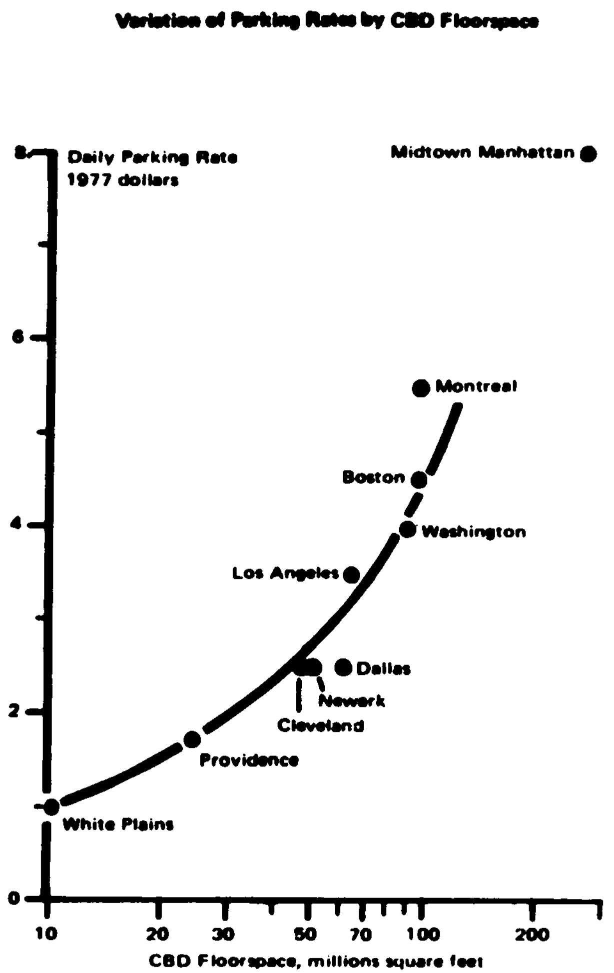
Once each of the trip "costs" is translated into money terms, i.e., measured in cents per minute, it becomes possible to compare the price of time and comfort to the out-of-pocket cost, i.e., the fare, the most easily measured of all price elements.

In sum, to properly assess the diversion of regional CBD transit travel to a DPM system it is necessary to have information on the distribution of activities in the CBD, the number of stations and route length of the DPM, its headway, speed (operating and maximum) and fare, the configuration of the transfer facilities, i.e., changes of elevation, escalators, stairways, and most important, the degree to which the DPM is designed to intercept transit users.

6.1.5 Diversion of Regional Auto Travel to DPM

Many of the factors relevant for assessing the diversion of transit users to a DPM are also relevant for auto users, but some important distinctions do exist. Most important, the auto user must dispose of his vehicle for at least part of the day and usually, in a CBD, pay for that privilege. The amount he pays depends on a number of factors. In the left half of Figure 6-2, it is clear that the highest prevailing daily parking rates for CBDs are a function of CBD floorspace. However, these parking fees differ from the price assignable to any one trip. First, the fee per trip must be divided in half since two vehicle trips are made per fee paid. Second, the average car occupancy for trips to CBDs is on the order of 1.3, further reducing the cost per trip. Finally, some auto parkers do not pay for the parking privilege from their own pockets, being reimbursed, at least in part, by their employer. In one parking survey in Boston, this occurred in 28 percent of the cases.

The auto user may also be able to lower this parking cost by increasing the distance he parks from his destination, trading off walking distance for less expensive parking elsewhere. The average walking distance for parkers in downtowns has been shown to vary by metropolitan area population, which is a surrogate for



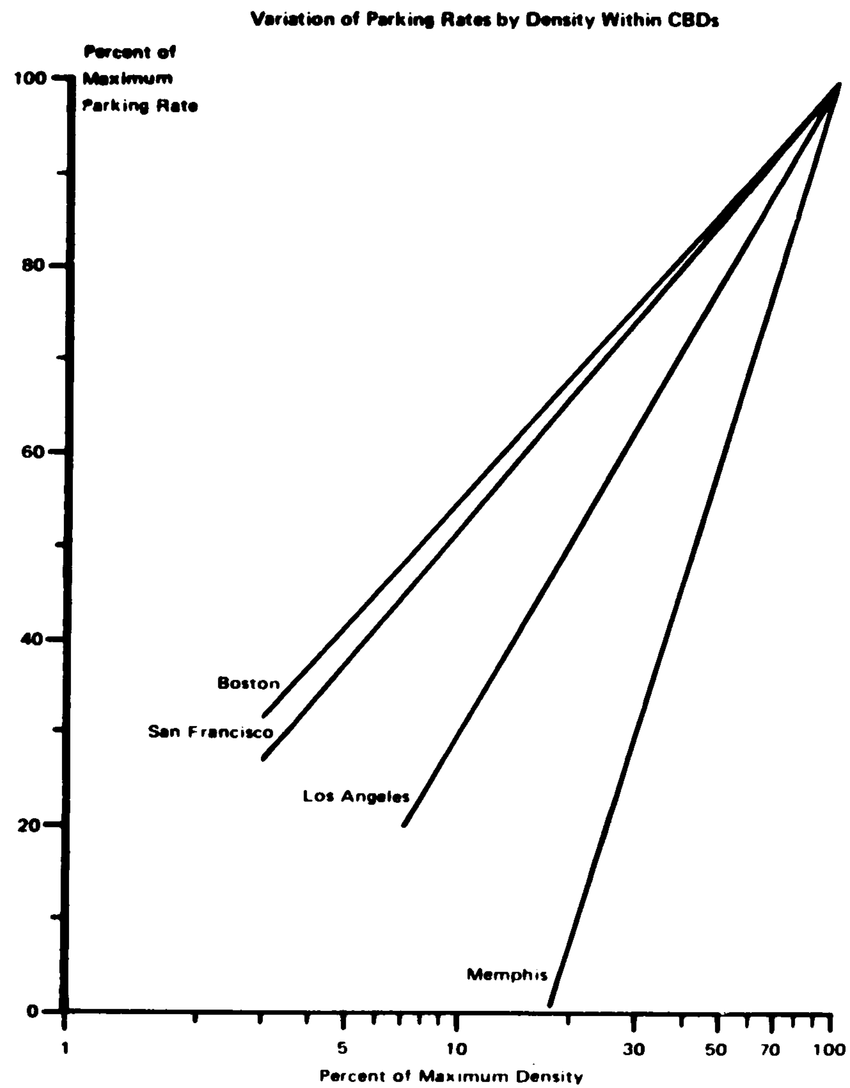


FIGURE 6-2

PARKING RATES AND CBD FLOORSPACE

the amount of CBD activity. Roughly speaking, walking distances for parkers for metropolitan areas of 200,000, 500 000 and over 1,000,000, average about 500, 600, and 700 feet, respectively. This pattern relfects the desire of auto users to avoid the higher parking costs in the center of the larger CBDs (or the total absence of such spaces) and the ability of the auto users in the smaller CBDs to find inexpensive parking close to the CBD's center. The manner in which these parking rates drop off in the less intensely used areas of the CBD is suggested by the curves in the right half of Figure 6-2. These curves were derived by plotting daily parking rates as a function of either floorspace or employment density on a small zone basis and converting the straight line of best fit to percent terms, where the 100 percent point is the one with the highest density and highest parking cost. Note that for the largest CBDs, Boston (with about 100 million square feet) and San Francisco (about 80 million square feet), parking costs decline quite slowly; zones with 1/10 the highest density still have parking charges of more than 50 percent of the highest parking rate. In smaller CBDs the rate of decline is more rapid; in Los Angeles (60 million square feet), the 1/10 highest density zones charge about 30 percent of the maximum parking rate and in Memphis (13 million square feet) parking costs drop to zero well before the 1/10 highest density areas.

Aside from parking costs, the auto users will be influenced by time. This is very much dependent on the prevailing speed of vehicle traffic within the CBD. With very slow CBD speeds he may be more willing to avoid the slowest segment of his trip and park on the CBD's fringe. In midtown Manhattan auto speeds generally range from 7 to 11 miles per hour with midday speeds as slow or slower than during the morning or evening peak hours. In the Denver CBD, speeds on the innermost CBD streets average about 13 miles per hour, with wide variation depending on time of day. Observations in the Los Angeles CBD suggest speeds of about 12 miles per hour.

The relationship between the limited-access highway network, including its access ramps, and the location of potential DPM stations on the CBD's fringe will play a major role in determining the divertibility of auto users. Examination of highway networks surrounding CBDs suggest that a well-located fringe DPM station may be in a position to intercept auto users from a sector of 90 degrees, or 45 degrees on each side. Thus, four well-located fringe stations, at four points on the compass 90 degrees from one another, are in a position to intercept almost all of the auto users. Of course, whether that is achievable depends on the capacity of the fringe parking areas to accommodate the vehicles that carry the diverted auto users. To provide sufficient parking capacity at fringe lots to accommodate the expected diversion to the DPM might lengthen the walking distances within the parking area, thereby reducing the DPM's attractiveness. In other words, the attempt to provide for more DPM riders may reduce the full potential for diverting auto users. This is an important paradox that will be dealt with in later discussions.

The price of using the DPM for auto users includes the same elements as for transit users -- time and comfort of transferring to, waiting for, riding on, and leaving the DPM, the fare, and the time and discomfort of walking between the DPM station and the final destination. Thus, all the characteristics of the DPM system that influence the choice for transit users will likewise influence the choice for auto users, including number and location of stations, station spacing, DPM vehicle speed, service frequency, and fare levels. However, if the auto user chooses the DPM there may be two added costs: (1) the parking fee for the fringe parking area serving the DPM (with appropriate adjustments for car occupancy and the allocation of half the fee to a one-direction trip), and (2) an added walking segment of the trip between a fringe parking area and the DPM station.

An added distinction between auto and transit users may be differing values placed on the various elements of the "price" of a trip. By the very choice he makes the auto user is likely to prize the avoidance of discomfort and inconvenience more highly than the transit user.

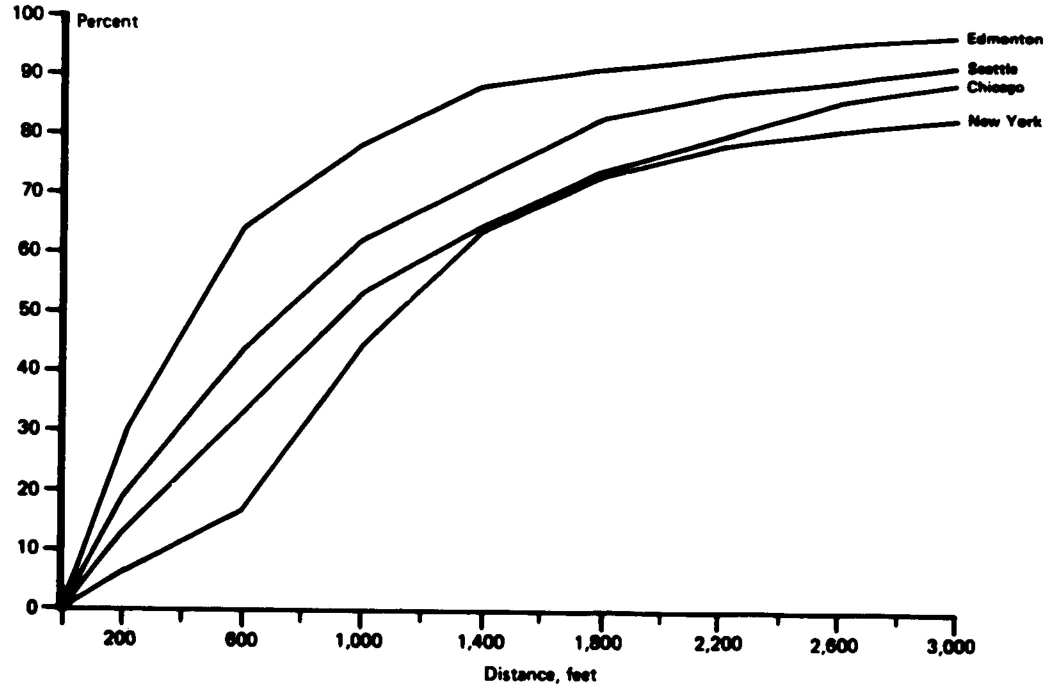
In sum, to properly assess the diversion of regional CBD auto travel to a DPM system, it is necessary to have information on most of the same items required for transit users. Only the configuration of the transit system i.e., the degree to which the transit system delivers passengers to the DPM, is irrelevant to auto users. Additional relevant factors for the auto user are the magnitude of the parking cost in the CBD and how it varies within the CBD, the cost of parking at a fringe DPM parking lot and its capacity, and the distances walked to and from whatever location at which the auto parker may choose to leave his vehicle.

6.1.6 Diversion of Internal CBD Travel to DPM

Because of their distinct properties, the diversion of internal walk trips to a DPM must be examined separately from internal trips by vehicle modes. With "walk-only" trips, the diversion rates will be determined largely by the distribution of walking trip lengths; the greater the proportion of relatively long walking trips, the more likely will be the diversion to a DPM that can save substantial walking distances. For the VM (1) trips the diversion to a DPM falls into two further categories: trips currently made by the existing transit system that will shift to the DPM if it offers service at a lower "price", and (2) trips currently made by auto that may shift to the DPM if it provides sufficiently attractive features.

The walking trips and their most relevant characteristics, trip length, will be discussed first. In Figure 6-3, the trip length frequency distributions of walking trips in four CBDs are

	Percent Walking in:							
	Given Distance Range				Given Distance Range or Less			
Distance, feet	Edmonton*	Seattle	Chicago	New York*	Edmonton	Seattle	Chicago	New York
0 - 200	30	18	13	6	30	18	13	6
200 - 600	34	26	20	11	64	44	33	17
600 - 100	15	18	20	28	79	62	53	45
1,000 - 1,400	9	11	12	20	88	73	65	65
1,400 - 1,800	4	10	9	9	92	83	74	74
1,800 - 2,200	2	4	6	4	94	87	80	78
2,200 - 2,600	2	2	6	3	96	89	86	81
2,600 - 3,000	1	3	3	2	97	92	89	83
over 3,000	3	9	11	17	100	100	100	100
Average	610	1,150	1,580	1,720				
Median	400	725	900	1,070				



*Walk to and from all .nodes. Others walk only.

FIGURE 6-3

WALKING DISTANCE DISTRIBUTION IN SELECTED CENTRAL BUSINESS DISTRICTS shown in tabulated form both by individual increments and cumulatively. The cumulative distributions are drawn in the lower part of the figure as well. For Edmonton and New York, the trips include the walk link to or from vehicle modes, i.e., they are not pure walk trips. Limited evidence in New York suggests that this may lower the average trip length slightly. Nevertheless, it is clear that the larger CBDs have longer walking trips. Measured in terms of average or medium trip length, Seattle walk trip length is almost double Edmonton's; Chicago and New York each have walking trips from two to three times longer than Edmonton's and 50 percent greater than Seattle's; New York's trips are slightly longer than Chicago's. Eighty percent of Edmonton's trips are less than 1000 feet but less than half of New York's walk trips are that short. With the exception of an explainable observation in New York's cumulative trip length curve the diminishing proportion of trips at longer distances follows a smooth and predictable pattern. (The New York curve does suffer from the limited number of locations in the survey on which the data was based, slanting the distribution toward the particular distances those survey locations are from subway stations.) The figure clearly suggests that larger CBDs have longer walking distances. Less clear is whether the longer distances are a result of the greater amount of activities in the CBD or whether more land area occupied by the CBD creates additional opportunities for walking. More data collected for a larger array of CBDs is required before this question can be satisfactorily resolved.

For a given walk trip length, the likelihood of diversion to the DPM will rest on whether the choice of using the DPM results in a cheaper price than the walk. Hence, as with diversions from transit or auto trips, the time, cost, comfort, and convenience of walking to and from the DPM, including transferring to it, waiting for it, paying a fare, and riding on it, all enter a potential user's choice.

The existing internal transit trips diverted to a DPM will be a function of the relative price the user places on the trip by the existing transit system, usually local bus, and the new DPM mode. To estimate their price differences requires the realization of basic differences between local bus service and the DPM. The local bus service has two major advantages over the DPM: (1) it can stop at every cross street, giving it coverage the DPM cannot match, and (2) it does not require a change in elevation at the beginning and end of each trip. The disadvantages of the bus are that speeds on local buses are subject to traffic congestion and that the headways on local buses will tend to be longer than on the DPM, pressured by operating costs that, unlike the DPM, will rise in almost direct proportion to service frequency. Also, the DPM is intended to be a mode with a new image, attracting riders independently of any measurable differences in time, cost, comfort, or convenience.

In practice, however, the most decisive differences to the user depends on the operating policies adopted for both the local bus service and the DPM when a DPM is inserted into a downtown. Will the same fare be charged for the local bus service as for the DPM? If the DPM is free will the local bus service be also? Will local bus service? Will service frequency be reduced? It is these policies that must be tested if the diversion of internal transit users to a DPM is to be estimated.

The internal auto trip presents a completely different situation. Here the question is how many of those now using an auto in the CBD are likely to be diverted to a new increment of transit service, namely the DPM. There are travellers who are currently using the auto even if it represents a price disadvantage. Thus, the question cannot so easily be addressed by comparing trip prices because many who drive within the CBD do not use transit for reasons difficult to quantify, e.g., they may be shoppers with packages or salesmen with samples. In addition, many may be reimbursed for parking, removing an attraction of transit. Further complicating the analysis is the interplay between the regional and internal auto traveller. By definition, they are the same people. If the regional auto traveler is diverted to the DPM, this greatly increases the likelihood he will use the DPM for this internal trip, formerly made by auto. However, the regional auto traveller who requires his auto within the CBD is less likely to be diverted to the DPM for this regional auto trip. Some dimensions of these phenomena will be suggested in Section 6.2.

6.2 DEVELOPMENT OF METHOD TO ESTIMATE AGGREGATE DPM DEMAND

6.2.1 The Sequence of Steps

The purpose of this section is to discuss the development of a method for making "ballpark" estimates of DPM demand, accounting for the factors discussed in the previous section. Sample results of applying the method are simultaneously described, encompassing "real-world" conditions, to show how demand varies with the size, intensity and distribution of CBD activities and with the characteristics of DPM systems. (Step-by-step documentation for a specific application of the method is presented in Appendix B.)

The "real-world" conditions assumed here are based on relationships that may not be precise in any particular situation. Therefore, the analyst is encouraged to substitute known relationships or data for particular settings. Moreover, the numerous assumptions made in this section are often based on limited information or on "best guesses." The steps are outlined in sufficient detail to permit alternate assumptions to be made when new data or specific situations warrant it.

The broad steps are as follows:

(1) Estimate total regional CBD trip ends by auto and transit based on either employment or floorspace data

(2) Estimate the internal CBD trip ends based on CBD floorspace data by floorspace type, including the amount made entirely on foot, by transit and by auto

(3) Estimate the proportion of regional CBD transit trips diverted to the DPM based on the proportion of transit trips delivered to a DPM station on the fringe, the degree of concentration of CBD activities, the total land area of the CBD, the number of DPM stations, station spacing, DPM vehicle speed, headways, and fare.

(4) Estimate the proportion of regional CBD auto trips diverted to the DPM based on the degree of concentration of CBD activities, parking costs, parking supply, the number of DPM stations, station spacing, DPM vehicle speed, headways and fare

(5) Estimate the proportion of internal CBD trips diverted to the DPM based on the amount and type of CBD floorspace, the degree of concentration of CBD activities, the number of DPM stations, station spacing, DPM vehicle speed, headways, fare, and characteristics of local bus service

(6) Estimate the number of regional CBD transit trips diverted to the DPM based on the results of steps 2 and 4

(7) Estimate the number of regional CBD auto trips diverted to the DPM based on the results of steps 2 and 5

(8) Estimate the number of internal CBD trips diverted to the DPM based on the results of steps 3 and 6

(9) Estimate the total number of daily DPM trips by adding the results of steps 7, 8, and 9

(10) Estimate the peak hours of DPM demand and its size by multiplying the three components of DPM demand found in steps 7, 8, annd 9 by peaking factors for the morning, midday, and evening peak hours

Each of these steps will now be described in detail.

6.2.2 Estimating Regional CBD Trip Ends by Transit and Auto

If data on regional auto and transit trips to the CBD are not readily available they can be estimated from CBD employment and floorspace, despite the difficulties in measurement discussed earlier. What follows here is an analysis of CBD data presented in Table 6-1. The intent is to determine a number of simple methods of estimating both transit and automobile trips to and from a CBD based on CBD employment and/or floorspace. Although they produce somewhat different results, all estimates fall in a reasonable range suitable for rough scaling.

To begin with, it is useful to determine the relationship between CBD employment and floorspace, so that a conversion can be made from one measure to another where only one is available. In Figure 6-4(a) a scatter diagram is plotted on a log-log scale, with CBD employment on the x-axis, and CBD floorspace on the y-axis for the 18 cities shown in the first part of Table 6-1. The straight line of best fit by the least squares method is calculated and shown in the figure along with its equation and correlation coefficient. The equation's slope of less than unity (0.8131) indicates that a given percent increase in employment is associated with a slightly smaller percent increase in floorspace, suggesting that floorspace per employee declines slightly with increasing CBD size; the curve shows that some 450 square feet per employee is found in CBDs with some 50,000 jobs, ranging down to about 350 square feet per employee in CBDs of 200,000 jobs. The floorspace/employee ratio for the 18 cities, while erratic, averages out to about 400 square feet per employee.

With these results it becomes possible to see how trips to and from CBDs vary as a function of either employment or floorspace. In Figure 6-4 (b) and (c), CBD employment is plotted against CBD trip destinations, i.e., one-way trip ends for 25 CBDs, and CBD floorspace is plotted against CBD trip destinations for 19 CBDs. Both of the relationships are strong with correlation coefficients above 0.900; both permit estimation of total trip destinations to a CBD, in one case if employment in the CBD is known, in the other if CBD floorspace is known.

The division of these trip ends between those made by transit and those made by automobiles is next. As the total number of trip ends increases, or as total floorspace increases, the proportion of trips by transit will increase; Figure 6-5 shows CBD trip ends (double the trip destinations of Figure 6-4 to account for trip origins) plotted on the logarithmic x-axis and the percent of trips by transit plotted on the linear y-axis for 17 CBDs from data in the second part of Table 6-1. These data were, for the most part, extracted directly from local area origin-destination surveys. Floorspace data were adjusted to match the geographic extent of the CBD defined in the O-D survey using Figure 6-1. Reasons for deviations from the straight line of best fit can be attributed to a number of factors. The CBD may be defined very narrowly, including only the most transit oriented trips, driving up the percent of trips by transit; this is the likely explanation for Baltimore's large deviation. The

TABLE 6-1

ACTIVITY AND TRIP DATA FOR SELECTED CENTRAL BUSINESS DISTRICTS

CBD	Area (Square Miles)	Year	Employment (000's)	Floor Space (Msf.)	Trip Destinations (000's)
Los Angeles	0.6	1960	130	42	158
Chicago	1.1	1956	300	92	466
Philadelphia	2.2	1960	225	124	389
Detroit	1.1	1953	114	50	253
San Francisco	2.2	1965	282	88	423
Boston	1.4	1963	246	90	400
Washington	4.5	1955	315	n.a.	442
Cleveland	1.0	1963	117	47	123
St. Louis	0.8	1957	119	39	125
Pittsburgh	0.5	1958	84	32	154
Minneapolis	0.9	1958	90	n.a.	188
Houston	0.9	1960	120	n.a.	113
Baltimore	0.8	1962	85	33	130
Dallas	1.5	1964	135	31	164
Milwaukee	0.9	1972	91	31	134
Seattle	0.6	1970	60	37	145
Miami	0.9	1965	28	12	49
Atlanta	0.6	1961	75	30	94
Cincinnati	0.5	1965	n.a.	35	113
Kansas City	0.9	1957	65	n.a.	107
Buffalo	0.9	1962	48	28	104
Denver	0.5	1959	50	24	105
New Orleans	1.5	1960	60	n.a.	129
Phoenix	0.7	1957	21	n.a.	65
Indianapolis	n.a.	1964	85	30	150
Nashville	0.6	1959	34	n.a.	64

CBD	Area (Square Miles)	Year	Floor Space (Msf.)	Total	Trip Ends (000's) Transit	Auto	% Transit
Atlanta	2.9	1961	40	284.5	65.5	219.0	23.0
Baltimore	0.5	1962	30	216.8	86.7	130.1	40.0
Boston	2.3	1963	100	700.6	373.1	327.6	53.0
Cleveland	n.a.	1976	47	400	150	250	37.5
Columbus	3.2	1972	25	162.8	28.7	134.1	17.6
Dallas	1.5	1964	31	292.3	46.0	246.3	15.7
Denver	0.5	1959	24	203.4	39.2	164.2	19.3
Detroit	1.2	1953	50	472.2	202.6	269.8	42.9
Houston	0.7	1960	35	269.6	53.4	216.2	19.8
Indianapolis	3.6	1964	23	268.6	36.2	232.4	13.5
Kansas City	0.5	1957	25	227.4	60.1	267.4	26.4
Montreal	4.3	1974	90	678.8	368.0	310.9	54.2
Oklahoma City	0.9	1965	n.a.	149.5	9.5	140.0	6.4
Philadelphia	1.9	1960	124	699.1	422.9	276.2	60.5
Salt Lake City	1.0	1960	n.a.	197.5	16.6	180.9	8.4
San Antonio	0.9	1969	n.a.	127.2	18.7	108.5	14.7
Springfield, Mass.	1.1	1965	n.a.	101.8	14.4	87.4	14.1

Sources: Origin-destinations studies and correspondence
n.a.-Not available

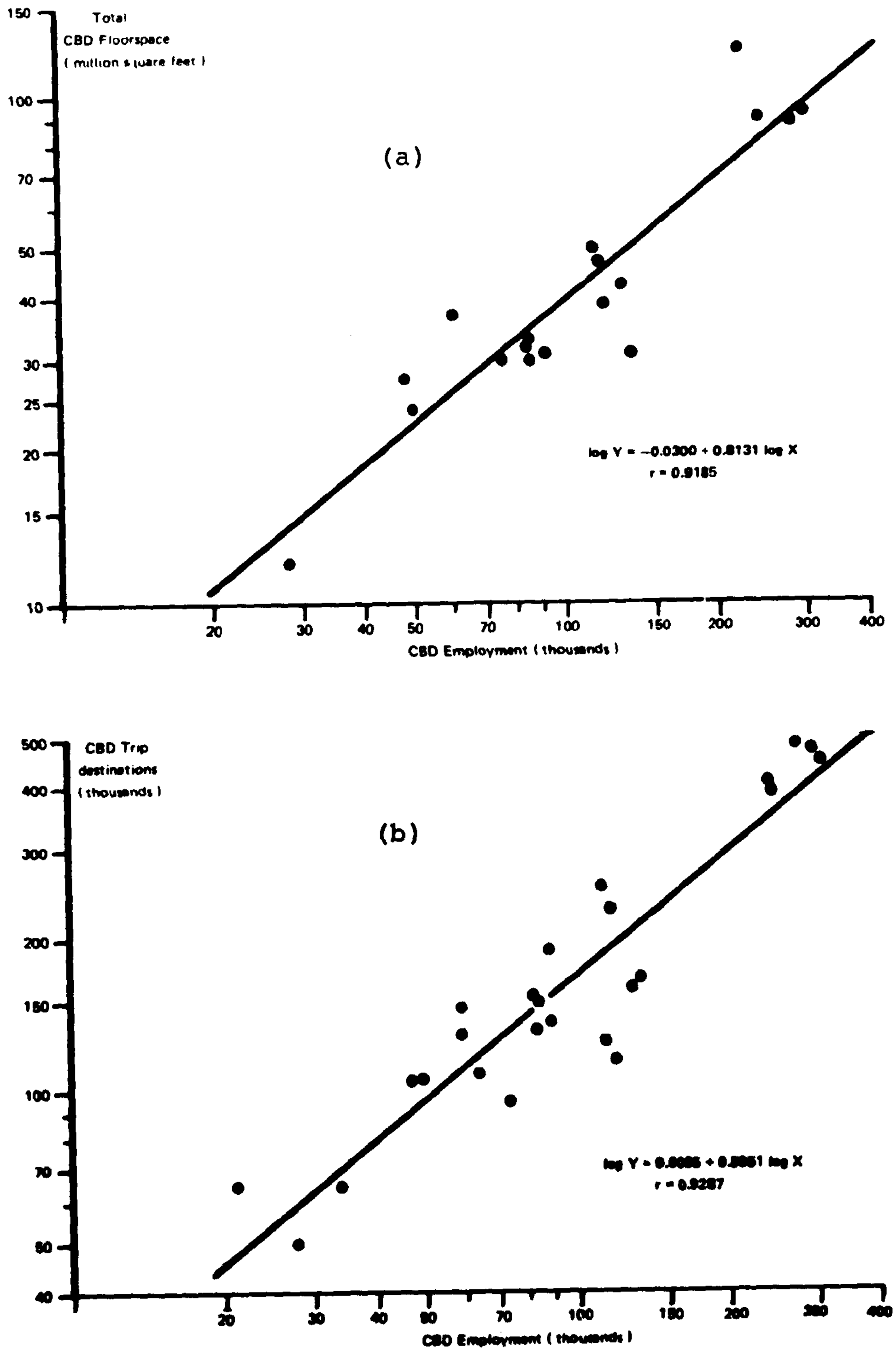


FIGURE 6-4

RELATIONSHIPS AMONG CBD EMPLOYMENT, FLOORSPACE, AND TRIP DESTINATION

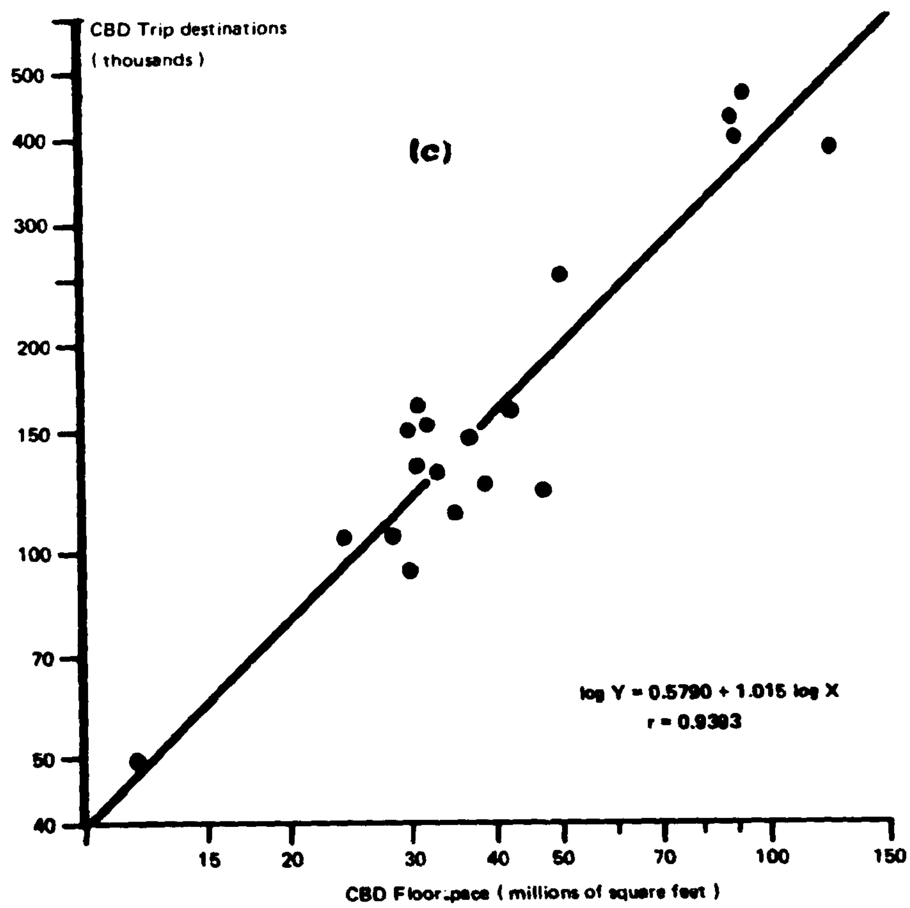


FIGURE 6-4 (CONT.)

RELATIONSHIPS AMONG CBD EMPLOYMENT, FLOORSPACE, AND TRIP DESTINATION

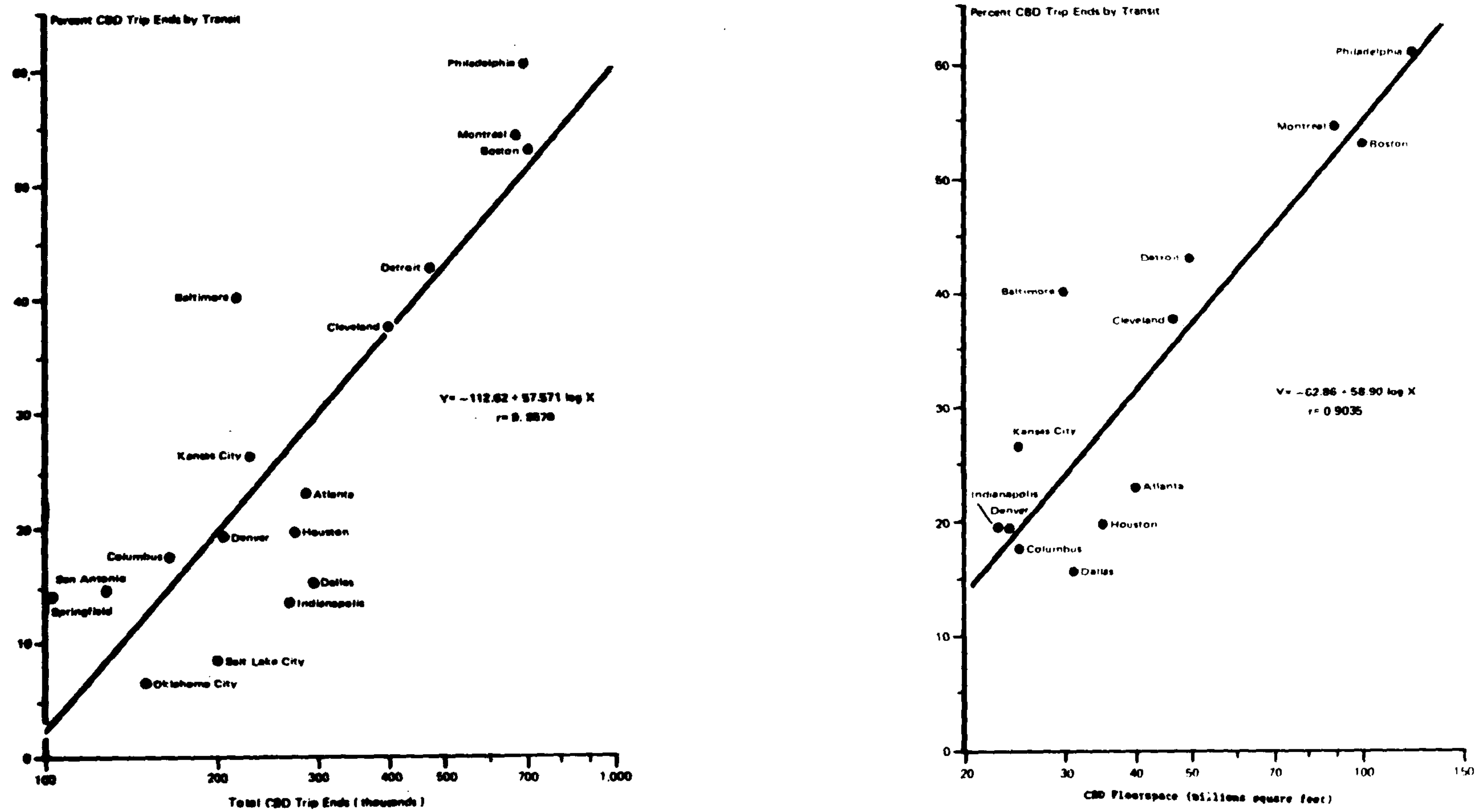


FIGURE 6-5

PERCENT TRANSIT RELATED TO CBD FLOORSPACE AND TRIP ENDS residential settlement pattern surrounding the CBD will influence transit usage. A tighter density gradient may explain Philadelphia, Baltimore and Springfield's points above the line and a more spread residential gradient may explain the Dallas, Salt Lake City, and Oklahoma City points below the line of best fit. Finally, the quality and extent of the transit service offered influences the share of travel by transit. Nevertheless, the figure suggests that CBDs with less than 300,000 trip ends or less than 40 million square feet of floorspace can expect under 25 percent of its CBD trips by transit, while those with more than 600,000 trip ends or 90 million square feet of floorspace can expect that half or more of the CBD trips will be made by transit.

Another method to estimate transit and auto trip ends is to do so directly, rather than estimating percent transit first. Figure 6-6 shows two separate scatter diagrams, one plotting total trip ends versus transit trip ends, the other total trip ends versus auto trip ends. The volume of trips by transit clearly rises linearly and dramatically on a log-log scale, jumping from some 30,000 for CBDs with 200,000 trip ends to some 30,000 for CBDs with 600,000 trip ends. Auto trip ends, on the other hand, start from a higher base and rise much more slowly. There also appears to be a distinct break in the slope at about the 250,000 to 300,000 point as auto trip ends begin to level off. This suggests the beginnings of saturation of auto traffic within the CBD. To catch this phenomenon analytically, two straight lines of best fit are calculated, each using the cluster of four CBDs near the "break point" as common data. These lines, along with the transit trip end line of best fit, are shown in the figure. For these to be internally consistent, the sum of the right-hand sides of the transit equation and the auto equation should approximate total trips.

Estimates of transit and auto trip ends can be done by using CBD floorspace directly if it is available, rather than first estimating total trip ends using employment data. In Figure 6-7, CBD floorspace is plotted against transit trip ends and auto trip ends using the floorspace data adjusted with the help of Figure 6-1, to match the CBD size of the origin-destination survey. A good data fit is found for the transit trip ends relationship, but the auto trip end equation is considerably weaker.

The foregoing relationships suggest a variety of methods to estimate transit and auto trip ends to and from a CBD. The starting point must be an estimate of either CBD employment or floorspace or both. Adjustments to such data may be necessary if the data does not conform to the CBD area under study; the adjustment could be upward or downward, using Figure 6-1, depending on whether the area of interest is larger or smaller than the area for which data is available. If employment data is available, two independent estimates of transit trip ends and of auto trip ends are possible. Method 1 would entail estimating trip ends using trip destinations from Figure 6-4, multiplying by two to get total trip ends, using that to get percent transit

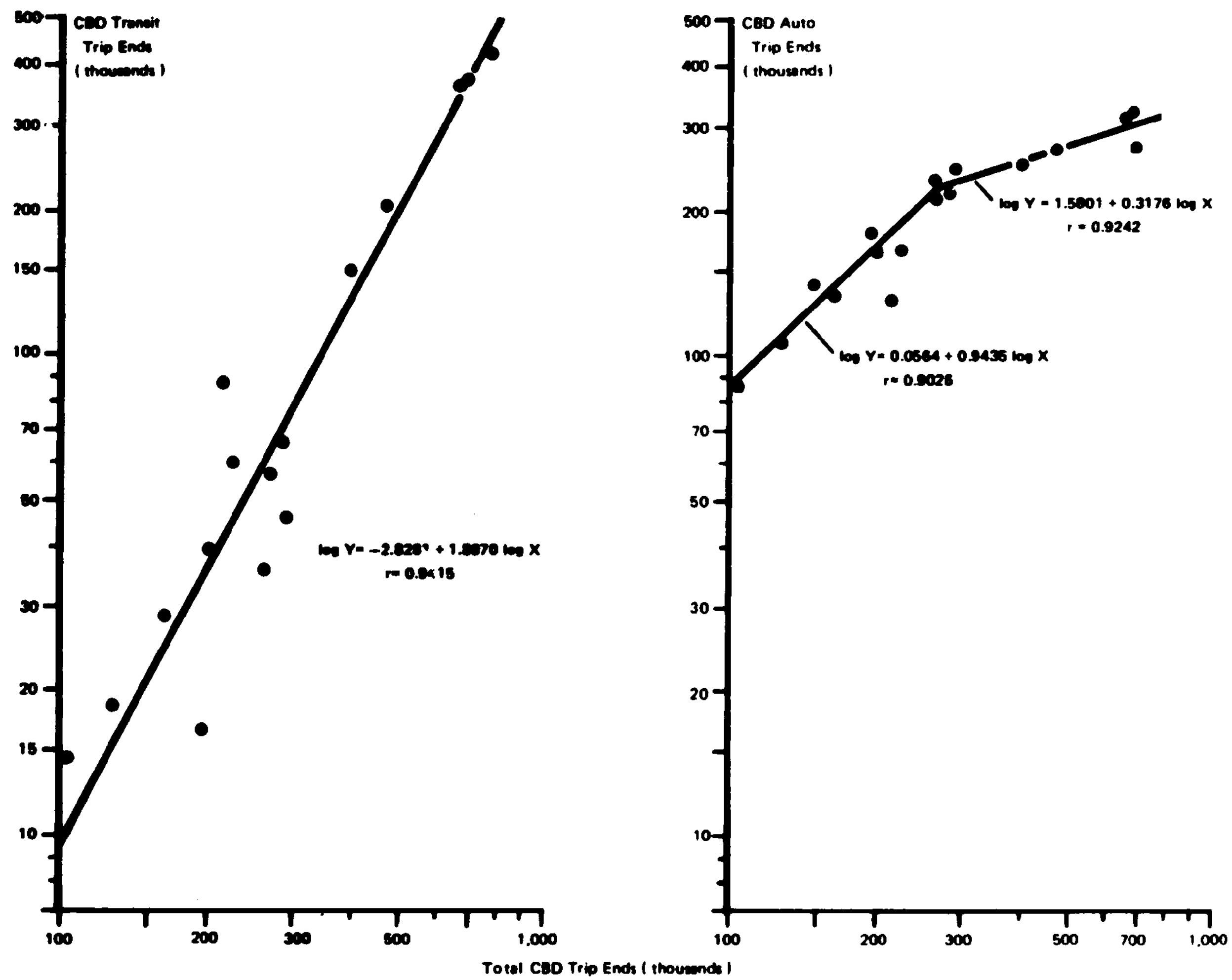


FIGURE 6-6

<u>TRANSIT AND AUTO TRIP ENDS VS. TOTAL CBD TRIP ENDS</u>

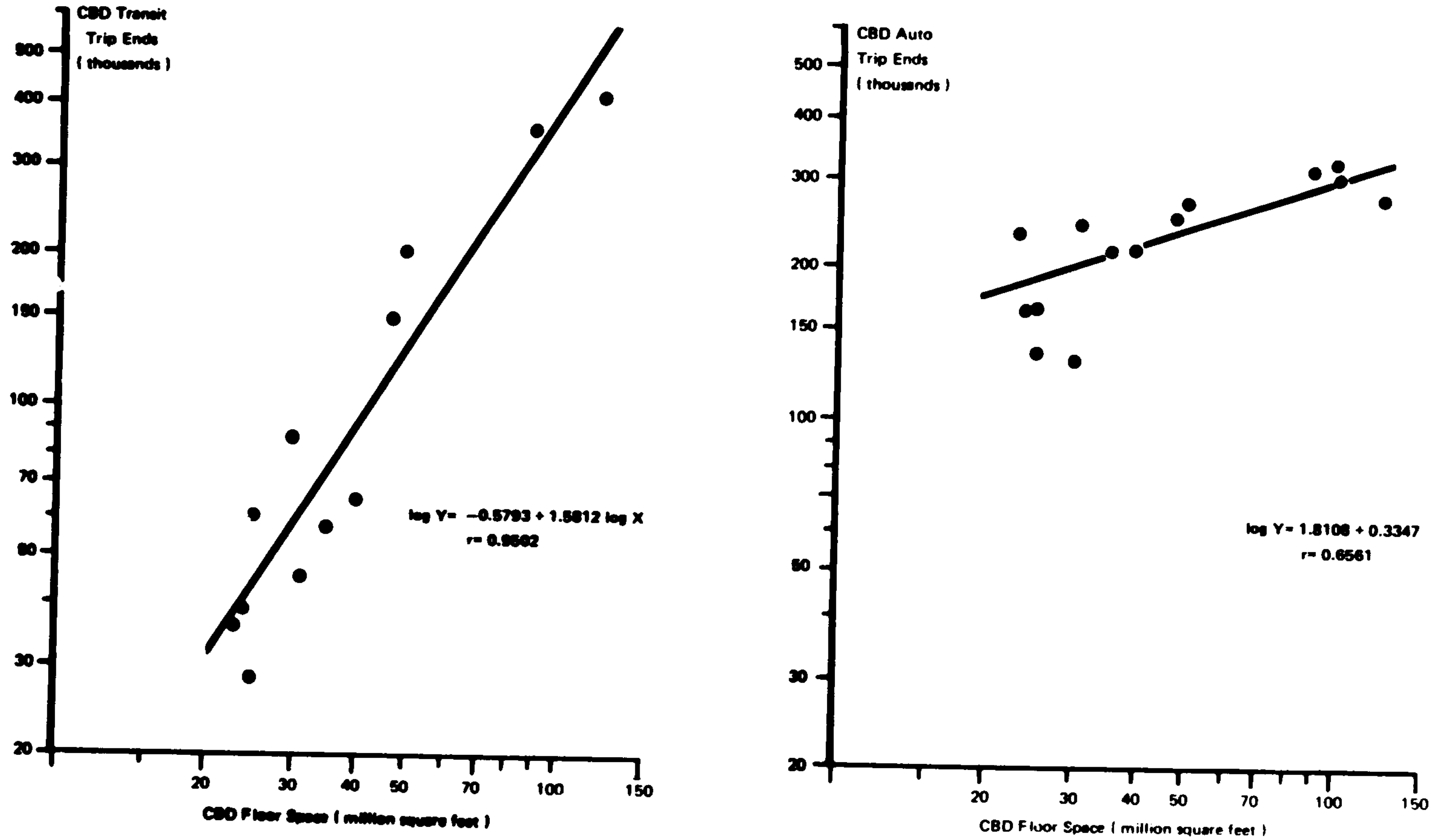


FIGURE 6-7

TRANSIT AND AUTO TRIP ENDS VS. FLOORSPACE trip ends from Figure 6-5; method 2 would use the same total trip ends of method 1 to get transit and auto trip ends directly from Figure 6-6. If floorspace data is available, four methods are possible: method 1 estimates trip ends from floorspace using Figure 6-4 and using the trip ends and the left half of Figure 6-5 to get percent transit; method 2 goes directly to Figure 6-6 with total trip ends to get transit trip ends and auto trip ends; methods 3 and 4 avoid using Figure 6-4 altogether, in the former case using floorspace and right half of Figure 6-5, and in the latter case using floorspace directly in Figure 6-7.

Table 6-2 compares the results of using these methods for a range of values of employment and floorspace. In the upper part of the figure the two methods using CBD employment are computed. The two sets of estimates, lines 5 and 6 with lines 7 and 8, compare quite nicely over most of the range, but at the upper and lower ends (20,000 jobs and 300,000 jobs) the results begin to diverge. Method 1 produces fewer transit trips at both ends and higher auto trips at the upper end of the range. This divergence is not at all surprising since the curves in Figures 6-4 through 6-7 may not continue linearly beyond the range of data for which they were calibrated. In particular, it is unlikely that transit trips would drop all the way to zero, as method 1 would indicate.

Much the same picture unfolds when the four methods (lines 13-14, 15-16, 18-19, 20-21) using floorspace are compared. Estimates for both transit and auto trip ends are quite similar, with exception of method 4 which produces much higher auto trip ends (line 21) at the lower end of the spectrum than do the other methods and much lower results at the upper end. In fact, the auto trip ends at the lower end of the range exceed total trip ends. Because of this, and because the auto trip end equation used in method 4 was weak to begin with, this method can be discarded. The estimates of the other methods produce a sufficiently narrow range of results to establish their credibility.

For the purposes of the exercise seven values of CBD employment are shown in Table 6-2: 20,000, 30,000, 50,000, 75,000, 100,000, 200,000, 300,000. This range of CBD sizes includes the full range of CBDs currently being considered for DPMs. Therefore, at a later point it will be possible to interpolate for employment anywhere in this range. The estimates of the total trips for these seven CBD sizes will be based on the employment data, assuming CBD employment is known. Therefore line 3 of Table 6-2 gives the total trip ends to be used, ranging from 90,000 to 800,000 trips. If floorspace had been known, it would have been more appropriate to use the estimates from line 11 in Table 6-2. To split total regional CBD trip ends into transit and auto, again assuming CBD employment is known, it is appropriate to use the estimates based on employment. Examination of lines 5, 6, 7, and 8 of Table 6-2 suggest two sets as likely estimates to choose from. Composite estimates of these two methods are settled on here, with the results of method 2 being preferred in the lower end of the range for reasons

TABLE 6-2

COMPARISON OF METHODS TO ESTIMATE TRANSIT AND AUTO TRIP ENDS

1.	If CBD Employment is :	20	30	50	100	200	300	
2.	Trip Destinations are : (from Figure VI-4)	45	63	95	166	290	400	
3.	Trip Ends equal : (line 1 x 2.0)	90	126	190	332	580	800	
4.	Percent Transit equals : (from Figure VI-5 and line 3)	0.0	8.2	18.6	32.6	46.5	54.7	
5.	Transit Trip Ends (line 3 x line 4)	0	10.3	35.3	108.2	269.7	437.6	METHOD 1
6.	Auto Trip Ends (line 3 – line 5)	90	115.7	154.7	223.8	310.3	362.4	
7.	Transit Trip Ends (from Figure VI-6 and line 3)	8	15	32	90	262	474	METHOD 2
8.	Auto Trip Ends (from Figure VI-6 and line 3)	80	108	160	240	287	314	
9.	If CBD Floorspace is :	10	15	20	40	70	100	
10.	Trip Destinations are : (from Figure VI-4)	39.5	59	80	160	280	405	
11.	Trip Ends equal : (line 10 x 2.0)	79	118	160	320	560	810	
12.	Percent Transit (from Figure VI-5 and line 11)	0.0	6.8	13.4	31.6	45.7	54.8	
13.	Transit Trip Ends (line 11 x line 12)	0.0	8.0	21.9	101.1	255.9	443.9	METHOD 1
14.	Auto Trip Ends (line 11 – line 13)	79.0	110.0	138.6	218.9	304.1	366.1	
15.	Transit Trip Ends (from Figure VI-6 and line 11)	6	13	23	86	245	484	METHOD 2
16.	Auto Trip Ends (from Figure VI-6 and line 11)	68	100	137	234	282	318	
17.	Percent Transit (from Figure VI-5 and line 9)	0.0	6.7	13.8	31.4	45.6	54.8	
18.	Transit Trip Ends (line 17 x line 11)	0.0	7.9	22.1	100.5	255.4	443.9	METHOD 3
19.	Auto Trip Ends (line 11 – line 18)	79.0	110.1	137.9	219.5	304.6	366.1	
20.	Transit Trip Ends (using Figure VI-7 and line 9)	10.5	20.0	31.5	92	220	380	METHOD 4
21.	Auto Trip Ends	140	160	177	220	268	300	

Note : All Employment and Trip data in thousands ; all Floorspace data in millions of square feet.

discussed earlier. The composite results are shown in the table below.

CBD Employment (000's)	Total Regional CBD Trips (000's)	Transit Trips (000's)	Auto Trips (000')
20	90	7	83
30	126	12	114
50	190	35	155
75	264	65	199
100	331	100	231
200	580	265	315
300	800	450	350

Noteworthy is the rising share of trips by transit as CBD activities get larger.

6.2.3 Estimating Internal CBD Trip Ends

The task at hand is to determine how many trips are made wholly within the CBD and how many of these are made entirely on foot, how many by transit, and how many by auto.

With the already computed estimate of external CBD trip ends, the internal CBD trip ends can be determined by subtracting external trip ends from an estimate of the total number of trip ends. This is a function of the amount and type of floorspace in the CBD. By dividing the CBD floorspace into categories, consistent with the observation that office floorspace rises and retail floorspace falls as a share of total floorspace as total floorspace increases, and applying the appropriate trip generation rates to each category of floorspace, the total CBD trip ends can be determined.

To separate internal CBD trip ends into walk and vehicle-mode requires an estimate of the share generated by each floorspace category that is walk trips. This will yield the total trip ends generated by CBD floorspace that are walk and are "VM". It will be assumed that all walk trip ends are internal. Similarly, if it is assumed that all external CBD trip ends are vehicle mode, then the VM internal CBD trip ends are determined by taking the difference between the total VM and the external CBD trip ends.

The last task is to divide the VM internal CBD trip ends into those that are made by transit and by auto, assuming that the share by transit rises with rising CBD floorspace.

In Figure 6-3 results of the above described procedure are shown. First, for each of the seven levels of CBD activity considered, floorspace is divided into office, retail, and other. Office floorspace is assumed to be 50 percent of total floorspace for the largest CBDs, falling to 40 percent for the small ones;

retail floorspace is assumed to be 10 percent of total floorspace for the larger CBDs rising to 20 percent for the smaller ones. Trip generation rates are then assigned to each of these categories of floorspace (lines 6, 7, 8) consistent with the discussion in Section A. These rates are based on limited data, especially for the retail category. Evidence suggests and logic dictates that retail trip generation rates are likely to be higher in areas of higher land value. For example, trip rates in suburban shopping centers fall below 70 trip ends per 1000 square feet and trip rates in Manhattan rise well above 100. This explains the use, in the table, of the variable retail trip generation rates ranging from 70 to 100 for the range of CBD activities.

Application of the three sets of trip generation rates to the three floorspace categories and summarizing the results yield total CBD trip ends (line 12). To obtain internal trip ends (line 14) the external trip ends determined earlier and shown here in line 13 are subtracted from total trip ends. To determine how many of these are made entirely on foot, the trip ends of each of the three floorspace categories that are VM are calculated assuming that 74 percent of all office, 25 percent of all retail and 80 percent of "other" trip ends are VM (lines 15, 16, 17), based on the discussion presented in Section A. Total VM trip ends (line 18) are the sum of these three lines. This estimate is higher than external trip ends, as it should be, since most, if not all of external trip ends are VM. If it is assumed that all external trip ends are VM, then the difference represents the number of internal VM trip ends (line 19). The remaining internal trip ends are therefore "walk-only" (line 20).

Using the evidence presented in Section 6.1.3 to estimate the percent of internal vehicle trip ends by transit (line 21) permits splitting such trips into the two vehicle modes (lines 22 and 23).

The results of the exercise in Table 6-3 show the overwhelming proportion of internal CBD trip ends that are made entirely on foot. In no case does the "walk-only" share fall below 90 percent. Clearly, these trips will deserve prime attention when diversions to a DPM are considered.

Two final methodological points remain. First, the calculations above are all done on the basis of trip ends. A trip internal to the CBD, by definition, has both its ends in the CBD. Therefore, all internal trip ends calculated above must be divided by two to obtain internal trips. Second, it is recognized that this procedure relies on numerous assumptions, either intentionally simplifying or made with imperfect or incomplete data. It is likewise recognized that some of the weaker techniques of modelling are employed, namely the use of long chains of calculations and the taking of differences between numbers of the same order of magnitude. Nevertheless, the results seem reasonable and internally consistent, and until

TABLE 6-3

CALCULATION OF INTERNAL CBD TRIP ENDS

1. CBD Employment (000's)	300	200	100	75	50	30	20
2. CBD Floorspace (mil. sq. ft.)	96	69	39.5	31.5	22.5	15	10
3. Percent office floorspace	50	48	46	44	43	42	40
4. Percent retail floorspace	10	11	12	13	15	17	20
5. Percent other floorspace	40	41	42	43	42	41	40
6. Trip ends per 1000 sq. ft. – office	15	15	15	15	15	15	15
7. Trip ends per 1000 sq. ft. – retail	100	95	90	85	80	75	70
8. Trip ends per 1000 sq. ft. – other	7	7	7	7	7	7	7
9. Trip ends – office lines 2x3x6	720	497	273	208	145	95	60
10. Trip ends – retail lines 2x4x7	960	721	427	348	270	191	140
11. Trip ends – other lines 2x5x8	269	198	116	95	66	43	28
12. Total trip ends sum of lines 9, 10, 11	1,949	1,416	816	651	481	329	228
13. External trip ends (From section B)	800	580	331	264	190	126	90
14. Internal trip ends line 12 minus line 13	1,149	836	485	387	291	203	138
15. Vehicle mode trip ends – office line 9 x 0.74	533	368	202	154	107	70	44
16. Vehicle mode trip ends – retail line 10 x 0.25	240	180	107	87	68	48	35
17. Vehicle mode trip ends – other line 11 x 0.80	205	152	89	73	50	33	22
18. Total vehicle mode trip ends sum of lines 15, 16, 17	979	700	398	314	225	151	101
19. Internal vehicle mode trip ends* line 18 minus line 13	179	120	67	50	35	25	11
20. Internal walk trip ends line 14 minus line 19	970	716	418	337	256	178	127
21. Percent internal vehicle mode trip ends by transit	60	45	30	25	20	15	10
22. Internal transit trip ends lines 19 x line 21	107	54	20	13	7	4	1
23. Internal auto trip ends line 19 minus line 22	72	66	47	37	28	21	10

*Assumes all external trips are vehicle mode

Note: All trip ends expressed in thousands.

substantially more data is collected on travel within CBDs, reliance can be placed on techniques of the sort employed here.

6.2.4 Estimating Diversion of Regional CBD Transit Trips to DPMs

The share of regional CBD transit users who will shift to a DPM for the portion of their trip in the CBD depends on how many will find the "price" of using the DPM cheaper than the "price" of not using it. Before these prices can be calculated it is necessary to know something about the location of possible users. Of prime importance then is whether the line-haul transit trip delivers them to the fringe of the CBD where an adjoining DPM station is located, or directly to the CBD's center, where a DPM can be used to disperse them throughout the CBD. For purposes of illustration in our exercise it will be assumed that four transit delivery possibilities exist: (1) the transit system delivers all its passengers to a central CBD point, (2) the transit system delivers one-quarter of its CBD passengers to a fringe DPM station, (3) it delivers one-half of its passengers to a fringe DPM, and (4) it delivers all of its passengers to a fringe DPM. In all four cases, the potential user will have to compare the price of transferring to, paying for, waiting for, riding on, and leaving and walking from the DPM with the price of not using the DPM. In some cases this will mean walking to his destination; in other cases it means use of another vehicle mode in the CBD. The distinction between the first transit delivery arrangement case and the other three is quite important. In the case of the transit system delivering the passengers to the CBD's center, a much larger share of the floor space (and trip ends) is likely to be close by, negating the advantage of a DPM.

The next locational consideration is the distribution of CBD activities. In Figure 6-1, it was shown that the concentration of CBD activities varies considerably. Some cities show a sizable spread of activities with relatively large portion of the total activities in the less dense locations. Some show a high proportion of the activities located in a small proportion of the CBD's land area. The more spread pattern would tend to increase DPM demand if the transit system delivered its passengers to a central location since a smaller proportion of the activities would be located in the center. Conversely, the more concentrated pattern would produce more DPM riders with a fringe delivery system since few riders are likely to be travelling to or from points near the fringe, thereby requiring additional transportation to the more central location. Since it appears that the degree of CBD concentration has influence on DPM ridership, two distributions of CBD activities will be assumed, a spread one approximating the majority of curves from Figure 6-1, and a concentrated one approximating the curve for Houston in Figure 6-1.

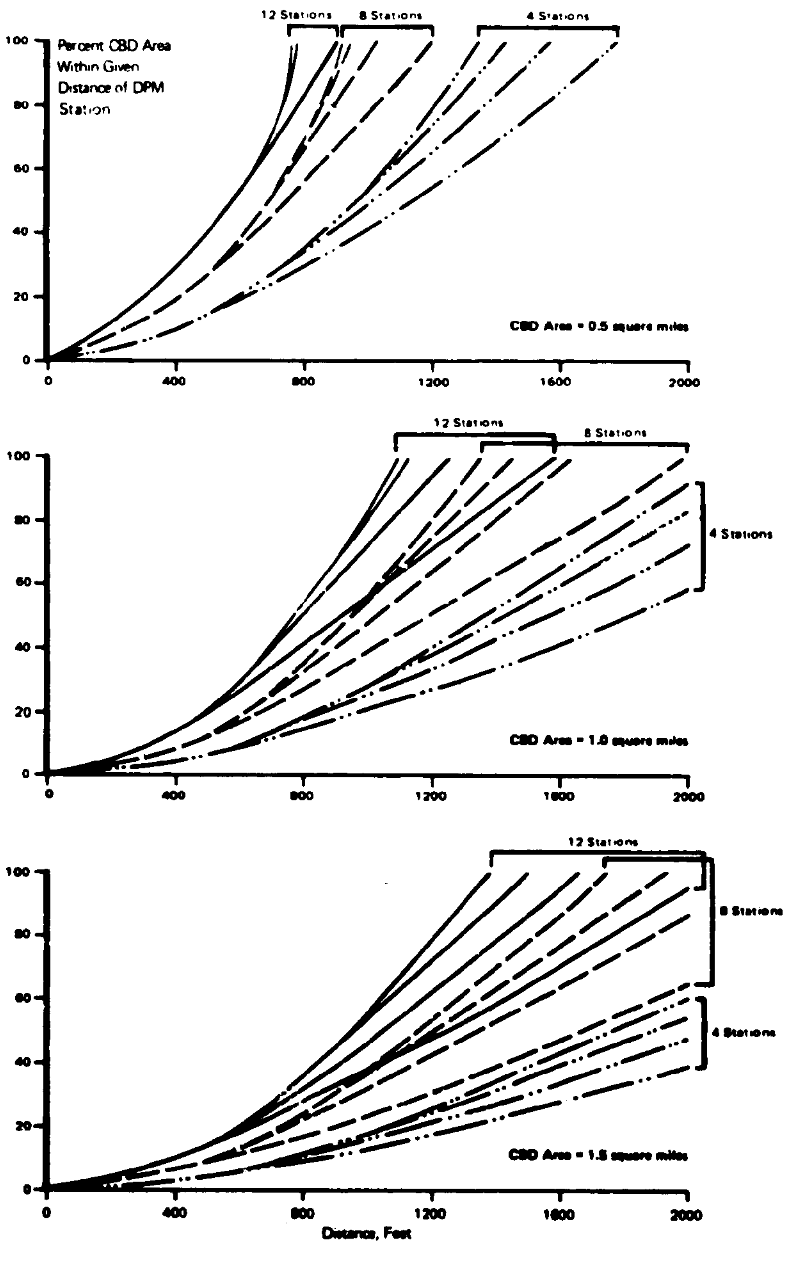
Before the "prices" of using or not using a DPM can be compared, it is necessary to understand how much coverage of the

CBD the DPM system will give. A CBD large in area with few DPM stations located within it will result in many of the trip ends unserved except those with exceedingly long walks; a small CBD with an excessive number of stations will result in an unnecessary duplication of coverage, with overlapping areas served. Figure 6-8 shows the percent of a CBD's area within a given distance from a DPM station as a function of CBD area, number of stations and station spacing. It is these access distances that the potential DPM user will have to walk if he chooses the DPM. The exhibit can be quite instructive for choosing the size of a DPM system for a given CBD. Data that can be used to plot additional curves for other CBD areas and number of stations are presented in Table 6-4.

The size of the system is defined by the combination of station spacing and number of stations. In a shuttle arrangement, the system route length will equal the average station spacing times the number of stations minus one; in a loop arrangement route length equals average station spacing times the number of stations. For example, the route length of a four station - 1200 foot spacing shuttle system is 3600 feet; for a loop arrangement, 4800 feet.

In Figure 6-8 for a CBD area of 1.0 square miles, it is obvious that a four-station DPM with 800 foot spacing would provide rather poor coverage; only about 25 percent of the CBD land area would be within 2000 feet of a station. Expanding the station spacing to 2000 feet would put over 90 percent of the area within 2000 feet of a station. However, it should be recognized that for this additional coverage, the system would have to be extended by more than twice its length. Additional coverage can also be gained by increasing the number of stations. The eight-station, 800 foot spacing system would provide considerably more coverage than the four-station, 1600 foot system, although if arranged in a loop the two systems would have the same total route length. This will always be the case if more stations are provided for the same length because a greater proportion of the area will be near a station.

When many stations are provided, however, the extension of the station spacing begins to show diminishing returns. In fact, it may even become impossible to fit a system into the CBD with many stations if they are spread too far apart. Note that with eight stations and a 1200 foot spacing, the entire CBD was within about 1000 feet walk of a station; with 1600 foot spacing, this occurs at about 1450 feet; and with 2000 foot spacing, the entire CBD would be within a walk of slightly greater than 1300 feet. Increasing the number of stations to 12 shows the same pattern; not only would little advantage be gained by extending the station spacing beyond 1200 feet, it is physically impossible to do so. Note that with 12 stations, the 800 foot spacing is significantly poorer than the others. This occurs because of the high degree of overlap produced by stations so close.



Notes: Each set of curves for a given number of stations show station spacing from right to left of 800, 1200, 1600 and 2000 feet.

FIGURE 6-8

DPM STATION COVERAGE BY CBD AREA, NUMBER OF STATIONS AND STATION SPACING

TABLE 6-4

PERCENT OF CBD AREA WITHIN GIVEN DISTANCE OF DPM STATIONS BY CBD SIZE, NUMBER OF DPM STATIONS AND STATION SPACING

Number of Stations	CBD Area, square miles	0.5				0.75				1.0			
	Station Spacing, feet	800	1200	1600	2000	800	1200	1600	2000	800	1200	1600	2000
	Distance Covered, feet												
4	400	9	9	9	9	6	6	6	6	5	5	5	5
	800	30	36	37	37	20	23	24	24	15	18	18	18
	1200	56	67	76	81	36	44	49	52	28	34	38	41
	1600	85	100	100	100	56	78	79	86	42	52	60	66
	2000	100	100	100	100	79	100	100	100	60	73	84	93
6	400	13	13	13		9	9	9	9	7	7	7	7
	800	43	62	54		29	36	36	36	22	26	27	27
	1200	78	98	100	not applicable	52	86	75	80	40	49	56	61
	1600	100	100	100		78	99	100	100	59	74	87	97
	2000	100	100	100		100	100	100	100	80	100	100	100
8	400	18	18			12	12			9	9	9	9
	800	57	[illegible]			31	37			29	35	37	37
	1200	100	100	not applicable		60	87	not applicable		51	65	75	81
	1600	100	100			100	100			75	97	100	100
	2000	100	100			100	100			100	100	100	100
10	400	23				15	15			12	12	12	12
	800	71				47	58			37	43	47	47
	1200	100	not applicable			83	100	not applicable		63	80	94	100
	1600	100				100	100			92	100	100	100
	2000	100				100	100			100	100	100	100
12	400	28				18				14	14		
	800	86				57				43	52		
	1200	100	not applicable			98	not applicable			74	96	not applicable	
	1600	100				100				100	100		
	2000	100				100				100	100		
16	400					21				17	17		
	800					69				53	65		
	1200	not applicable				100	not applicable			91	100	not applicable	
	1600					100				100	100		
	2000					100				100	100		

Number of Stations	CBD Area, square miles	1.5				2.0			
	Station Spacing, feet	800	1200	1600	2000	800	1200	1600	2000
	Distance Covered, feet								
4	400	3	3	3	3	2	2	2	2
	800	10	12	12	12	5	9	9	9
	1200	18	22	24	26	12	17	19	20
	1600	28	34	39	43	19	26	30	33
	2000	39	48	55	61	28	37	42	47
6	400	4	4	4	4	3	3	3	3
	800	14	17	18	18	11	13	14	14
	1200	26	33	37	40	19	24	28	30
	1600	39	49	58	65	29	37	44	49
	2000	52	66	79	90	40	51	60	68
8	400	6	6	6	6	5	5	5	5
	800	16	23	25	25	14	17	18	18
	1200	31	43	50	54	25	32	37	40
	1600	49	65	77	86	37	49	58	64
	2000	66	87	100	100	51	65	79	90
10	400	8	8	8	8	6	6	6	6
	800	24	29	31	31	18	22	23	23
	1200	41	53	62	67	31	40	47	51
	1600	60	79	93	100	45	60	71	80
	2000	81	100	100	100	61	80	97	100
12	400	9	9	9	9	7	7	7	7
	800	28	35	37	37	21	26	28	28
	1200	49	64	75	81	37	48	56	61
	1600	71	94	100	100	53	71	85	96
	2000	95	100	100	100	71	95	100	100
16	400	11	11	11	11	9	9	9	9
	800	34	42	45	45	26	32	34	34
	1200	60	79	92	100	45	60	70	76
	1600	87	100	100	100	65	88	100	100
	2000	100	100	100	100	87	100	100	100

Note: Not applicable means that given station number spacing configuration cannot fit into CBD of given size

The curves of coverage for a CBD area of 0.5 and 1.5 square miles in Figure 6-8 teach many of the same lessons. In addition, it is obvious that the same system placed in a smaller area will cover a larger percent of the area, and in a larger area, a smaller percent of the area. For example, with a CBD area of 0.5 square miles, four stations with 1200 foot spacing places about 68 percent of the CBD within 1200 feet of a station, while a CBD of 1.0 square miles would be only 33 percent covered within 1200 feet for the same DPM system and a CBD of 1.5 square miles would be only 21 percent covered. In Table 6-4 the cumulative percent coverages for CBD area of 0.5, 0.75, 1.0, 1.5 and 2.0 square miles are given to permit the analyst to further pursue these complex relationships for various-sized CBDs. Systems that cannot fit into the given CBD are designated by a "not applicable" notation.

Quantification of the area covered by a given DPM system still leaves the task of determining the proportion of activities covered. Consider a DPM of four stations with 1600 foot spacing set in a CBD of 1.0 square miles. Figure 6-8 shows that about 84 percent of the area would be within 2000 feet of a DPM station. With four stations, each would cover 21 percent of the CBD's area. From Figure 6-1, the densest 21 percent of a CBD with a sparead activity distribution would contain 42 percent of the CBD's activities; the concentrated activity distributions would contain about 67 percent of the CBD's activities. These percentages represent the amount of activity surrounding the busiest DPM station. Similarly, from Figure 6-1, the second busiest station for the spread CBD would contain 25 percent of the CBD activities, the third busiest, 16 percent, the four, 11 percent, for a total of 94 percent of the activities covered by the four stations. For the concentrated distribution, the second, third, and fourth stations would contain 22, 9 and 2 percent of the CBD's activities which, when added to the first-ranked station, totals 100 percent coverage of activities. This simulated activity pattern around DPM stations can be determined in a similar manner for any CBD size, number of DPM stations, and station spacing.

If, for example, an eight station-1200 foot station spacing system were to be examined for a 1.5 square mile CBD, then Table 6-4 shows that 87 percent of the CBD's area would be covered withn 2000 feet, or an average of about 11 percent per station. Figure 6-1 suggests that the densest station would include about 20 percent of the CBD activities for a spread CBD and 40 percent for a concentrated CBD. The second, third, etc. busiest stations could be calculated similarly.

With a DPM arranged to pick up transit passengers at a fringe station, the location of each of the four stations, each with varying amounts of activities around them, becomes relevant. It shall be assumed that the fringe station where the transit to DPM transfer is made is the one surrounded by the least amount of activity. Thus, the pattern of activities for our example is assumed to be the following:

Station number	1	2	3	4
Station rank by activity density	4	2	1	3
Activities-spread CBD	11%	25%	42%	16%
Activities-concentrated CBD	2%	22%	67%	9%

It is assumed that this is a reasonable arrangement of activities in typical CBDs with the greatest density of activities near the center and a decline outward.

Now the diversion of transit passengers to the DPM can be calculated. Consider a transit system delivering passengers to station #1. It is obvious that none of these passengers with trip ends near the first station (either 11 or 2 percent of all trip ends) will switch to the DPM. The DPM will not take them any closer to where they want to go. The passengers with trip ends surrounding the second station will use the DPM if the "price" of using it is less than the price of the walk between the transfer point and the trip end location. To test this a price must be assigned to each of the trip elements. On the basis of evidence presented earlier on the value of time, for transit users the following will be used:

Transferring (including effort of ascending escalators)	= 5 cents per minute
Waiting	= 3 cents per minute
Riding	= 2 cents per minute
Walking	= 5 cents per minute

It is also necessary to make some assumptions about the operating characteristics of the DPM. It will be assumed that headways will be two minutes, meaning that the average passenger waits one minute, placing a 3 cent value on his wait. Assumed maximum system speed will be 10 miles per hour with 2.5 miles per hour per second acceleration and deceleration rates and 10 second dwell times. These assumptions convert to operating speeds of 8.0, 8.5, 8.8 and 9.1 mph for station spacings of 800, 1200, 1600, and 2000 feet, respectively. The time passengers spend riding on the system will be 1.14, 1.60, 2.05 and 2.50 minutes, respectively, for these four station spacings. At 2 cents per minute for the value placed on riding in a vehicle, the cost of riding one stop will be 2.3, 3.2, 4.1 and 5.0 cents, respectively. Each added station travelled means an added cost in even multiples of these values, assuming uniform station spacing. It will be assumed for the moment that no fare will be charged for use of the DPM.

For the second station, the cost of not using the DPM, walking all the way to the trip end, will be the cost of walking 1600 feet. This is the average distance from the transfer point of trip ends surround each station 2. At walking speeds of 230 feet per minute, allowing time for waiting at intersections, this walk will require just under 7 minutes and with walking time valued at 5 cents per minute, the price of not using the DPM turns out to be 34.8 cents. The use of the DPM costs 5 cents for the one-minute transfer, 3 cents for the one-minute wait and 4.2

cents for the 1600 foot ride on the DPM plus the cost of the walk between the DPM and the trip end. In other words, if the cost of the walking link from the DPM is less than 22.7 cents (34.8 - (5 + 3 + 4.1)) then the DPM will be used. At 5 cents per minute and a walking speed of 230 feet per minute, this walk would have to be less than 1044 feet. Interpolating from Figure 6-8 or from the data in Table 6-4, it is found that 30 percent of the CBD is within that distance. Since 84 percent of the CBD was found to be within 2000 feet of DPM stations, then the percent of the 2000 foot coverage that is within 1000 feet can be computed: 30/84, or 36 percent. Assuming that within a station's covered area, activity densities are evenly distributed, this means that 36 percent of the activities grouped around the station will be reached using the DPM in this case, 9 percent of the CBD's activities for the spread CBD (.36 x 25) and 8 percent for the concentrated CBD (.36 x 22).

It is clear that this method requires an understanding of how many stops there are from the fringe station to each of the other stations. In Figure 6-9, sketches of three configurations of an eight station system are given to illustrate how the number of stops to each station varies. In the linear system many stops are required to reach the stations at the far end. A one-way loop arrangement produces the same situation. In addition persons with trip ends near the last station visited on the loop are likely to have a relatively shorter walk as an alternative to using the DPM. A two-way loop system remedies the problem of the other two systems; in this example, the maximum number of stops is reduced from seven to four. Of course, this comes at a price of additional capital and operating costs for the two-way loop over the one-way loop.

In a similar manner the proportion of the trip ends surrounding the third station can be calculated. In this case the length of the "walk-only" alternative is sufficient to divert all transit users surrounding that station to the DPM. All trips to and from the area of the fourth station will be similarly diverted. Adding up the proportions of trip ends diverted for the spread and concentrated CBDs, respectively, for each station gives, for this case, 67 and 84 percent diversions.

These diversions are for only those transit users delivered to the fringe DPM station. If the transit system is arranged to deliver only a small portion of its users to the fringe DPM station, a system that delivers its passengers to the center rather than the fringe may produce a larger diversion to the DPM. In the manner described above, diversions for different assumptions of CBD size, number of stations, and station spacing can also be calculated.

Likewise the diversions for different assumptions of DPM operating characteristics can be calculated. Five variations of the basic assumptions have been chosen for examination: (1) 20 miles per hour maximum DPM speed instead of 10 mph, (2) one minute headways instead of 2 minutes, (3) 4 minute headways

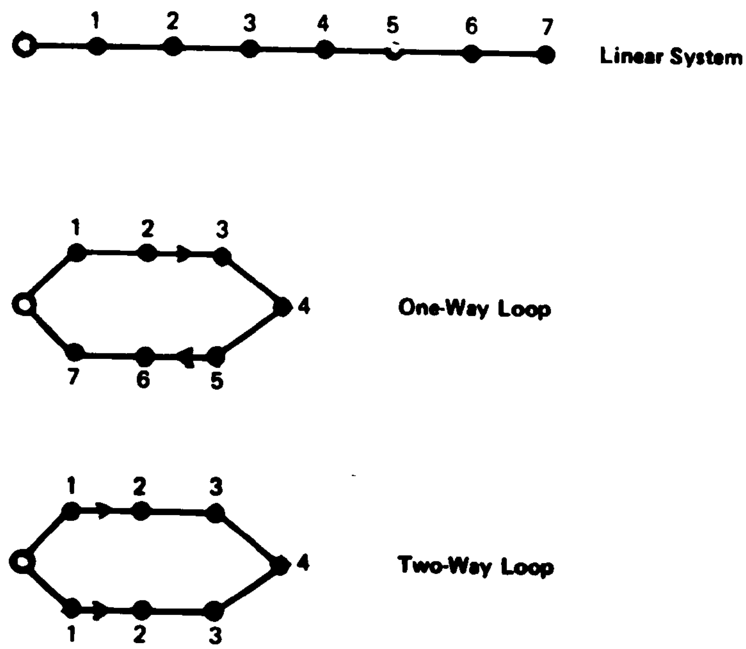


FIGURE 6-9

ILLUSTRATIVE EIGHT STATION DPM CONFIGURATIONS instead of 2 minutes, (4) 10¢ fare instead of free fare, and (5) 25¢ fare instead of free fare.

The results of all these calculations are presented in the next series of tables and figures. In Table 6-5 the percent of all regional CBD transit users diverted to the DPM is given for differing CBD land area (0.5, 1.0 and 1.5 square miles), CBD activity distributions (spread and concentrated), numbers of stations (4, 8 and 12), station spacing (800, 1200, 1600, and 2000 feet), and four arrangements of the delivery of transit passengers (all to the central delivery point, 25% to fringe, 50% to fringe, and 100% to fringe). In Figure 6-10, these data are shown graphically for the 50% delivery to fringe arrangement and for central delivery only.

A number of observations relevant to DPM design are suggested by examination of these two exhibits:

1) Short station spacings may be very inefficient; spacing of 800 feet generally attracts less than half the passengers of 1200 foot spacings, while requiring two-thirds of the route length. However, if station spacing is increased beyond 1200 feet, the diversion rate begins to show diminishing returns. For systems with many stations, or in CBDs of small land areas, the diminishing returns become evident at shorter station spacings.

2) Similar route length produces similar diversion rates. More stations for the same route length produces only marginally more diversion.

3) In many cases, the increase in the number of stations can be desirable. For example, for the CBD land area of one square mile, eight stations achieve more than double the diversions of four stations, at least at lower station spacings. At the higher spacings, doubling the number of stations from four to eight remains efficient if a central delivery arrangement is used, but for the fringe delivery, returns diminish.

4) Delivery of 100% of the transit passengers to the fringe for transfer to the DPM will always produce greater diversions to the DPM than will a central delivery arrangement. In reality, it is exceedingly difficult to intercept all transit passengers at DPM stations since they are arriving from all directions, nor is it desirable since many transit passengers who transfer to the DPM will be largely determined by the manner in which the existing line-haul transit system is modified to create the necessity for that transfer.

5) Comparison of the central delivery system to the more realistic 50 percent fringe delivery arrangement suggests that the former will work better for spread CBD distributions and the larger systems.

TABLE 6-5

PERCENT DIVERSION OF REGIONAL CBD TRANSIT USERS TO DPM AS FUNCTION OF CBD CONCENTRATION, TRANSIT DELIVERY ARRANGEMENT, NUMBER OF STATIONS AND STATION SPACING

Number of Stations	4				8				12		
Station Spacing, feet	800	1200	1600	2000	800	1200	1600	2000	800	1200	1600
Route length, feet*	2400	3600	4800	6000	5600	8400	11,200	14,000	8800	13,200	17,600
CBD Area = 0.5 sq. miles – Spread Activity Distribution											
Transit Delivery											
To Center	7	23	36	52	37	56	na	na	58	na	na
25% to fringe	9	18	20	22	22	23	na	na	23	na	na
50% to fringe	19	36	40	45	43	46	na	na	47	na	na
100% to fringe	38	71	79	89	87	92	na	na	94	na	na
CBD Area = 0.5 sq. miles – Concentrated Activity Distribution											
Transit Delivery											
To Center	2	8	17	29	15	28	na	na	34	na	na
25% to fringe	8	21	23	25	24	25	na	na	25	na	na
50% to fringe	16	42	46	50	49	50	na	na	50	na	na
100% to fringe	32	83	91	100	97	100	na	na	99	na	na
CBD Area = 1.0 sq. miles – Spread Activity Distribution											
Transit Delivery											
To Center	5	17	26	34	26	49	58	71	43	66	na
25% to fringe	6	13	17	19	20	23	23	24	23	24	na
50% to fringe	12	26	34	39	40	45	46	48	45	47	na
100% to fringe	23	51	67	77	79	91	93	95	90	95	na
CBD Area = 1.0 sq. miles – Concentrated Activity Distribution											
Transit Delivery											
To Center	4	12	13	18	9	23	24	48	24	42	na
25% to fringe	7	17	21	22	23	25	25	25	25	25	na
50% to fringe	14	34	42	45	45	50	50	50	49	50	na
100% to fringe	29	68	84	90	91	99	100	100	98	99	na
CBD Area = 1.5 sq. miles – Spread Activity Distribution											
Transit Delivery											
To Center	1	7	13	39	17	37	56	60	38	59	68
25% to fringe	2	5	7	10	13	20	22	22	23	23	24
50% to fringe	4	9	13	21	26	40	44	44	46	47	47
100% to fringe	7	18	26	42	52	79	87	88	81	93	94
CBD Area = 1.5 sq. miles – Concentrated Activity Distribution											
Transit Delivery											
To Center	2	7	11	24	11	21	25	31	20	36	45
25% to fringe	2	7	10	14	15	21	25	25	23	23	23
50% to fringe	5	14	21	28	31	43	50	50	46	46	46
100% to fringe	10	28	41	56	61	85	100	100	92	92	93

* Assumes a shuttle system where route length = station spacing times number of stations minus one

na - Not applicable

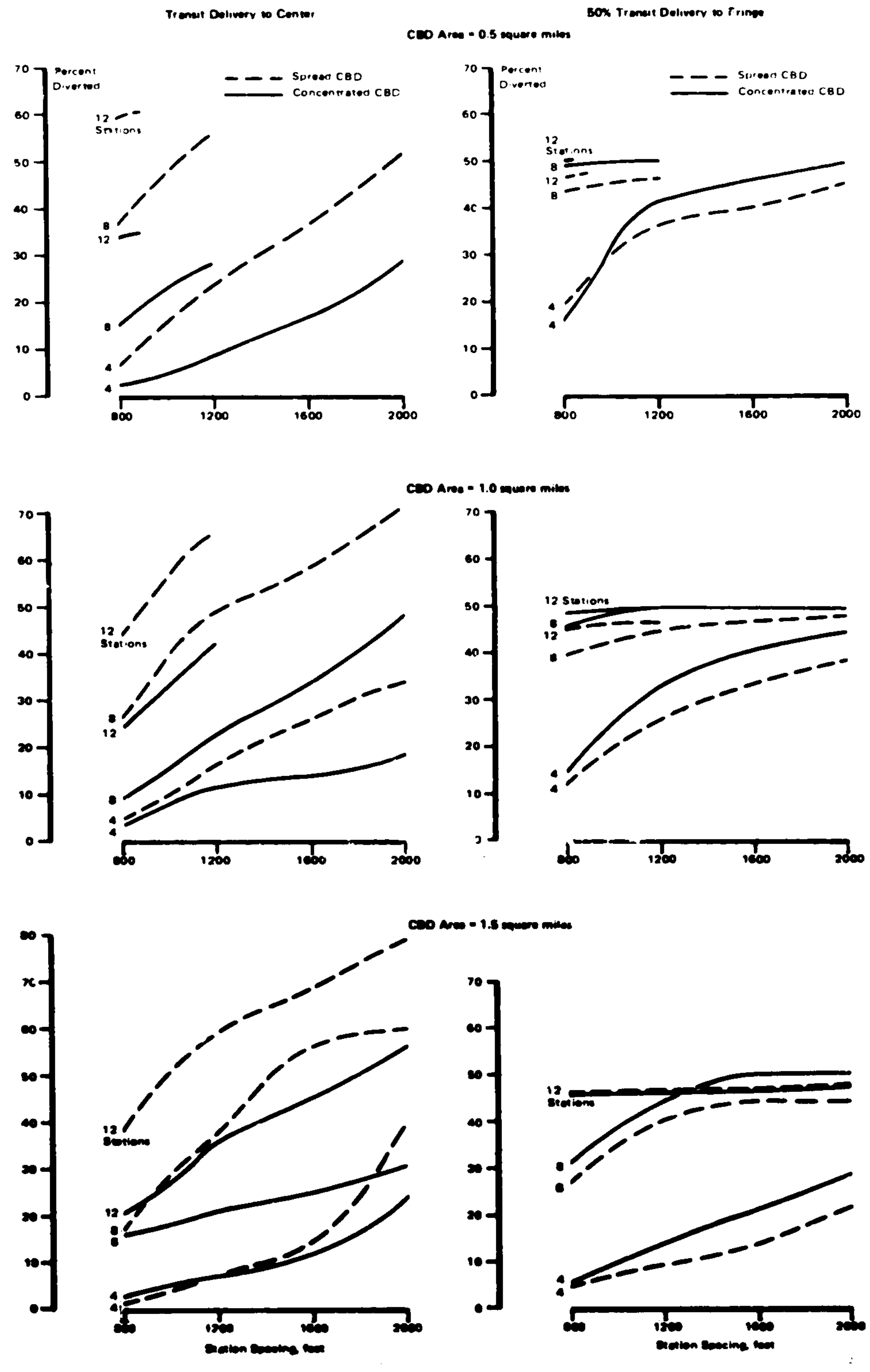


FIGURE 6-10

PERCENT DIVERSION OF REGIONAL CBD TRANSIT USERS TO DPM AS A FUNCTION OF CBD AREA, CBD CONCENTRATION, TRANSIT DELIVERY ARRANGEMENT, NUMBER OF STATIONS, AND STATION SPACING

Sensitivity to Operating Characteristics - Regional Transit Diversion to DPM

The sensitivity of diversions to DPM of regional CBD transit users to changes in the operating characteristics of the DPM is shown in Table 6-6. Diversion rates for the five variations of the base operating characteristics are shown for the CBD land area of one square mile, for two delivery arrangements, 50% delivery to fringe and central delivery, and for both the spread and concentrated CBD distributions. To illustrate the impact of the five operating variations, the data is graphed in Figure 6-11 for the eight station DPM.

A number of relevant observations about how the operating characteristics of a DPM can influence the diversion of transit users can be drawn from the exhibits:

1) Under any conditions, increase in maximum DPM cruise speeds from 10 to 20 miles per hour diverts very few additional passengers to the DPM. This occurs because maximum speeds affect only the in-vehicle portion of the total DPM trip, which is a small share of its price to the user. Furthermore, the higher maximum speeds are diminished by frequent stopping and starting of the system.

2) The impact of more frequent service has a similar limited effect. Doubling of frequencies, i.e., reductions in headways by half from two minutes (base conditions) to one minute, gains only 30 seconds of waiting time for the DPM passenger, again only a small portion of the total price of the DPM trip.

3) Reductions in service frequency by half, i.e., doubling of headways from two minutes to four minutes, also produces quite modest differences in the diversion rate.

4) The imposition of fares begins to have a sizable effect on diversion to the DPM. This is particularly noticeable for the central delivery arrangement and for fringe deliveries with short station spacings. The percent reductions in ridership for the 25 cent fare would appear to be greater for the smaller systems. Since smaller systems are more likely to be planned for smaller CBDs this tends to confirm the finding reported elsewhere that fare elasticities tend to be larger in smaller metropolitan areas. The magnitudes of differences between no fare and fare systems also conform generally to the evidence that ridership doubles for CBD systems when fares are eliminated.

5) Operating changes generally have more impact for the central delivery arrangement than for the fringe delivery arrangement. This apparently occurs because more transit users delivered to the fringe are sufficiently far away from their trip end locations to require another mode. Those delivered to the center will be more sensitive to the characteristics of the DPM since they have greater freedom of choice.

TABLE 6-6

SENSITIVITY OF REGIONAL CBD TRANSIT DIVERSIONS TO DPM SPEED, SERVICE FREQUENCY AND FARE

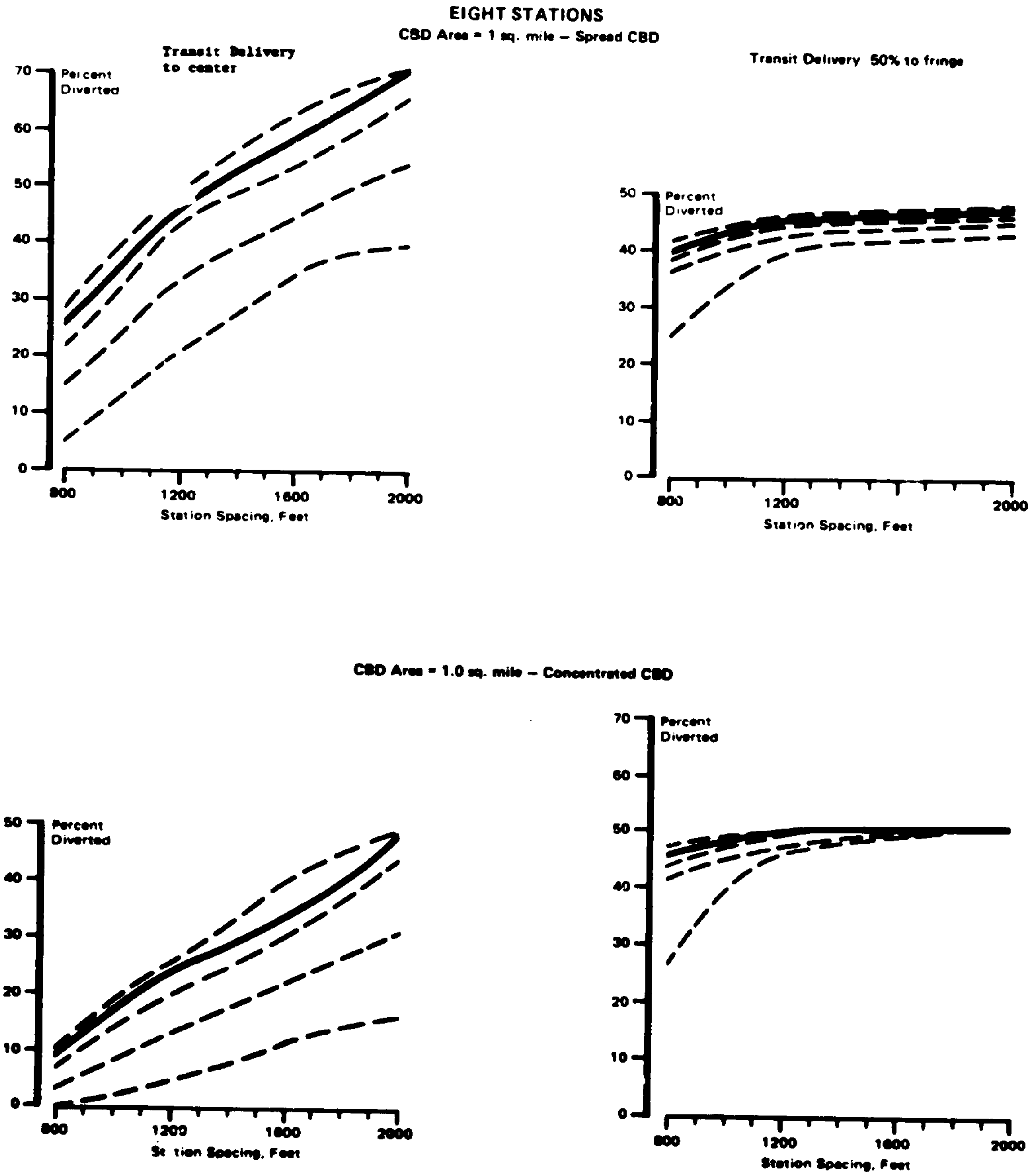
CBD Area = 1.0 sq. mi. – Spread Activity Distribution

Number of Stations		4				8				12			
Station Spacing, Ft.		800	1200	1600	2000	800	1200	1600	2000	800	1200	1600	2000
Transit Delivery to Center	–Base	5	17	26	34	26	47	58	71	43	66	na	na
	20 mph	7	19	28	37	28	49	63	71	44	68	na	na
	1 min	8	19	28	37	28	49	63	71	44	68	na	na
	4 min	5	14	22	30	22	44	54	66	40	62	na	na
	10 ¢	2	8	16	22	15	34	45	54	33	57	na	na
	25 ¢	0	4	6	11	5	21	35	40	12	46	na	na
50% to Fringe	–Base	12	26	34	39	40	45	46	48	45	47	na	na
	20 mph	14	27	35	40	41	46	47	48	46	48	na	na
	1 min	13	27	35	40	41	46	47	48	46	48	na	na
	4 min	10	24	33	37	38	45	46	47	45	47	na	na
	10 ¢	6	19	31	35	37	43	45	46	44	46	na	na
	25 ¢	[illegible]	12	18	32	25	40	43	44	39	44	na	na

CBD Area = 1.0 sq.mi.– Concentrated Activity Distribution

Number of Stations		4				8				12			
Station Spacing, Ft.		800	1200	1600	2000	800	1200	1600	2000	800	1200	1600	2000
Transit Delivery to Center	–Base	4	12	13	18	9	23	34	48	24	42	na	na
	20 mph	5	13	15	20	10	25	40	48	25	44	na	na
	1 min	6	13	15	20	10	25	40	48	26	44	na	na
	4 min	3	9	10	17	7	20	30	43	22	38	na	na
	10 ¢	1	4	6	9	3	13	22	31	14	32	na	na
	25 ¢	0	2	1	2	0	5	12	16	1	18	na	na
50% to Fringe	–Base	14	34	42	45	45	50	50	50	49	50	na	na
	20 mph	17	37	43	46	46	50	50	50	49	50	na	na
	1 min	17	37	43	46	46	50	50	50	49	50	na	na
	4 min	13	32	41	44	44	49	50	50	49	50	na	na
	10 ¢	6	24	39	42	41	48	49	50	47	49	na	na
	25 ¢	0	14	21	38	26	46	49	50	45	48	na	na

na – Not applicable



Note - Solid lines represent base condition. Dashed lines indicate, from top to bottom: 20 mph speeds or 1 minute headways shown as one line for clarity, 4 minute headways, 10¢ fare, and 25¢ fare.

FIGURE 6-11

SENSITIVITY OF REGIONAL CBD TRANSIT DIVERSIONS TO DPM OPERATING CHARACTERISTICS

6.2.5 Estimating Diversion of Regional CBD Auto Trips to DPMs

As with the methodology used to estimate transit user diversions to a DPM, the perceived price of transferring to the DPM to the price of not transferring will be compared. This will be done here by calculating the auto user's cost of parking in various parts of the CBD, adding his cost of walking between his parking location and his trip end, plus his cost of driving within the CBD. The sum will be the highest amount he will be willing to pay for the use of the DPM. Then his cost of parking at the DPM fringe parking lot will be subtracted. The remaining costs will be the greatest amount he will be willing to pay to walk to and from the DPM, transfer to it, wait for it, ride on it, and pay its fare.

Using Figure 6-2 showing the maximum daily parking fees as a function of CBD floorspace (top of figure) and the variation of that parking fee with CBD density, it is possible to estimate the parking fee for the full range of CBD activities considered. Dividing those parking fees by two to account for the fact the parking fee really pays for two vehicle trips and also dividing by 1.3 to reflect the average auto occupany, i.e., number of auto users who pay that fee, the matrix of actual parking costs per trip (38% of the actual parking fee) for those who are not reimbursed for their parking is obtained. These results are found in the top portion of Table 6-7. To this is added the cost of the walk trip between parking location and trip end location and the price of the auto trip within the CBD. The price of the walk is calculated using walking trip length frequency distributions for auto parkers for different sized metropolitan areas, and assuming a walking speed of 230 feet per minute and a value of eight cents per minute for walking by auto users, the result is a price of the walking link ranging from 15 to 22 cents, the larger values in the larger CBDs. The latter price of the auto ride within the CBD is calculated by assuming driving speeds in the CBD that range from 10 miles per hour in the largest CBD up to 16 miles per hour in the smallest CBD. Assuming that the average auto trip will travel half way into the CBD and a value of 3 cents per minute for time the auto user spends in his vehicle, a one square mile CBD will have a cost of driving of from 6 to 9 cents, the larger values for the CBDs with more activity. Adding both of these cost elements, the walk and ride, for the auto user, the second matrix in Table 6-7 is obtained. It is these prices the DPM must beat to attract the user of the automobile.

Next the cost per trip of parking in the fringe DPM lot is subtracted. By doing so that result can be compared to the various prices of using the DPM itself, just as was done earlier for the transit user. The third matrix in Table 6-7 shows those prices assuming that the cost of parking in the fringe lot will be one-fifth of the highest priced parking fee in the CBD. Parking fees in fringe lots for express buses in Cleveland, Atlanta and Seattle suggests that this is a reasonable assumption. These fees are also reduced for one-way trips and

TABLE 6-7

AUTO COST INPUT TO CALCULATE REGIONAL CBD AUTO USER DIVERSIONS TO DPM

CBD Employment (000's)	CBD Floorspace (mil.sq.ft.)	CBD Maximum Daily Parking Fee, 1977 $		Parking Cost per Person-Trip at Given Percent of Maximum Density, cents							
				100	75	50	33	25	10	5	1
300	96	4.50		173	162	149	135	126	95	73	0
200	69	3.40		131	123	108	95	86	57	33	0
100	39.5	2.30		88	80	63	50	43	18	0	0
75	31.5	2.00		75	69	53	40	34	9	0	0
50	22.5	1.60		62	54	40	28	21	0	0	0
30	15	1.30		50	43	31	20	14	0	0	0
20	10	1.00		38	33	23	11	6	0	0	0
CBD Employment (000's)	**CBD Floorspace (mil.sq.ft.)**	**Cost of Auto Walk Link, cents**	**Cost of Auto Ride Link,* cents**	**Total Cost of Trip By Auto, cents****							
300	96	22	9	204	193	180	166	157	126	104	31
200	69	21	8	160	152	135	122	115	86	62	29
100	39.5	19	7	114	106	89	76	69	44	26	26
75	31.5	18	7	100	94	78	65	59	34	25	25
50	22.5	17	6	85	77	63	51	44	23	23	23
30	15	16	6	72	65	53	42	36	22	22	22
20	10	15	6	59	54	44	32	27	21	21	21
CBD Employment (000's)	**CBD Floorspace (mil.sq.ft.)**	**Fringe Parking: Daily Fee cents**	**Fringe Parking: Cost per Person-Trip cents**	**Breakeven Price of DPM Trip, cents*****							
300	96	90	35	169	158	145	131	122	91	69	-4
200	69	70	27	133	125	108	95	88	59	35	2
100	39.5	45	17	97	89	72	59	52	27	9	9
75	31.5	40	15	85	79	63	50	44	19	10	10
50	22.5	35	13	72	64	50	38	31	10	10	10
30	15	25	10	62	55	43	32	26	12	12	12
20	10	20	8	51	46	36	24	19	13	13	13

* Assumes 0.5 mile auto trip within CBD at speeds from 10 to 16 mph.

** Equals parking cost per trip plus cost of walk and ride links.

*** Equals total cost per trip by auto minus the fringe parking cost per trip.

auto occupancy (2.0 x 1.3). Note the very low values for the smaller CBDs, particularly at their low density portions, suggesting that few if any auto users could be diverted to a DPM if they are already able to park in a low density location at the edge of a CBD.

Before proceeding to the calculation of the auto user diversions to the DPM, those who will not be susceptible to diversion must be accounted for. Included are three groups of auto users. First are those who are reimbursed for their parking costs by their employer, assumed here to be 20 percent of all auto users. Second are those for which driving to a DPM station on the fringe constitutes a major "back-haul", i.e., travelling substantially out of their way. While the proportion of auto users accessible to a fringe station is a function of the particular highway configuration, it will be assumed here that each fringe station will be conveniently located for a 90 degree sector, or roughly one-quarter of all auto users. To encompass all 360 degrees, four fringe stations, each 90 degrees apart, would be required. Third are those who may not be able to use the fringe parking areas if insufficient capacity exists.

Now the diversion rates of the regional CBD auto users can be calculated and shown by means of example. The DPM system assumed for this example is the same as that used earlier when calculating the diversion of transit users, namely a system of four stations, each 1600 feet apart, located in a CBD of one square mile. Likewise, two distributions of CBD activity, spread and concentrated, and the pattern of activities surrounding each station derived from Figure 6-5 will be used. However, two major differences exist for the auto user calculations. First, since the parking costs vary by the total amount of activity in a CBD (top of Figure 6-2), their diversion rates will differ also. Second, it will be assumed that the values auto users place on the time and comfort elements of their trip are higher than the transit user's values by approximately 50 percent, namely:

Transferring (including effort of ascending escalator)	= 8 cents per minute
Waiting	= 5 cents per minute
Riding	= 3 cents per minute
Walking	= 8 cents per minute

Table 6-8 illustrates the steps involved for a CBD of 75,000 jobs (31.5 million square feet of floorspace). Having set up the activity pattern around each station (line 3), it is possible to determine the breakeven DPM price for travel to each station with a DPM fringe parking lot located at station 1. First, the density of each station relative to the maximum density station is calculated. Next the breakeven DPM price is found by interpolating from Table 6-7. For example, station 2 in the spread CBD is 25/42 or 70 percent of the maximum density and its breakeven DPM price is therefore 75 cents (interpolated between the 69 cents of the 50 percent density point and 85 cents for the 75 percent density point of the 75,000-job CBD).

TABLE 6-8

ILLUSTRATION OF CALCULATION OF DIVERSION TO DPM FOR REGIONAL CBD AUTO USERS FOR CBD WITH 75,000 JOBS, AREA OF ONE SQUARE MILE, AND FOUR DPM STATIONS 1600 FEET APART

		Spread CBD				Concentrated CBD			
1.	Station number	1	2	3	4	1	2	3	4
2.	Station rank	4	2	1	3	4	2	1	3
3.	Percent of CBD activities surrounding station: (derived from Figure VI - 1 see explanation in transit section)	11	25	42	16	2	22	67	9
4.	Percent of maximum density of station (from Figure VI - 6 and line 3)	26	60	100	38	3	33	100	13
5.	Breakeven DPM price, cents (interpolated from Table VI - 6)	*	75	91	58	*	53	91	25
6.	Price of transferring to, waiting for and riding on base DPM, cents	–	27	33	39	–	27	33	39
7.	Breakeven price of walk link between DPM and trip end, cents (line 5 – line 6)	–	48	58	19	–	26	58	**
8.	Breakeven distance of walk link at value of 8 ¢ / min. and walking speed of 230 ft./min., feet	–	1380	1668	546	–	748	1668	–
9.	Percent of station coverage within distance in line 8, or 2000 feet, whichever is less. From Table VI - 4	–	48	64	8	–	17	64	–
10.	Percent of auto trip ends diverted by each station (line 9 X line 3)	–	12	27	1	–	4	43	–
11.	Percent of unreimbursed auto trip ends diverted by all stations (sum of line 10)		40				47		
12.	Percent of all auto trips diverted (line 11 times 0.80)		32				38		

* First DPM station at fringe lot, therefore no diversions to it possible.

** Price of using DPM greater than price of using auto, therefore no diversion to station possible.

With the breakeven prices known (line 5), the price of the DPM transfer, wait and ride can be subtracted. This includes 16¢ for transferring to the DPM (one minute walk from the parking lot priced at 8¢ plus the cost of a transfer priced at 8¢), 5¢ for the one-minute average wait for the DPM, and the price of the time spent on the vehicle valued at 3¢ per minute. For the example of 1600 foot station spacing, this last item will be priced at about 6¢ for the 2.05 minutes consumed per stop. Line 7 shows the total DPM price and line 8 is the result of subtracting it out, representing the maximum price that will be tolerated by the auto users for the last unaccounted for element of the DPM alternative, walking between the DPM station and the trip end location. Converting to distance using average walking speed (230 feet per minute) and value of walking (8¢ per minute) gives the maximum distance tolerated.

It now remains to find out what proportion of the activities surrounding each station are to be found within that walking distance. In Table 6-4, the percent of a CBD's area within a given distance for each station is given. Using that table or Figure 6-8 for CBD areas of 0.5 , 1.0, and 1.5 square miles, and assuming that auto users will not walk beyond 2000 feet, the percent of the activities covered for each station can be estimated. If the tolerable walking distance for a particular station is 2000 feet or more, all the trip ends in the covered area will be diverted to the DPM. By multiplying these percentages by the percent of activities surrounding each station (line 3), the percent of all CBD activities delivered to the DPM is determined. The sum of the percentage points for each station is the total rate of diversion for the 90 percent of all auto users who are not reimbursed for their parking. To find the diversion rate for all users including the 20 percent assumed to be reimbursed, line 11 is multiplied by 0.8. The results are shown in line 12. To the extent that the fringe stations are not located to intercept auto users leaving the highway network, this diversion rate must be reduced. For example, if only one fringe DPM station and parking area is built, then the expected diversion rate will be only one-quarter of that calculated by the method shown in Table 6-8. If more fringe parking areas and DPM stations had been provided the reductions in the last step could be smaller. For example, if a DPM contains three stations well placed at the CBD's fringe (this would require more than four stations in the entire system), the DPM may capture auto users from 270 degrees of the compass and line 12 need only be reduced by one-quarter.

The exercise described above was performed assuming a DPM with the basic operating characteristics, i.e., 10 miles per hour, 2 minute headways, and no fare, for CBDs with four levels of activities: 300,000, 200,000, 75,000, and 20,000 jobs corresponding to 96, 69, 31.5, and 10 million square feet of floorspace, respectively. The auto user diversion rates for the alternatives of a spread or concentrated CBD activity arrangement, of three CBD areas (0.5, 1.0, and 1.5 square miles) and of DPM systems of 4, 8, and 12 stations with spacings of 800, 1200, 1600, and 2000 feet, all were calculated. The results are shown in tabular form in Table 6-9.

It must be recognized that the diversions shown in Table 6-9 assume that there are at least four ideally situated fringe DPM stations to intercept the auto user. To the extent that there are fewer stations or their location with respect to the highway network does not permit 360 degree coverage, the diversion rates shown must be reduced. For example, with only one fringe DPM station, the diversion rates in Table 6-9 must be reduced to one-quarter of the values shown.

Since it is exceedingly difficult to show these complex results in any comprehensive manner in graphical form, and since much of it would be irrelevant to any particular reader, it is suggested that readers tailor the results in Table 6-9 to their specific needs. For example, if the design of a DPM is contemplated for a spread CBD of 100,000 jobs (39.5 million square feet of floorspace) with an area of 1.2 square miles, then the diversion rates for the first, third and fifth matrices in Table 6-9 (the spread CBDs) can be interpolated to obtain the expected diversion rates for a new matrix, the 1.2 square mile spread CBD. With that data in hand, curves can be plotted of CBD activity versus diversion rates for each station number-station spacing combination, interpolating for the 100,000 job point on the curves. Interpolation is then possible for any number of stations between four and twelve, and for any station spacing between 800 and 2000 feet.

In Table 6-9, the complex interplay of the relationships that contribute to the diversion of auto users suggests a number of relevant observations for DPM system planning.

1) Each CBD configuration (jobs-area-distribution combination) would appear to have a DPM configuration that can maximize diversion of auto users to a DPM. This occurs because systems that are too small may not capture travel to a high proportion of CBD activities while ambitious systems with many stations and longer station spacings may lose riders who would have to spend excessive amounts of time on the system. The 75,000 job, 1.0 square mile-concentrated CBD illustrates this point well. A four-station DPM diverts from 26 to 38 percent of auto users, with the upper end of the range for the 1600 and 2000 foot spacings. With eight stations, the diversion rate increases to a high of 46 percent for a 1200 foot spacing but declines for larger spacings. Similarly, increasing the system to twelve stations results in a diminished diversion rate.

2) A CBD with a large area will require a larger system to reach the same diversion rates as a CBD of small area, but with the same overall amount of activities. For example, the 300,000 job-96 million square feet CBD could conceivably divert over 70 percent of auto users to a four-station system if the CBD is contained in 0.5 square miles. However, if the area of the CBD

TABLE 6-9

PERCENT DIVERSION OF REGIONAL CBD AUTO USERS TO DPM AS FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING (UNLIMITED FRINGE PARKING CAPACITY)

Number of stations		4				8				12			
Station spacing, feet		800	1200	1600	2000	800	1200	1600	2000	800	1200	1600	2000
Route length, feet *		2400	3600	4800	6000	5600	8400	11,200	14,000	8800	11,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)	CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	71	71	71	71	76	76	na	na	77	na	na	na
200	69	71	71	71	71	73	73	na	na	72	na	na	na
75	31.5	48	54	59	54	49	42	na	na	51	na	na	na
20	10	10	8	6	5	7	3	na	na	4	na	na	na
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	75	75	75	75	76	77	na	na	78	na	na	
300	96	75	75	75	75	76	77	na	na	78	na	na	na
200	69	75	75	75	75	74	75	na	na	69	na	na	na
75	31.5	53	60	61	60	44	48	na	na	42	na	na	na
20	10	13	10	8	6	10	5	na	na	9	na	na	na
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	33	45	56	65	75	74	75	74	76	74	na	na
200	69	33	45	54	58	69	70	69	66	70	69	na	na
75	31.5	22	28	32	31	38	45	34	30	40	38	na	na
20	10	3	4	4	4	3	2	0	0	2	1	na	na
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	44	58	64	70	75	77	76	75	75	74	na	na
200	69	42	51	60	69	67	66	66	65	63	65	na	na
75	31.5	26	31	38	38	38	46	38	35	38	34	na	na
20	10	5	4	4	2	4	1	0	0	4	2	na	na
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	18	22	28	33	40	62	74	74	70	74	74	70
200	69	18	22	28	31	38	57	64	62	61	65	62	61
75	31.5	12	15	17	19	20	29	22	22	27	25	20	14
20	10	2	3	2	2	3	2	0	0	2	1	0	0
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	26	34	38	43	49	67	70	70	71	74	74	72
200	69	26	34	35	39	43	54	54	51	56	60	58	55
75	31.5	15	18	20	18	22	25	23	21	26	26	28	16
20	10	2	2	2	2	3	1	0	0	2	1	0	0

* Assumes a shuttle system where route length = station spacing times number of stations minus one.

na – Not applicable

is 1.5 square miles, eight or more stations with longer spacings are required to achieve the same diversion rate.

3) The more concentrated CBD activity distribution generally diverts more auto users for the smaller DPM systems (four stations). The reverse seems to be the case for larger systems (twelve stations). This occurs because a small system can more efficientl service the fewer centers of activity in a concentrated CBD while a spread CBD requires a more extensive system to service its more scattered locations.

4) High activity CBDs can divert a substantial portion of all auto users; low activity CBDs can divert relatively few. This occurs largely because of parking costs. The price of parking in low activity CBDs is sufficiently low that there is little incentive to avoid it.

5) Although not shown explicitly in Table 6-9, the most dramatic differences in diversion rates for auto users occurs as a result of the placement of sufficient parking areas at fringe DPM stations. Four well placed stations around the CBD's fringe could conceivably produce the diversions shown; one station would reduce those rates by three-quarters.

Sensitivity to Operating Characteristics - Regional Auto Diversions to DPM

Now the sensitivity of the diversion of auto users to changes in the operating characteristics of the DPM will be examined. This is illustrated in Table 6-10, where the expected diversion rates for a DPM system with eight stations and 1600 foot station spacing are shown for a CBD of one square mile for six alternative operating conditions. The base condition used earlier to develop Table 6-9 assumes a DPM cruise speed of 10 miles per hour, two minute service frequencies and no fare. Tested are a cruise speed of 20 miles per hour, 1 and 4 minute headways, and fares of 10¢ and 25¢. A number of relevant observations emerge.

1) Very high activity CBDs show only minor changes in diversion rates for variations of operating conditions. This occurs because the use of the DPM for most auto users was overwhelmingly advantageous to begin with and the changes postulated make little difference.

2) For very low activity CBDs, the diversion rates also change very little. This is so because the use of the DPM for auto users was overwhelmingly <u>disadvantageous</u> to begin with and the postulated changes make little difference.

3) CBDs in the middle range of activity show greater variation in diversion rates. This occurs because the choice of using the DPM is often not that clear-cut and small differences

TABLE 6-10

SENSITIVITY OF REGIONAL CBD AUTO DIVERSION TO DPM SPEED, SERVICE FREQUENCY AND FARE (UNLIMITED FRINGE PARKING CAPACITY)

CBD Arrangement	Spread				Concentrated			
CBD Employment (000's)	300	200	75	20	300	200	75	20
CBD Floorspace (mil.sq.ft.)	96	69	31.5	10	96	69	31.5	10
System								
Base	75	69	34	0	76	66	38	0
20 mph	75	74	46	3	77	68	47	4
1 minute headway	75	70	38	2	76	66	42	2
4 minute headway	75	68	27	0	76	66	30	0
10 ¢ fare	74	66	22	0	75	64	25	0
25 ¢ fare	71	54	6	0	74	53	7	0

can tip the potential rider's decision in one direction or another.

4) As with transit users, auto users will be most influenced by changes in fares; a 10 cent change has considerably more impact than doubling speeds or doubling or halving headways.

One last but critical point must be made about the diversion rates for auto users. All calculations to this point have assumed that sufficient parking exists at fringe DPM areas to handle the diverted vehicles. This may not be so. The assumption of a 230 foot (one minute) average walk in the parking area implies a parking lot of some 330,000 square feet or, at 300 square feet per space, a capacity of 1100 spaces. Four such well placed lots around the CBD would provide for the diversion of less than 14,000 two-way trips by auto users assuming the car occupancy of 1.3 and a turnover rate of 1.2. (With these assumptions each space provides for 3.12 auto trips.) To the extent that the diversion rates in Tables 6-9 and 6-10 produce higher numbers of diverted trips than can be accommodated, the parking capacity would have to be enlarged. Such enlargement creates three difficulties: (1) it decreases the likelihood of finding sufficiently large sites for fringe parking, (2) it increases the complexity of the highway delivery system, including on and off ramps with sufficient capacity necessary to serve such parking areas, and (3) it may dampen demand because walking distances are lengthened within the parking area. Furthermore, even if the area of the parking lots were quadrupled, producing four lots each about 1150 feet square, they could accommodate only 36,000 auto trips per day. But a diversion rate of 75 percent of the 350,000 regional CBD auto trips in a 300,000 job CBD calculated earlier would require spaces for 262,000 trips. True, the larger parking lots would increase the walking distances in the lot, with a possible reduction in the diversion rate. However, examination of Table 6-10 suggests that an increase of one minute to the walking distance (equal to eight cents), which the larger lot implies, would have slightly less impact than a fare increase of 10 cents. It would appear then, at least in the larger CBDs, the numbers of auto users diverted are limited by the supply of parking facilities. These and related demand-supply matters cannot be lightly dismissed.

6.2.6 <u>Estimating Diversion of Internal CBD Trips to DPM Walk Trips</u>

The first step in estimating the diversion of internal CBD walk-only trips to a DPM requires an estimate of the trip length distribution of such trips. It is the length of the walk trip that determines the price that a DPM must beat to achieve diversions. Based on the evidence given in Section 6.1, a walking trip length distribution can be adopted for CBDs with varying amounts of employment and floorspace. This has been done here for the four CBD activity sizes analyzed throughout this section. The Edmonton walking trip length distribution is chosen here to approximate the distribution of a 20,000 job-10 million square feet CBD; Seattle's distribution will be used for the 75,000 job-31.5 million square feet CBD (Seattle's downtown core is variously defined to include some 60,000 to 80,000 jobs and about 30 million square feet of floorspace at the time of their pedestrian survey). For the 300,000 jobs-6 million square feet CBD the Chicago trip length distribution will be used, and for the 200,000 job-69 million square foot CBD an interpolated distribution between Chicago's and Seattle's was created for use here.

The next basic set of assumptions to be made is the values of time that walk-only CBD trip-makers would place on the various elements of their trip if they have the alternative of using the DPM. It will be assumed that the values selected earlier for regional transit users are applicable, namely:

Transferring (including effort of ascending escalators)	= 5 cents per minute
Waiting	= 3 cents per minute
Riding	= 2 cents per minute
Walking	= 5 cents per minute

With these basic points defined, the calculation of diversion rates for a specific situation can be illustrated. For this example a one square mile CBD of 200,000 jobs and 69 million square feet of floorspace arranged in a relatively spread fashion will be used. The DPM will have eight stations 1200 feet apart, and run at 10 miles per hour maximum speed on 2 minute headways. A no fare policy will be assumed.

In Table 6-11, the price of the walk-only operation is first calculated. It is merely the distance walked divided by the walking speed of 230 feet per minute times the value of time of five cents per minute. By taking each increment of the walking trip length distribution and assuming that the mid-point represents the average distance within that increment (reasonable for small increments of distance), the price of the walk trip can be found. For example, for walk trips of 1400 to 1800 feet, the price of walking would be (1600 / 230)(5) or 34.8 cents. The price of the DPM trip of the same length, 1600 feet, depends on the DPM characteristics. If the DPM has stations 1200 feet apart, the price of a 1600 foot trip can be assumed to include 5¢ for the transfer to the DPM, plus 3¢ for an average wait of one minute (assumes the base condition of two minute headways), plus 3.2¢ for the ride of 1.6 minutes at 2¢ per minute to the next station, plus 8.4¢ for the walk of 400 feet (1600 minus 1200), plus an additional, as yet undetermined, walk to and from the DPM stations. The known costs for the DPM enumerated above total 19.9¢. Therefore, if the walking links to and from the DPM station are less than the difference between the "walk-only" cost of 34.8¢ and 19.9¢, or 14.9¢, then the DPM would divert the 1600 foot walk trip.

TABLE 6-11

ILLUSTRATION OF CALCULATION OF INTERNAL CBD WALK TRIP DIVERSION TO DPM

1 Walking range, feet	2 Distance average, feet	3 Price of walk, cents	4 Price of DPM w/o access, cents	5 Breakeven Price of DPM walk links, cents	6 Breakeven access distances, feet
0 – 200	100	2.2	*	–	–
200 – 600	400	8.7	*	–	–
600 – 1000	800	17.4	19.9	negative	–
1000 – 1400	1200	26.1	11.2	14.9	686
1400 – 1800	1600	34.8	19.4	14.9	686
1800 – 2200	2000	43.5	23.1	20.4	938
2200 – 2600	2400	52.2	14.4	37.8	1738
2600 – 3000	2800	60.9	23.1	37.8	1738
over 3000	3400	73.9	22.0	51.9	2388

7 Percent of area covered by both trip ends (square root)	8 Percent of activities covered by both trip ends (diversion rate)	9 Percent of walk trips in distance range	10 Percent of walk trips diverted to DPM
–	–	15	0.00
–	–	23	0.00
–	–	19	0.00
10	1.4	11	0.35
10	1.4	10	0.32
19	4.7	5	0.50
57	29.5	4	2.12
57	29.5	3	1.59
90	60.7	10	8.8
			Sum =13.18%

Notes: column 3 equals column 2 x 5 cents per minute divided by 230 feet per minute,
column 5 equals difference between columns 3 and 4,
column 6 equals column 5 multiplied by 230 feet per minute and divided by 5 cents per minute
column 7 obtained by multiplying column 6 by 0.64 and applying result to Figure VI-8
column 8 obtained by applying column 7 to Figure VI-12.
column 9 is walk trip length distribution of a 200,000 job CBD
column 10 equals column 9 times column 10

Once the differences between the "walk-only" price and the DPM price without the access walks are determined the maximum access walking distances that can permit diversion can be calculated. The 1600 foot trip, with a 14.9¢ difference, could produce a total access walk at both ends of the DPM trip of 686 feet. This is determined using the walking speed and value of time described earlier. Thus, the DPM will attract those 1600 foot long walk trips whose trip ends are within a total distance of 686 feet from DPM stations.

The next step is to determine the possibility that a walking trip would fit the above qualifications. First, assuming for the moment that trip ends are distributed uniformly throughout the CBD, the probability that a trip ends within a given distance of a DPM station can be approximated using the percent of the CBD area around the station corresponding to that distance (Table 6-4). The product of two such probabilities is then the joint probability that a trip has its ends within two given distances of the DPM stations. However, what must be determined is the joint probability of all pairs of such distances whose sum equals the total breakeven walk distance. In the example above, this would mean the probability of a trip starting, for instance, within 100 feet of one station and ending within 586 feet of another, or within 120 feet of one and 566 feet of another, etc. In order to use Figure 6-8 or Table 6-4, a simple approximation to an otherwise complicated computation was found which requires multiplying the total breakeven distance by 0.65, reading the percent of CBD area from Figure 6-8 or Table 6-4, and squaring this percentage to yield the probability of a DPM trip.

However, it is known that the assumption that trip ends are distributed evenly throughout the CBD is false; Figure 6-1 presented dramatic evidence of that, suggesting, for example, a CBD is likely to have about 24 percent of its activities in 10 percent of its area, and for highly concentrated CBDs, about 50 percent. The joint probabilities for the spread and concentrated CBDs would be .24 x .24 = .058 and 0.45 x .45 = 0.203 respectively. Applying such data here without some downward adjustment would be misleading, however. To do so would imply that DPM stations could all be located in the densest areas of the CBD. In reality, this is seldom possible since station spacing and the network configuration must also be considered. However, if the "divertible" areas around stations become large enough, the curves of Figure 6-1 come closer to representing the percent of activities covered by those areas. Consequently, a sliding scale is used to reduce the activity coverage given by Figure 6-1, with larger reductions, up to half, when the divertible areas are small. In the 1600 foot trip example, this reduces the activity coverage for a spread CBD from 24 to 18 percent. For a concentrated CBD, the reduction is from 45 to 34 percent. The probability of a trip having both ends in the "divertible" area is then 0.18 x 0.18 or 0.0324 for the spread CBD and 0.34 x 0.34 or .116 for the concentrated CBD.

This conversion is shown graphically in Figure 6-12 which gives, for both spread and concentrated CBDs, the relationship between the percent of the CBD's area within the divertible area at one end of an internal trip and the probability of both ends of the internal trip being located within the divertible area. The dashed lines indicate the example cited earlier in this paragraph.

Once the diversion rate for each walking trip length is determined (column 8), the percent of trips in each distance range can be multiplied by those rates. The sum of those products is the total diversion of all "walk-only" trips. Note the rapid rise in diversion rates with increasing distance. Walking trip lengths of less than 600 feet would never be diverted to a DPM with 1200 foot spacing; this occurs because walk trips of less than half of the station spacing will always require a larger walk going to or from the DPM than the walk itself. Note also that the price of using the DPM as a replacement for the 800 foot walk is greater than walking only. The "DPM price without access walk" column indicates that some larger trips may cost less on a DPM than some shorter trips; this occurs when the longer trip coincides with the station spacing or its multiples, requiring no additional walking. For this example no diversion occurs until the 1000 to 1400 foot walking range is reached and then the rate is only 4.3 percent. This rate rises to 91 percent for walking trips in excess of 3000 feet. The rather low overall diversion rate of 14 percent reflects the fact that the higher diversion rates occur in distances ranges where there are few trips, and the low diversion rates (mostly zero) occur where there are many trips.

In the manner described above, diversion rates were calculated for spread and concentrated CBDs for four activity sizes, for three CBD areas, and for twelve DPM station count-station spacing combinations. Similarly, the diversion rates for DPMs with operating characteristics other than the base conditions were calculated.

The diversion rates for walk-only trips are shown in Table 6-12 for 232 combinations of CBD and DPM characteristics. The exhibit suggests six major points:

1) A DPM rarely attracts more than about one-third of all walking trips. This occurs because a large share of such trips are for very short distances when the savings in time and convenience of using the DPM cannot be realized.

2) CBDs with more activities will attract a larger share of their walking trips to a DPM. This occurs because walking trips lengths are generally long in such CBDs, making the choice of a DPM relatively more attractive.

3) CBDs with concentrated activities will attract a larger share of walkers than spread CBDs. This occurs because a concentrated CBD is more likely to have a larger share of its

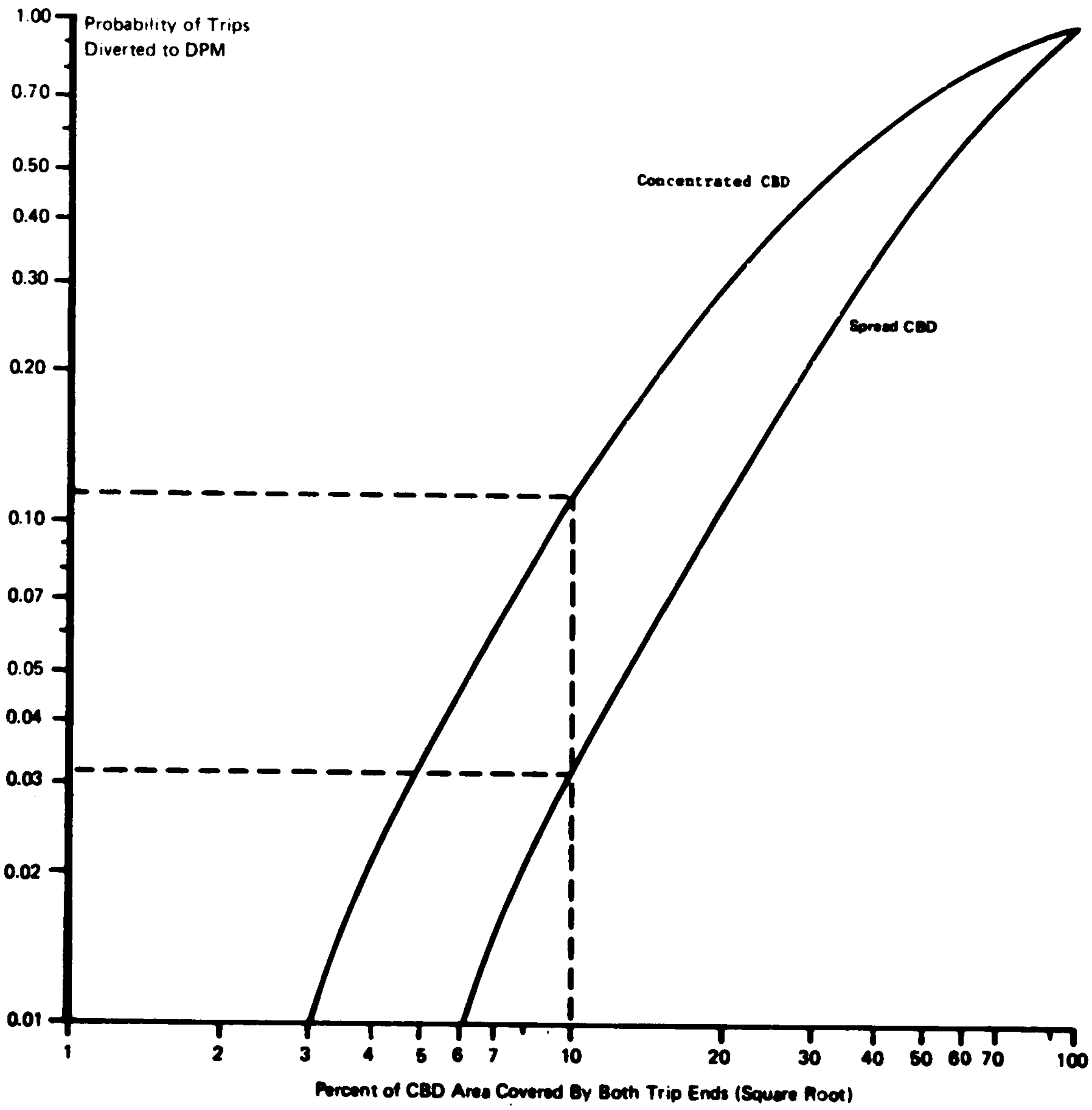


FIGURE 6-12

PROBABILITY OF TRIPS DIVERTED TO DPM AS FUNCTION OF DPM COVERAGE

TABLE 6-12

PERCENT DIVERSION OF INTERNAL WALK TRIPS TO DPM AS FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	10	13	16	11	24	24	n.a.	n.a.	30	n.a.	n.a.	n.a.
200	69	9	15	15	10	20	21	n.a.	n.a.	27	n.a.	n.a.	n.a.
75	31.5	7	12	12	7	16	17	n.a.	n.a.	23	n.a.	n.a.	n.a.
20	10	3	5	5	3	8	8	n.a.	n.a.	11	n.a.	n.a.	n.a.
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	20	23	20	15	31	30	n.a.	n.a.	38	n.a.	n.a.	n.a.
200	69	17	20	20	17	28	27	n.a.	n.a.	30	n.a.	n.a.	n.a.
75	31.5	15	16	17	14	23	22	n.a.	n.a.	19	n.a.	n.a.	n.a.
20	10	7	9	7	6	11	11	n.a.	n.a.	15	n.a.	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	3	8	8	4	10	13	16	12	15	21	n.a.	n.a.
200	69	3	6	7	4	11	13	14	10	13	19	n.a.	n.a.
75	31.5	2	6	6	3	7	11	12	8	11	16	n.a.	n.a.
20	10	2	2	2	2	3	5	5	4	5	7	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	9	14	13	10	19	22	18	21	25	27	n.a.	n.a.
200	69	8	12	12	9	16	19	20	18	22	23	n.a.	n.a.
75	31.5	6	9	10	6	14	15	13	14	19	18	n.a.	n.a.
20	10	3	4	3	3	6	7	7	6	9	10	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	2	3	4	2	8	10	11	7	9	15	14	8
200	69	1	3	4	2	4	8	10	6	8	13	15	7
75	31.5	1	3	3	1	4	7	8	5	7	11	12	6
20	10	1	1	2	1	2	3	3	2	3	4	5	3
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	5	8	8	6	12	17	16	14	19	22	21	14
200	69	5	8	8	5	10	15	15	12	17	24	20	13
75	31.5	4	6	6	4	8	11	12	10	14	15	14	10
20	10	2	3	2	2	4	6	5	4	6	7	7	6

* Assumes a shuttle system where route length = station spacing times number of station spacing times number of stations minus one.

n.a. Not applicable

trip ends located near one DPM station or another resulting in short walking links to the station. The concentrated CBDs generally have higher diversion rates by one-third or more.

4) CBDs small in area divert walkers at a greater rate than CBDs of larger size but with the same amount of activity. This finding is intuitively logical because a larger share of trip ends are likely to be within a short walk of a DPM station if the CBD is small in area.

5) Diversion rates generally increase at least in direct proportion to the increase in the number of DPM stations.

6) As station spacing increases, diversion rates for a fixed number of stations increase, up to a point. In most cases, there appears to be an optimum spacing of about 1600 feet. This occurs because at very short station spacings the DPM will be unable to reach a large share of activities, and at very long station spacings, potential users will find the access walk to or from the DPM station excessive.

Variations in diversion rates as a function of operating characteristics are shown in Table 6-13 for a one square mile CBD with a DPM of eight station and 1200 foot spacing. As done earlier for regional CBD travel, five variations are examined: (1) increase of maximum DPM cruise speed from 10 to 20 miles per hour, (2) reduction of headways from two minutes to one minute, (3) increase in headways from two minute to four minutes, (4) imposition of a 10¢ fare, and (5) imposition of a 25¢ fare.

Two general observations are suggested by the figure. First, variation of service characteristics of speed and headways within the range tested do not alter the diversion rates dramatically. They do, however, result in modest but significant shifts in relative terms. The increase of speed to 20 mph generally adds one or two percentage points to the diversion. In effect, this would increase ridership among walkers up to 20 percent or more. The reduction of headways to one minute have slightly less impact, while an increase in headways to four minutes lowers the diversion rates in more or less an equal but opposite direction.

Second, the imposition of a fare causes a dramatic drop in the diversion rates. A ten cent fare tends to lower the diversion rates close to half; a 25 cent fare lowers the rate by about two-thirds.

<u>Internal Transit Trips</u>

Again, the share of any particular market diverted to a DPM will be a function of the relative price of the alternatives. Compared to local bus service, the DPM suffers because of two changes in grade required of the potential customer. To the extent DPM can overcome this liability by higher speeds, shorter

TABLE 6-13

SENSITIVITY OF INTERNAL CBD WALK TRIP DIVERSION TO DPM SPEED, SERVICE FREQUENCY AND FARE FOR CBD OF ONE SQUARE MILE AND DPM OF EIGHT STATIONS 1,200 FEET APART

CBD Arrangement	Spread				Concentrated			
CBD Employment (000's)	300	200	75	20	300	200	75	20
CBD Floorspace (mil. sq. ft.)	96	69	31.5	10	96	69	31.5	10
System								
Base	15	14	11	5	22	19	15	7
20 mph	17	16	12	6	23	22	17	8
1 minute headway	16	15	12	5	23	21	16	8
4 minute headway	14	11	9	5	20	18	14	6
10¢ fare	9	9	7	3	16	15	12	5
25¢ fare	6	4	4	2	6	6	4	2

waits, or cheaper fare, it will capture a larger and larger share of the market.

For this exercise it shall be assumed that the price of the additional grade changes required of the DPM is five cents, equivalent to the cost of transferring used earlier.

To estimate the gain the DPM achieves over local bus because of higher speeds, a number of assumptions are necessary. First, it is assumed that local bus speeds diminish in CBDs of greater activity, from 10 mph in a 20,000 job-10 million square feet CBD down to 6 mph in a 300,000 job-96 million square feet CBD. Second, DPM speed is a function of station spacing; a 10 mph maximum cruise speed reduces to 8.0 mph for a 900 foot spacing and to 9.9 mph with stations 2000 feet apart. Third, the average trip length of an internal transit trip increases as the area of the CBD increases; for the 0.5 square mile CBD the average trip length is assumed at 0.5 miles, for the 1.0 square CBD, 0.7 miles, for the 1.5 square mile CBD, 1.0 miles. With these assumptions in place the price advantage of the DPM because of speed can be calculated using a 2¢ per minute value of time spent in vehicles. This varies from 2.5 to 3.4¢ for the 300,000 jobs-96 million square feet CBD to a net disadvantage of 0.6 to 1.5¢ for the 20,000 job-10 million square feet CBD. (In the latter case the bus speeds are higher than the DPM speeds). If the DPM had a maximum speed of 20 mph instead of 10 mph, the advantage for the ride itself could be as much as 9¢ in the largest activity CBD and 5¢ in the smallest activity CBD. Both DPM speeds will be tested.

The DPM can gain an advantage over local bus service if its headways are lower also. It shall be assumed that the DPM operates with two minute headways and that local buses operate either with two or with five minute headways. In the latter case the DPM gains an additional 4.5¢ with waiting time valued at 3¢ per minute.

Differential fares on the two systems can also have a major impact on diversion. The impact of a 25¢ lower fare on the DPM will be examined here.

With these assumptions, the price advantage the DPM has over the local bus service, if any, can be calculated. This advantage is equivalent to the additional distance a potential DPM users will be willing to walk to and from a DPM station rather than to and from a local bus stop. As with the analysis of the diversion of internal walking trips, the percent of the CBD area covered by such distances for any particular DPM configuration can be determined using Figure 6-8 or Table 6-4. These can be converted to the percent of activities covered using Figure 6-12, which gives the probability of both trip ends being found within the breakeven distance as explained earlier in the section on internal walk trip diverions. For example, if the price differential equals 20 cents in favor of the DPM, the total breakeven walking distance is 920 feet (20 x 230)/5 where 230 is the average walking speed in feet per minute and 5 is the value of time in cents per minute. This distance (multiplied by a .64 as previously described) can be applied to Figure 6-8 for the particular DPM and CBD configuration in question. Applying this distance to one square mile CBD and an eight station - 1200 foot spacing DPM, the coverage is about 18 percent. Using Figure 6-12 we find that with a spread CBD the probability of both trip ends being covered is 0.09. When applying this method the breakeven distances for divertibility were expanded by 20 percent to account for the back-hauling often necessary to reach a bus stop.

Before proceeding with the calculations, some assumptions about the route structure of the DPM and local buses are in order. It will be assumed that the DPM system replaces bus routes running on the same street. Also, at least in the central portion of the CBD, the existing bus routes operate in a tight grid pattern, running on every street, and stopping every 400 feet.

Application of the above described method revealed quite clearly that, unlike some of the other trip categories, the diversion of internal transit trips to a DPM is very sensitive to the operating policies assumed. This is so because the competitition in this case, the local bus, has similar, directly comparable features. Small changes can easily tip the scales toward one mode or the other. That was not the case for diversion of regional auto trips where the cost of central CBD parking and the availability of fringe parking by a DPM station weighed more heavily than changes in DPM operation. Nor was it the case for walking trips, where trip length largely determined diversion rates.

Consequently, it would be presumptuous to choose a "base" operating condition as a starting point here. Rather, eight combinations of operating variations, representing differing advantages of the DPM over local bus service, are assumed. These are presented for the 200,000 job-69 million square foot spread CBD in Table 6-14. The table shows quite dramatically that the DPM will attract no internal transit trips with only a headway advantage or with speeds of 20 miles per hour. In fact, having both the headway advantage and a high speed system will not attract passengers under most circumstances. A fare differential is required to attract local bus trips, attracting more and more passengers as the system becomes larger. Furthermore, with a fare differential, the other DPM advantages begin to have an impact; the fare advantage combined with either higher speed or closer headways increases the DPM diversion rates by up to two times. All three advantages in combination produce a still more potent impact, with diversion rates of up to three times often achieved. The synergistic effect that the relative headway and speed improvements can have when combined with the fare differential requires some explanation. Without the fare difference, the other advantages can barely, if at all, overcome the negative impact of the change in grades of a DPM. Consequently, the breakeven walking distances around the DPM

TABLE 6-14

PERCENT DIVERSION OF INTERNAL CBD TRANSIT TRIPS AS A FUNCTION OF DPM AND LOCAL BUS OPERATING CHARACTERISTICS FOR CBD OF 200,000 JOBS

Number of Stations												
Station spacing, feet	800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*	2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8800	13,200	17,600	22,000
DPM Advantage												
None	0	0	0	0	0	0	0	0	0	0	n.a.	n.a.
Headway**	0	0	0	0	0	0	0	0	0	0	n.a.	n.a.
Speed ***	0	0	0	0	0	0	0	0	0	0	n.a.	n.a.
Headway and Speed	0	0	0	2	0	0	0	2	2	2	n.a.	n.a.
Fare****	6	6	6	7	11	16	16	18	20	27	n.a.	n.a.
Fare and Speed	9	10	11	11	19	23	24	27	30	41	n.a.	n.a.
Fare and Headway	9	10	11	11	20	23	27	27	31	42	n.a.	n.a.
All Three	11	15	18	18	24	34	39	28	41	58	n.a.	n.a.

*Assume a shuttle system where route length = station spacing times number of stations minus one.
**DPM headway equals 2 minutes and local bus headway equals 5 minutes.
***DPM maximum cruise speed equals 20 mph.
****DPM fare assumed to be 25 cents lower than local bus fare.
n.a.- Not applicable

stations are miniscule, and few trips are captured. With a 25 cent fare differential, and the wider area coverage created by longer breakeven walking distances, any further improvement (headways or speeds) expands the covered area as the square of distance with a consequent increase in the diversion rates.

Since the operating policy that makes the most difference in diversion rates of internal transit trips is the fare differential, it is useful to see how the diversion rate varies by CBD activity level, concentration and size, given a 25 cent fare differential. This is done in Table 6-15 for the now familiar set of CBD and DPM variations. Examination of this table suggests the same conclusions reached earlier for walk trips, namely:

1) CBDs of greater activity divert a larger share of trips.

2) CBDs of larger land area divert a smaller share of trips.

3) Concentrated CBDs divert a larger share of trips than spread CBDs.

4) DPMs attract trips in direct proportion to the number of stations.

5) Diversion rates increase with longer station spacing but with greatly diminishing returns.

Internal Auto Trips

Estimating the diversion of auto trips with both ends in the CBD creates an analytical problem quite different from other trip categories. A large segment of those trip-makers are unlikely to be susceptible to the sort of price analysis used elsewhere. This occurs either because their costs are reimbursed or the use of the auto for multi-stop shopping or business trips provides a huge convenience over every form of public transit. The analysis is further complicated by the interplay betweeen regional auto trips and internal ones; if the DPM is successful in diverting the regigonal auto user to a fringe parking area, then these trip-makers will no longer have an auto available for internal auto travel. These trip-makers will then be faced with the same choice betwen the DPM and the local bus for their internal trips as were internal transit trip-makers.

Accordingly, an estimate of the diversion of these internal auto trip-makers to the DPM is made by assuming that the share of regional auto users diverted to the DPM at the fringe (Table 6-9) equals the share of internal auto trip makers without their auto available for their internal trips. These trips are further split between DPM and local bus in the same manner as internal transit trips (Table 6-15). Therefore, by multiplying the

TABLE 6-15

PERCENT DIVERSION OF INTERNAL CBD TRANSIT TRIPS TO DPM AS A FUNCTION OF AMOUNT AND DISTRIBUTION OF OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING ASSUMING 25 CENT FARE DIFFERENTIAL BETWEEN DPM AND LOCAL BUS

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CP Floor sp. (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	14	19	20	20	36	38	n.a.	n.a.	58	n.a.	n.a.	n.a.
200	60	13	15	15	17	30	33	n.a.	n.a.	48	n.a.	n.a.	n.a.
75	31.5	11	12	12	13	22	28	n.a.	n.a.	37	n.a.	n.a.	n.a.
20	10	8	9	9	9	21	21	n.a.	n.a.	35	n.a.	n.a.	n.a.
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	31	37	41	41	64	65	n.a.	n.a.	[illegible]	n.a.	n.a.	n.a.
200	60	28	31	31	37	55	60	n.a.	n.a.	75	n.a.	n.a.	n.a.
75	31.5	23	[illegible]	27	29	47	52	n.a.	n.a.	65	n.a.	n.a.	n.a.
20	10	20	22	24	24	45	45	n.a.	n.a.	63	n.a.	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	6	9	9	9	16	20	20	22	27	35	n.a.	n.a.
200	60	6	6	6	7	11	16	16	18	20	27	n.a.	n.a.
75	31.5	4	4	5	5	11	12	13	13	18	19	n.a.	n.a.
20	10	2	2	2	2	7	7	8	8	14	15	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	16	20	20	20	33	41	41	45	50	64	n.a.	n.a.
200	60	14	16	16	18	27	33	33	37	42	50	n.a.	n.a.
75	31.5	12	12	13	15	25	26	28	28	38	40	n.a.	n.a.
20	10	7	7	8	8	18	18	20	20	30	33	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	4	6	6	6	10	15	15	15	19	24	27	28
200	60	2	2	2	2	7	9	11	11	14	18	19	20
75	31.5	2	2	2	2	7	8	8	8	11	13	15	15
20	10	1	1	2	2	3	4	4	4	7	7	8	8
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	13	15	15	15	23	33	33	33	39	49	50	52
200	60	9	10	10	10	18	23	24	27	30	37	39	41
75	31.5	8	8	10	8	17	19	20	20	26	29	32	32
20	10	3	3	4	4	10	12	14	14	17	18	20	20

* Assumes a shuttle system where route length = station spacing times number of stations minus one.
n.a. Not applicable

corresponding diversion rates in these two tables by one another one portion of the diversion rate is determined.

To this must be added the regional auto user not diverted at the fringe who brings his auto into the CBD. This trip-maker falls into two categories. The first is the reimbursed parker who will be assumed to be non-divertible to DPM. The second is the parker not reimbursed; he faces three choices, using the auto, the local bus, or the DPM. It should be recognized that before the DPM was available, he had rejected the local bus in favor of the auto. The issue then is to what degree the increment of transit service provided by the DPM will attract the internal auto user when the original transit service could not. Because of the high value he places on the comfort and convenience of his autc, particularly if he is involved in sales, service calls, or shopping, it can be argued that the diversion of this group will be small, certainly smaller than the share of internal transit users diverted to the DPM.

If it is concluded that convenience is really the decisive factor for these trip-makers, then an appropriate surrogate could be walking distance. It will be assumed that the internal auto user who has his auto available in the CBD will only use the DPM if the walking distances to and from the DPM station are less than half the walking distances he accepts when he uses his auto. Since average walking distances to and from parked autos vary from 400 to 800 feet in CBDs, with the longer distances for the larger CBDs, DPM coverage will comprise areas from 250 to 400 feet of a DPM station. Knowing that, the percent coverage is easily calculated for DPM systems of varying number of stations and CBDs of varying area. With coverage known, the percent of the trip ends likely to use a DPM can be estimated in the same manner as was done for other trip categories. This diversion rate can then be applied to the portion of internal auto users not diverted by the DPM at the fringe, and not reimbursed for their parking costs.

Thus an estimate of the diversion of these internal auto trip-makers to the DPM requires the following steps:

1) Determine the share of regional auto users diverted to the DPM at the fringe.

2) Multiply this share by the diversion rate for internal transit trips. This assumes that former internal auto users now without an auto available in the CBD will behave like internal transit usrs.

3) From the percent of regional auto trips not diverted at the fringe (100 percent minus answer in Step 1 above) subtract 20 percentage points because these auto users are reimbursed for their parking costs and will not be diverted.

4) Determine the diversion rate of the remaining group in Step 3 (above) using the walk access assumptions described in the previous paragraph.

5) Add the results of Steps 2 and 4. This is the total diversion rate of internal auto trips.

For example, suppose for a particular DPM and CBD configuration, 35 percent of regional auto users are diverted at the fringe DPM station (Step 1). Suppose also that the local bus and DPM characteristics produce a diversion of one-fifth of internal transit users to DPM. Thus, this component of the diversion is one-fifth of 35 percent, or seven percent (Step 2). Sixty-five percent of regional auto trips were not diverted at the fringe (100-35). Subtract 20 percent (the reimbursed), yielding 45 percent of internal auto users who have their vehicles available in the CBD but susceptible to diversion (Step 3). Suppose, on the basis of CBD activities distribution and walk access assumptions one-ninth of this group is determined to be divertible. Then, one-ninth of 45 percent, or 5 percent of the internal auto users are diverted (Step 4). Add 7 percent and 5 percent, or a total of 12 percent of all internal auto trips diverted to the DPM (Step 5).

In sum, the diversion rate to a DPM for internal auto users comprises two groups: the regional auto user who diverts to a DPM at the fringe and then behaves like a transit user for his internal trip; and the non-diverted regional auto user, who is paying for his own parking but still values his comfort and convenience highly. The calculation of the combined diversion rates for these two groups for the full array of CBD and DPM configurations is shown in Table 6-16, assuming the fringe parking areas are in a position to intercept all regional auto users. If not, the diversion rates must be reduced by tracing through the five steps above with appropriate changes.

Table 6-16 suggests a similar set of conclusions about internal auto trip diversions to a DPM as earlier exhibits showing the diversion rates of other trip categories. They are:

1) The rate of diversion rises dramatically for the largest activity CBDs.

2) The smaller the CBD's land area, the larger the share of trips that are diverted, all else remaining the same.

3) The CBD with concentrated activities will attract a significantly larger share of these trips to the DPM. This occurs because a larger proportion of trip ends will be located close to DPM stations with a concentrated CBD.

4) Diversion rates increase in direct proportion, or better, to the increase in the number of stations.

TABLE 6-16

PERCENT DIVERSION OF INTERNAL CBD AUTO TRIPS TO DPM AS FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS, AND STATION SPACING

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	11	14	16	16	28	30	n.a.	n.a.	46	n.a.	n.a.	n.a.
200	69	10	12	12	13	23	25	n.a.	n.a.	36	n.a.	n.a.	n.a.
75	31.5	6	7	8	8	14	15	n.a.	n.a.	21	n.a.	n.a.	n.a.
20	10	2	2	1	1	3	2	n.a.	n.a.	4	n.a.	n.a.	n.a.
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	24	29	32	32	50	52	n.a.	n.a.	67	n.a.	n.a.	n.a.
200	69	22	23	23	28	42	46	n.a.	n.a.	57	n.a.	n.a.	n.a.
75	31.5	15	18	18	19	25	30	n.a.	n.a.	35	n.a.	n.a.	n.a.
20	10	4	4	3	3	9	6	n.a.	n.a.	12	n.a.	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	3	5	6	6	13	17	17	18	22	27	n.a.	n.a.
200	69	3	3	3	4	9	13	13	14	16	21	n.a.	n.a.
75	31.5	2	2	2	2	5	7	6	5	9	9	n.a.	n.a.
20	10	0	0	0	0	1	1	0	0	1	1	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	10	14	15	17	26	32	32	34	39	49	n.a.	n.a.
200	69	8	10	11	14	20	24	24	26	30	35	n.a.	n.a.
75	31.5	4	5	6	7	13	15	15	14	18	18	n.a.	n.a.
20	10	1	1	1	1	2	1	1	1	2	2	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	2	2	3	3	5	11	13	13	15	20	23	21
200	69	2	2	2	2	3	7	8	8	10	14	14	15
75	31.5	1	1	1	1	2	3	3	3	4	5	5	4
20	10	0	0	0	0	1	1	0	0	1	1	0	0
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	5	7	8	9	15	24	24	24	29	37	38	39
200	69	3	4	4	5	11	16	17	17	20	25	25	25
75	31.5	2	2	3	2	6	7	7	7	8	11	12	9
20	10	1	1	1	1	1	1	1	1	2	1	1	1

* Assumes a shuttle system where route length = station spacing times number of station spacing times number of stations minus one.
n.a.–Not applicable

Typically, eight station systems attract at a rate more than double four-station systems, and twelve station systems attract at least 50 percent more than eight station systems.

5) Diversion rates increase with increased station spacing but at a diminishing rate. How that rate increases differs for different CBD and DPM configurations.

Two important points must be understood about the data presented in Table 6-16. First, the vast majority of diverted internal auto trips comprise those who left their autos at the fringe, becoming "captive" transit riders for their internal trips. This leads directly to the second point. The diversion of regional auto users to the fringe DPM stations will, in many cases, be constrained by fringe parking location and capacity. If such constraints exist, diversion rates will be lower and fewer will become captive transit riders for their internal trips.

6.2.7 Total Diversion to DPM

The total number of trips that will use the DPM are composed of five major sub-groups treated explicitly in the previous sections: (1) diverted regional CBD transit trips, (2) diverted regional CBD auto trips, (3) internal CBD walk trips, (4) internal CBD transit trips, and (5) internal CBD auto trips. These diversion rates must be applied to the number of trips in each category to yield the number of DPM trips. The number of regional CBD transit and auto trips can be found by using the methods described in Section B.2 and the number of internal CBD trip ends by foot, by transit and by auto can be found by using the methods described in Section B.3. To obtain internal trips it is necessary to divided internal trip ends by two.

In the six tables, 6-17 through 6-22, the results of multiplying DPM diversion rates by trips for the five trip categories are shown (two exhibits are included for regional CBD transit trips). Included are values for three additional CBD activity sizes found by extrapolation using the results of earlier exhibits. IT MUST BE STRESSED THAT THE TOTAL DPM DEMAND CANNOT BE FOUND BY SIMPLY ADDING UP ONE NUMBER FROM EACH OF FIVE EXHIBITS. THE RESULTS IN EACH EXHIBIT ARE SUBJECT TO BASIC ASSUMPTIONS THAT MUST BE EXPLICITLY UNDERSTOOD AND APPLIED TO THE INDIVIDUAL EXHIBIT BEFORE ANY NUMBER IN AN EXHIBIT CAN BE USED. The basic assumptions and caveats are spelled out below.

For regional CBD transit trips the key issue is the configuration of the line-haul transit system; if the system will be delivering anything other than 50 percent of the regional transit users to the fringe DPM stations, the volumes in Table 6-7 must be factored proportionately. For example, if only 20 percent of the regional transit users are delivered to the fringe DPM, the diverted trips will be two-fifths of the values in Table

TABLE 6-17

REGIONAL TRANSIT TRIPS DIVERTED TO DPM AS FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING ASSUMING FIFTY PERCENT OF TRANSIT RIDERS DELIVERED TO FRINGE DPM STATIONS

Number of Stations		4				8				12			
Station Spacing, feet		800	1200	1600	2000	800	1200	1600	2000	800	1200	1600	2000
Route length, feet*		2400	3600	4800	6000	5600	8400	11,200	14,000	8800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
CBD Area = 0.5 sq. miles, Spread Activity Distribution													
300	96	86	162	162	180	194	207	na	na	212	na	na	na
200	69	50	95	106	119	114	122	na	na	125	na	na	na
100	39.5	19	36	40	45	43	46	na	na	47	na	na	na
75	31.5	12	23	26	29	28	30	na	na	31	na	na	na
50	22.5	7	13	16	16	15	16	na	na	16	na	na	na
30	15	2	4	5	5	5	6	na	na	6	na	na	na
20	10	1	3	3	3	3	3	na	na	3	na	na	na
CBD Area = 0.5 sq. miles, Concentrated Activity Distribution													
300	96	72	180	207	225	221	225	na	na	225	na	na	na
200	69	42	111	122	133	130	133	na	na	133	na	na	na
100	39.5	16	42	46	50	49	50	na	na	50	na	na	na
75	31.5	10	27	30	33	32	33	na	na	33	na	na	na
50	22.5	6	15	16	18	17	18	na	na	18	na	na	na
30	15	2	5	6	6	6	6	na	na	6	na	na	na
20	10	1	3	3	4	3	4	na	na	4	na	na	na
CBD Area = 1.0 sq. miles, Spread Activity Distribution													
300	96	54	117	153	176	180	203	207	216	203	212	na	na
200	69	32	69	80	103	106	119	122	127	119	125	na	na
100	39.5	12	26	34	39	40	45	46	48	45	47	na	na
75	31.5	8	17	22	25	26	29	30	31	29	31	na	na
50	22.5	4	8	12	14	14	16	16	17	16	16	na	na
30	15	1	3	4	4	4	5	6	6	5	6	na	na
20	10	–	2	2	3	3	3	3	3	3	3	na	na
CBD Area = 1.0 sq. miles, Concentrated Activity Distribution													
300	96	63	153	189	203	203	225	225	225	221	225	na	na
200	69	37	90	111	119	119	133	133	133	130	133	na	na
100	39.5	14	34	42	45	45	50	50	50	49	50	na	na
75	31.5	9	22	27	29	29	33	33	33	32	33	na	na
50	22.5	5	12	15	16	16	18	18	18	17	18	na	na
30	15	2	4	5	5	5	6	6	6	6	6	na	na
20	10	1	2	3	3	3	4	4	4	3	4	na	na
CBD Area = 1.5 sq. miles, Spread Activity Distribution													
300	96	18	41	60	96	117	180	198	198	207	213	213	216
200	69	11	24	36	56	69	106	117	117	122	125	125	127
100	39.5	4	9	13	21	26	40	44	44	46	47	47	48
75	31.5	3	6	8	14	17	26	29	29	30	31	31	31
50	22.5	1	3	5	7	9	14	15	15	16	16	16	17
30	15	–	1	2	3	3	5	5	5	6	6	6	6
20	10	–	1	1	2	2	3	3	3	3	3	3	3
CBD Area = 1.5 sq. miles, Concentrated Activity Distribution													
300	96	23	63	96	126	140	194	225	225	207	207	207	207
200	69	13	37	56	74	82	114	133	133	122	122	122	122
100	39.5	5	14	21	28	31	43	50	50	46	46	46	46
75	31.5	3	9	14	18	20	28	33	33	30	30	30	30
50	22.5	2	5	7	10	11	15	18	16	16	16	16	16
30	15	1	2	3	3	4	5	6	6	6	6	6	6
20	10	1	1	2	2	2	3	4	4	3	3	3	3

* Assumes a shuttle system where route length = station spacing times number of stations minus one.
na – not applicable
Note: – All trips in thousands

TABLE 6-18

REGIONAL CBD TRANSIT TRIPS DIVERTED TO DPM AS FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING ASSUMING ALL TRANSIT RIDERS DELIVERED TO CENTER DPM STATION

Number of stations		4				8				12			
Station spacing, feet		800	1200	1600	2000	800	1200	1600	2000	800	1200	1600	2000
Route length, feet*		2400	3600	4800	6000	5600	8400	11,200	14,000	8800	13,200	17,600	22,000
CBD Employ (000's)	CBD Floorsp (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300		32	104	162	234	167	252	na	na	261	na	na	na
200	69	19	61	95	138	98	148	na	na	154	na	na	na
100	39.5	7	23	36	52	37	56	na	na	58	na	na	na
75	31.5	5	15	23	34	24	36	na	na	38	na	na	na
50	22.5	2	8	13	18	13	20	na	na	20	na	na	na
30	15	1	3	4	6	4	7	na	na	7	na	na	na
20	10	–	2	3	4	3	4	na	na	4	na	na	na
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	9	36	77	131	68	126	na	na	153	na	na	na
200	69	5	21	45	77	40	74	na	na	90	na	na	na
100	39.5	2	8	17	29	15	28	na	na	34	na	na	na
75	31.5	1	5	11	19	10	18	na	na	22	na	na	na
50	22.5	1	3	6	10	5	10	na	na	12	na	na	na
30	15	–	1	2	3	2	3	na	na	4	na	na	na
20	10	–	1	1	2	1	2	na	na	2	na	na	na
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	23	77	117	153	117	221	261	320	194	297	na	na
200	69	13	45	69	90	69	130	154	188	114	175	na	na
100	39.5	5	17	26	34	26	49	58	71	43	66	na	na
75	31.5	3	11	17	22	17	32	38	46	28	43	na	na
50	22.5	2	6	9	12	9	17	20	25	15	23	na	na
30	15	1	2	3	4	3	6	7	9	5	8	na	na
20	10	–	1	2	3	2	3	4	5	3	5	na	na
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	18	54	59	81	41	104	108	216	108	189	na	na
200	69	11	32	36	48	24	61	64	127	64	111	na	na
100	39.5	4	12	13	18	6	23	24	48	24	42	na	na
75	31.5	3	8	8	12	6	16	16	31	16	27	na	na
50	22.5	1	4	5	6	3	8	8	17	8	15	na	na
30	15	–	1	2	2	1	3	3	6	3	5	na	na
20	10	–	1	1	1	–	2	2	3	2	3	na	na
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	5	32	50	131	77	167	262	270	171	286	306	351
200	69	3	19	35	77	45	98	148	158	101	156	180	207
100	39.5	1	7	13	29	17	37	56	60	38	59	68	78
75	31.5	1	6	8	19	11	24	38	40	25	38	44	51
50	22.5	–	2	5	10	8	13	20	21	13	21	24	27
30	15	–	1	2	3	2	4	7	7	6	7	8	9
20	10	–	1	1	2	1	3	4	4	3	4	5	6
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	9	32	50	108	50	96	113	140	80	162	203	252
200	69	5	19	29	64	29	56	66	82	53	96	119	148
100	39.5	2	7	11	24	11	21	25	31	20	36	45	56
75	31.5	1	5	7	16	7	14	16	20	13	23	29	36
50	22.5	1	2	4	8	4	7	9	11	7	13	16	20
30	15	–	1	1	3	1	3	3	4	2	4	5	7
20	10	–	1	1	2	1	2	2	2	1	3	3	4

* Assumes a shuttle system where route length = station spacing times number of stations minus one
na – Not applicable
Note: All trips in thousands
– Dash indicates less than 500 trips

TABLE 6-19

REGIONAL CBD AUTO TRIPS DIVERTED TO DPM AS FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING ASSUMING UNLIMITED, WELL-PLACED PARKING CAPACITY

Number of Stations		4				8				12			
Station spacing, feet		800	1200	1600	2000	800	1200	1600	2000	800	1200	1600	2000
Route length, feet*		2400	3600	4800	6000	5600	8400	11,200	14,000	8800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	249	249	249	249	266	266	na	na	270	na	na	na
200	64	224	224	224	224	239	239	na	na	243	na	na	na
100	38.5	130	142	145	140	120	108	na	na	230	na	na	na
75	31.5	96	107	117	107	98	84	na	na	101	na	na	na
50	22.5	57	61	68	64	53	44	na	na	58	na	na	na
30	15	26	29	28	28	22	16	na	na	24	na	na	na
20	10	8	7	5	4	6	2	na	na	3	na	na	na
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	263	263	263	263	286	270	na	na	273	na	na	na
200	64	236	236	236	236	233	236	na	na	217	na	na	na
100	38.5	140	149	150	156	110	121	na	na	106	na	na	na
75	31.5	105	119	121	119	88	96	na	na	84	na	na	na
50	22.5	60	58	64	54	44	52	na	na	40	na	na	na
30	15	28	25	27	22	19	33	na	na	17	na	na	na
20	10	11	8	7	5	8	4	na	na	7	na	na	na
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	116	158	186	228	263	250	263	250	286	250	na	na
200	64	104	141	170	183	217	221	217	208	221	217	na	na
100	38.5	57	74	82	86	100	115	96	88	105	100	na	na
75	31.5	44	56	64	62	76	80	68	60	80	76	na	na
50	22.5	23	34	40	36	43	50	35	28	43	37	na	na
30	15	11	17	20	17	11	24	14	11	17	14	na	na
20	10	2	3	3	3	2	2	–	–	2	1	na	na
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	154	203	224	245	283	250	263	250	286	250	na	na
200	64	132	161	189	217	211	208	208	205	186	205	na	na
100	38.5	70	84	108	110	180	120	110	108	104	100	na	na
75	31.5	52	62	76	76	76	92	76	70	76	68	na	na
50	22.5	30	33	44	46	54	62	40	32	46	40	na	na
30	15	12	13	13	12	30	29	11	–	18	14	na	na
20	10	4	3	3	2	3	1	–	–	3	2	na	na
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	63	77	98	116	140	217	280	280	246	280	280	246
200	64	57	68	88	98	120	180	202	186	182	286	186	182
100	38.5	30	40	46	52	86	82	66	66	80	75	70	52
75	31.5	24	38	34	38	40	58	44	44	54	50	40	28
50	22.5	14	20	18	20	18	26	18	18	28	21	12	9
30	15	5	8	8	11	7	9	6	5	8	5	–	–
20	10	1	2	1	1	2	2	–	–	2	1	–	–
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	91	110	133	161	172	226	246	246	240	280	280	282
200	64	82	107	110	123	126	170	170	161	138	180	183	173
100	38.5	44	48	54	48	62	70	60	66	70	75	78	86
75	31.5	30	38	40	38	44	50	46	42	52	52	56	32
50	22.5	16	18	28	18	22	28	17	14	28	30	25	12
30	15	7	8	10	8	9	5	3	3	7	4	6	2
20	10	2	2	2	2	2	1	–	–	2	1	–	–

* Assumes a shuttle system where route length = station spacing times number of stations minus one.
na – Not applicable
Note: All trips in thousands.
– Dash indicates less than 500 trips

TABLE 6-20

INTERNAL CBD WALK TRIPS DIVERTED TO DPM AS FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	49	69	78	53	116	116	n.a.	n.a.	146	n.a.	n.a.	n.a.
200	69	32	54	54	36	72	75	n.a.	n.a.	97	n.a.	n.a.	n.a.
100	39.5	17	21	27	17	37	39	n.a.	n.a.	51	n.a.	n.a.	n.a.
75	31.5	12	20	20	12	27	29	n.a.	n.a.	38	n.a.	n.a.	n.a.
50	22.5	8	13	13	8	18	19	n.a.	n.a.	25	n.a.	n.a.	n.a.
30	15	4	7	7	4	10	11	n.a.	n.a.	14	n.a.	n.a.	n.a.
20	10	2	3	3	2	5	5	n.a.	n.a.	7	n.a.	n.a.	n.a.
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	97	112	97	73	150	146	n.a.	n.a.	184	n.a.	n.a.	n.a.
200	69	61	72	72	61	100	97	n.a.	n.a.	107	n.a.	n.a.	n.a.
100	39.5	34	37	39	34	52	48	n.a.	n.a.	60	n.a.	n.a.	n.a.
75	31.5	25	27	29	24	39	36	n.a.	n.a.	47	n.a.	n.a.	n.a.
50	22.5	17	18	19	17	25	24	n.a.	n.a.	31	n.a.	n.a.	n.a.
30	15	9	10	11	9	13	14	n.a.	n.a.	19	n.a.	n.a.	n.a.
20	10	4	6	4	4	7	7	n.a.	n.a.	10	n.a.	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	15	39	19	49	63	78	63	73	102			
300	96	15	39	39	19	49	63	78	63	73	102	n.a.	n.a.
200	69	11	21	25	14	39	47	50	36	47	68	n.a.	n.a.
100	39.5	10	12	13	7	18	25	26	17	25	36	n.a.	n.a.
75	31.5	10	10	10	5	12	19	20	13	19	27	n.a.	n.a.
50	22.5	5	6	6	3	8	12	13	8	12	17	n.a.	n.a.
30	15	3	3	3	2	5	7	7	4	7	9	n.a.	n.a.
20	10	2	1	1	1	2	3	3	3	3	4	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	44	39	39	19	49	63	78	58	73	102	n.a.	n.a.
200	69	31	21	25	14	39	47	50	36	47	68	n.a.	n.a.
100	39.5	12	16	19	11	27	30	27	27	36	39	n.a.	n.a.
75	31.5	10	15	17	10	24	25	22	24	32	30	n.a.	n.a.
50	22.5	7	10	11	7	15	16	14	15	21	20	n.a.	n.a.
30	15	4	6	5	4	9	9	8	9	12	12	n.a.	n.a.
20	10	2	3	2	2	4	4	4	4	6	6	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	10	15	19	10	39	49	53	34	44	73	68	39
200	69	4	11	14	7	14	29	36	21	29	47	54	25
100	39.5	3	6	7	3	9	16	20	11	16	25	27	13
75	31.5	2	5	5	2	7	12	13	8	12	19	20	10
50	22.5	2	3	3	2	5	8	10	5	8	12	13	6
30	15	1	2	2	1	2	5	5	3	5	7	7	3
20	10	1	1	1	1	1	2	2	1	2	3	3	2
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	24	39	39	29	98	82	78	68	92	107	102	68
200	69	18	29	29	18	36	54	54	43	61	86	72	47
100	39.5	9	14	14	9	20	26	26	22	34	39	36	25
75	31.5	7	10	10	7	13	19	20	17	24	25	24	17
50	22.5	4	6	6	4	10	14	13	11	17	17	17	11
30	15	2	3	3	2	5	8	7	6	9	9	9	6
20	10	1	2	2	1	3	4	3	3	4	[illegible]	4	4

* Assumes a shuttle system where route length = station spacing times number of stations minus one.
na – Not applicable
Note: All trips in thousands.

TABLE 6-21

INTERNAL CBD TRANSIT TRIPS DIVERTED TO DPM AS A FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ (000's)	CBD Floorsp. (mil.sq.ft.)	CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	7	10	11	11	19	20	n.a	n.a	31	n.a	n.a	n.a
200	69	4	4	4	5	8	9	n.a	n.a	13	n.a	n.a	n.a
100	39.5	4	4	4	4	7	9	n.a	n.a	12	n.a	n.a	n.a
75	31.5	3	4	4	4	7	9	n.a	n.a	12	n.a	n.a	n.a
50	22.5	2	3	3	4	5	8	n.a.	n.a	11	n.a	n.a	n.a
30	15	2	2	2	2	3	5	n.a.	n.a.	8	n.a	n.a	n.a
20	10	0	0	0	0	0	0	n.a	n.a	0	n.a	n.a	n.a
		CBD Area = 0.5 miles, Concentrated Activity Distribution											
300	96	17	20	21	21	34	35	n.a.	n.a	44	n.a	n.a	n.a
200	69	8	8	8	10	15	16	n.a	n.a	20	n.a	n.a	n.a
100	39.5	2	3	3	3	6	6	n.a	n.a	8	n.a	n.a	n.a
75	31.5	2	2	2	2	3	3	n.a.	n.a	4	n.a	n.a	n.a
50	22.5	1	1	1	1	2	2	n.a.	n.a	3	n.a.	n.a	n.a
30	15	0	1	1	1	1	1	n.a.	n.a	1	n.a	n.a	n.a
20	10	0	0	0	0	0	0	n.a.	n.a	0	n.a	n.a	n.a
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	3	5	5	5	9	11	11	12	14	19	n.a	n.a
200	69	2	2	2	2	3	4	4	5	5	7	n.a	n.a
100	39.5	1	1	1	1	1	2	2	2	2	3	n.a	n.a
75	31.5	0	0	0	0	1	1	1	1	1	1	n.a	n.a
50	22.5	0	0	0	0	1	1	1	1	1	1	n.a	n.a
30	15	0	0	0	0	0	0	0	0	0	0	n.a.	n.a
20	10	0	0	0	0	0	0	0	0	0	0	n.a	n.a
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	9	11	11	11	18	22	22	24	27	34	n.a	n.a
200	69	4	4	4	5	7	9	9	10	11	14	n.a.	n.a
100	39.5	1	2	2	2	3	3	3	4	4	5	n.a.	n.a.
75	31.5	1	1	1	1	2	2	2	2	2	3	n.a.	n.a
50	22.5	1	1	1	1	1	1	1	1	2	2	n.a.	n.a
30	15	0	0	0	0	0	1	1	1	1		n.a.	n.a
20	10	0	0	0	0	0	0	0	0	0	0	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	2	3	3	3	5	8	8	8	10	13	14	15
200	69	1	1	1	1	2	2	3	3	4	5	5	5
100	39.5	0	0	0	0	1	1	1	1	1	2	2	2
75	31.5	0	0	0	0	0	1	1	1	1	1	1	1
50	22.5	0	0	0	0	0	0	0	0	0	0	1	1
30	15	0	0	0	0	0	0	0	0	0	0	0	0
20	10	0	0	0	0	0	0	0	0	0	0	0	0
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	7	8	8	8	12	18	18	18	21	26	27	28
200	69	2	3	3	3	5	6	6	7	8	10	11	11
100	39.5	1	1	1	1	2	2	2	3	3	4	4	4
75	31.5	1	1	1	1	1	1	1	1	2	2	2	2
50	22.5	0	0	0	0	1	1	1	1	1	1	1	1
30	15	0	0	0	0	0	0	0	1	1	1	1	1
20	10	0	0	0	0	0	0	0	0	0	0	0	0

* Assumes a shuttle system where route length = station spacing times number of stations minus one.

n.a. – Not applicable

Zero indicates less than 500 trips

Note: All trips in thousands.

TABLE 6-22

INTERNAL CBD AUTO TRIPS DIVERTED TO DPM AS FUNCTION OF CBD ACTIVITIES CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
		CBD area = 0.5 sq. miles, Spread Activity Distribution											
300	96	4	5	6	6	10	11	n.a.	n.a.	17	n.a.	n.a.	n.a.
200	69	3	4	4	4	8	8	n.a.	n.a.	12	n.a.	n.a.	n.a.
100	39.5	1	2	2	2	4	4	n.a.	n.a.	6	n.a.	n.a.	n.a.
75	31.5	1	1	1	1	3	3	n.a.	n.a.	4	n.a.	n.a.	n.a.
50	22.5	0	0	0	0	2	2	n.a.	n.a.	2	n.a.	n.a.	n.a.
30	15	0	0	0	0	1	1	n.a.	n.a.	1	n.a.	n.a.	n.a.
20	10	0	0	0	0	0	0	n.a.	n.a.	0	n.a.	n.a.	n.a.
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	9	10	12	12	18	19	n.a.	n.a.	24	n.a.	n.a.	n.a.
200	69	7	8	8	9	14	15	n.a.	n.a.	19	n.a.	n.a.	n.a.
100	39.5	4	4	4	5	7	8	n.a.	n.a.	7	n.a.	n.a.	n.a.
75	31.5	3	3	3	4	3	6	n.a.	n.a.	6	n.a.	n.a.	n.a.
50	22.5	2	2	2	3	3	3	n.a.	n.a.	3	n.a.	n.a.	n.a.
30	15	1	1	1	2	2	2	n.a.	n.a.	2	n.a.	n.a.	n.a.
20	10	0	0	0	0	0	0	n.a.	n.a.	1	n.a.	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	2	2	2	2	5	6	6	6	8	10	n.a.	n.a.
200	69	1	1	1	1	3	4	4	5	5	7	n.a.	n.a.
100	39.5	0	0	0	0	1	2	2	2	3	3	n.a.	n.a.
75	31.5	0	0	0	0	1	1	1	1	2	2	n.a.	n.a.
50	22.5	0	0	0	0	1	1	1	1	1	1	n.a.	n.a.
30	15	0	0	0	0	0	0	0	0	1	1	n.a.	n.a.
20	10	0	0	0	0	0	0	0	0	0	0	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	4	5	5	6	9	12	12	12	14	18	n.a.	n.a.
200	69	3	3	4	5	7	8	8	9	10	12	n.a.	n.a.
100	39.5	1	1	2	2	3	4	4	4	5	5	n.a.	n.a.
75	31.5	1	1	1	1	2	3	3	3	3	3	n.a.	n.a.
50	22.5	1	1	1	1	1	2	2	2	2	2	n.a.	n.a.
30	15	0 0	0	0	0	1	1	1	1	1	1	n.a.	n.a.
20	10	0	0	0	0	0	0	0	0	0	0	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	1	1	1	1	2	4	5	5	5	7	8	8
200	69	1	1	1	1	1	2	3	3	4	5	5	5
100	39.5	0	0	0	0	0	1	1	1	2	2	2	2
75	31.5	0	0	0	0	0	1	1	1	1	1	1	1
50	22.5	0	0	0	0	0	1	1	1	1	1	1	1
30	15	0	0	0	0	0	0	0	0	0	0	0	0
20	10	0	0	0	0	0	0	0	0	0	0	0	0
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	2	3	3	3	5	9	9	9	10	13	14	14
200	69	1	1	1	2	4	5	6	6	7	8	8	8
100	39.5	0	0	1	0	2	2	2	2	2	3	3	3
75	31.5	0	0	1	0	1	1	1	1	1	2	2	2
50	22.5	0	0	1	0	1	1	1	1	1	1	1	1
30	15	0	0	0	0	0	0	0	0	1	1	1	1
20	10	0	0	0	0	0	0	0	0	0	0	0	0

* Assumes a shuttle system where route length = station spacing times number of stations minus one.
n.a. - Not applicable
Zero indicates less than 500 trips
Note: All trips in thousands.

6-17. Similarly, Table 6-18 will permit estimation of DPM demand for regional transit trips delivered to the CBD's center. If less than 100 percent are delivered to the center these volumes must be factored downward.

The adjustments necessary to Table 6-19 to estimate the diversion of regional auto trips are critical. It will be recalled that the diversion of auto users to the fringe DPM station and parking area is constrained by two factors, the judicious location of fringe DPM parking around the CBD to capture CBD-bound auto users from every direction, and sufficiently large parking areas to provide spaces for all who might choose to park there. To the extent these conditions cannot be met, the number of diverted trips in the category must be lowered. If, for example, only two fringe parking locations and DPM stations are provided, only half of the potential auto users divertible to the DPM can be captured, and the volumes in Table 6-19 must be cut in half. These volumes may have to be cut further if the amount of parking cannot provide for that volume of trips in accordance with the assumption that one parking space can provide for 3.12 two-way trips. Suppose, for example, that for a particular CBD and DPM configuration, Table 6-19 shows 100,000 regional auto trips can can be diverted. If only two fringe parking areas are provided, intercepting only an 180 degree sweep of the compass, this potential is reduced to 50,000. But if these two parking areas provide a total of only 10,000 spaces, they can accommodate only 31,200 diverted trips, which would be the appropriate demand to use for this trip category.

The volumes of internal walk trips diverted to the DPM shown in Table 6-20 are very sensitive to the walking trip length distributions assumed. It is recommended that, to the degree possible, these distributions for a particular CBD be determined directly, rather than relying on interpolated data from a few CBDs. This is particularly important because the total volume of internal walk trips can be relatively large compared to the other trip categories.

Internal transit trips diverted to the DPM, shown in Table 6-21, are particularly sensitive to the assumptions made about the coverage of local bus service within the CBD and to the relative fare assumed for local buses and the DPM. Table 6-21 assumes the DPM is 25¢ cheaper and the local bus route structure is extensive. In Section B-6 adjustments for other assumptions are suggested.

The internal auto trips diverted to the DPM, shown in Table 6-22, are very much affected by the assumptions for the regional auto trip and the internal transit trip. This is so because the vast majority of internal auto trips diverted to the DPM are made by travellers who left their autos at the fringe parking areas and became transit users for their internal trips. To the degree adjustments must be made in the resuls of both Table 6-19 and VI-20, the DPM demand of internal auto trips, adjustments must also be made in Table 6-22. For example, if the 100,000 potential diversions of regional auto trips must be reduced to 31,200, as in the illustration above, and if the internal transit diversions are adjusted, say, upward by 1.5 times, then the internal auto trips would require an adjustment of 0.321 x 1.5 or 0.468.

In addition to these specific points about each of the trip categories, some general comments about methodology are in order. First, it is recognized that the methods described in this section rely, in many cases, on average values or assumptions which may or may not be correct in specific situations. It is highly recommended that where data is available locally or justification for other assumptions exist, such substitutions be made. This is why the steps and assumptions made in the procedures have been discussed in detail. Second, Exhibits 6-17 through 6-22 are based on a set of specific DPM operating assumptions. The adjustments necessary for other assumptions of headways, speeds or fare levels can be estimated from the material presented. Third, only demand estimates for discrete values of CBD activity, CBD land area, CBD concentrations, number of DPM stations, and DPM station spacings are presented. To estimate values other than the ones given, interpolation can be performed. Values have been given, however, that span the full range of proposed DPM systems and CBD characteristics.

6.2.8 Induced Trips

Up to this point, the only DPM demand explicitly considered is that generated by existing land use and diverted to the DPM. Additional elements of DPM demand may exist though. The DPM may gain riders who formerly did not travel at all. These "induced" trips will occur if the DPM enables a trip to be made that was very difficult via existing modes, requiring either excessive time unavailable to the potential trip-maker (lunch hour shopping trips), or high costs and great inconvenience. It is likely that most of these trips will be internal CBD trips; regional CBD trips are less spontaneous because of their greater length. Also, since the DPM represents a small portion of a longer trip, regional CBD trips are less likely to be induced because of a new DPM serving a small segment of the total trip.

Empirical evidence indicating the magnitude of trips induced by expanded transportation service is sparse. Passenger surveys at the Dupont Circle Metrorail station in Washington indicates that 12.8 percent of the passengers on the five-station segment of system wholly contained in the CBD, were induced. In Milwaukee, 8.2 percent, and in Los Angeles, 16.5 percent of the passengers on CBD shuttle buses claimed they would not make the trip if the service were eliminated In Los Angeles, the survey respondents indicated they would not have made the trip prior to the institution of the service. Whether all of these trips were truly induced by the added service or whether other factors generated the travel is unclear. For this exercise it would appear that a conservative assumption is warranted. Internal CBD trips diverted to the DPM, including those formerly made on foot, by transti, and by auto, can be expanded by 10 percent to account for induced trips.

Additional travel may also result if additional trip generating facilities are built in future years. To the extent that future development is committed, it would be appropriate to estimate DPM demand on the employment and/or floorspace such new development is expected to create. More speculatively, DPM demand may be based on the additional development that could be built at prevailing densities in the vicinity to replace CBD parking facilities made unnecessary by the DPM system and their associated fringe parking areas.

6.2.9 An Illustrative Example

Application of the methodology is illustrated using a hypothetical CBD and DPM system.

Given:

1) A CBD of 0.80 square miles with 35 million square feet of nonresidential floorspace arranged in a relatively spread manner.

2) A DPM system of five stations, 1100 feet apart. Headways are two minutes, cruise speed is 10 miles per hour, and there is no fare.

3) A regional bus transit system that delivers 40 percent of its CBD-bound passengers to fringe DPM stations. The remaining 60 percent are distributed directly by the line-haul bus with no need to transfer. The local bus network runs at five minute headways and charges 25¢ for internal CBD travel.

4) A highway configuration that is capable of delivering half its CBD-bound users to DPM stations at two fringe park-and-ride lots with 5,000 spaces each.

To estimate aggregate DPM demand a series of interpolations from Tables 6-17 through 6-22 are necessary. To be interpolated are: (1) floorspace, (2) CBD area, (3) number of stations, and (4) station spacing. Interpolation can be performed in any order using these four parameters. Where appropriate, interpolation can be done graphically using either full or semi-logarithmic paper.

Table 6-17 gives the number of regional transit trips that would use the DPM if the transit system delivered 50 percent of the transit users to fringe DPM stations. Whatever volume is interpolated from the exhibit must be reduced by 20 percent since it is given that only 40 percent of all regional transit trips are delivered to the DPM. Successive interpolations produce an estimated 25,000 trips, reduced by 20 percent to 20,000.

Table 6-18 need not be used in our example since the transit delivery system does not bring riders directly to the center of the CBD.

In Table 6-19 the number of regional auto trips diverted to the DPM are estimated to be 87,000, using four successive interpolations. But since the highway network and fringe parking locations are situated to capture only half of all auto users, this volume must be reduced by 50 percent, or to 43,500 trips. Furthermore, this volume must be checked against the capacity of the fringe parking lots. With 10,000 spaces they can serve only 31,200 auto-diverted DPM trips per day. Therefore, the number of regional auto trips diverted to the DPM is 31,200.

Table 6-20 gives the internal CBD walk trips diverted to the DPM. Successive interpolations produce an estimated 10,000 diverted walk trips.

Interpolations of Table 6-21 yield an estimated 1,000 internal transit trips diverted to the DPM. But Table 6-21 assumes that the only advantage of the DPM over the local bus service is a 25 cent lower fare. With a headway advantage as well, diversions might total 2,000 riders, as Table 6-14 suggests.

Table 6-22 gives the estimated diversion of internal autc trips to be less than 1,000. But this table assumes sufficient fringe DPM stations and parking that can intercept and provide for all regional auto users that choose to use them. In our example this is not the case. Therefore, a larger share of the internal auto users will have an auto available to them for internal auto trips than Table 6-22 was predicated on. To the extent that the diversion rate of those with an auto available is lower than the rate for those who left their auto at the fringe, the values in Table 6-22 are somewhat inflated. An estimate of 1,000 trips, perhaps too generous, will be used here.

Internal trips diverted to the DPM are the sum of the last three components, or 12,000 trips. Induced trips are conservatively assumed to amount to 10 percent of this, or 1,200 trips.

Total DPM Demand:

Regional transit trips	20,000
Regional auto trips	31,200
Internal walk trips	10,000
Internal transit trips	1,000
Internal auto trips	1,000
Induced trips	1,200
TOTAL DAILY TRIPS:	64,400

6.3 EVALUATING DPM SYSTEM FEASIBILITY

6.3.1 Threshold Criteria

To examine whether a DPM is a reasonable solution to circulation problems in a downtown, the estimates of demand described to this point can be compared to a set of criteria that relate to both realistic benefits of the system and are in scale with other tranportation investment decisions. It should be noted, however, that the criteria described below and the comparisons for which they are used reflect the same rough level of analysis as that presented above, i.e., calculations are based on gross averages and simplifying assumptions. Numerical values can be assumed to have wide bands of uncertainty around them. Results are meant to be indicative only and cannot be applied, as presented, to specific urban areas.

In a concurrent study, a series of threshold demand criteria for fixed guideway systems, including rapid transit, light rail and people movers, have been indicated. These criteria for people movers include the possibility of labor savings as compared to local bus service, the possibility of energy savings compared to the modes that would have been used by DPM riders, limitation of capital investment as compared to prevailing fixed guideway investment, and the savings of land in downtowns compared to other transportation users. Each criterion represents a level above which DPM is likely to hold an advantage.

For ease of comparison, each of these criteria is expressed in the same units, annual place-miles of service per line-mile of route, at an assumed average rate of occupancy. Therefore, understanding of this unit of measurement is central to any discussion of the criteria. A place on a vehicle is the average gross floor area available to a passenger at a given level of comfort. Two space standards are advanced, a comfortable standard of 5.4 square feet (0.5 m^2) of gross floor area per passenger and a minimum standard of 3.75 square feet (0.35 m^2) per passenger. The latter is acceptable for short periods of travel such as might exist on a downtown people mover, but represents a condition when standees are in the majority. A place-mile then, is one place, defined by a given comfort standard, moving on a system for a distance of one mile. By dividing the supply of annual place-miles by the length of the

DPM route, in miles, annual place-miles per line-mile, is determined. This is a measure of traffic density. Line-miles are defined in two-track equivalents; a one-track DPM loop of two miles would be only one line-mile.

The DPM demand estimates discussed to this point in the aggregate demand analysis have been expressed as the number of two-way trips on an average weekday. To convert these estimates to annual place-miles per line-mile, these demand estimates must be 1) multiplied by average trip length to obtain daily passenger-miles, 2) multiplied by the ratio of annual-to-average weekday demand to obtain annual passenger-miles, (3) divided by an assumed average load factor for the places on the DPM to obtain annual place-miles, and (4) divided by the length of the DPM system, in miles, to obtain annual place-miles per line-mile.

To establish threshold criteria for labor savings, the number of employees required per million place-miles of output is compared for different systems. Labor costs for people movers are to some extent independent of the route length and service frequency because, unlike buses, vehicle operation is performed off the vehicle. Thus, the number of employees required does not grow in more or less direct proportion to output measured in place-miles; a longer system operating at a given speed will require fewer workers per mile. Consequently, the threshold of labor savings compared to local buses operating at 6 miles per hour varies: for a one-mile DPM in the threshold is 10 million place-miles per line-mile; for a three-mile system the threshold is 5 million place-miles per line mile. For the range of route lengths examined here, 0.45 miles to 4.2 miles (0.72 to 7.7 km.) the labor savings thresholds vary from about 4.5 to 15 million annual place-miles per line-mile, the higher figure for the shortest system.

To estimate the energy savings thresholds, a number of categories of DPM energy consumption must be considered: energy to operate the vehicles, energy to operate the fixed facilities, including maintenance yards, wayside equipment, stations and snow melting if necessary, energy to manufacture and replace vehicles, and energy for construction and replacement of guideways. The total of these items must be compared to the energy saved by the portion of trips not taken because the people mover exists. Assuming that the travel replaced by the DPM, measured in passenger-miles, comes in three equal parts from a future auto obtaining 24 miles per gallon, a 12 mile per hour bus, and on foot, requiring 1990, 1111 and 0 BTUs per place-mile, respectively, then the energy breakeven point for people movers will be about 50 million annual place-miles per line-mile if snow melting is required, and 28 million if no snow melting is required. These thresholds are based on a 60-year amortizaton period for energy savings. If that period is cut in half, energy savings can be realized, but at about 80 million annual place-miles per line mile if snow melting is required and at about 45 million if snow melting is required. One way of avoiding the huge energy consumption necessary to keep the right-of way clear of snow would be to place the facility underground or to operate steel-wheel vehicles. If the right-of-way were underground the energy costs would just about balance the energy losses saved.

The potential savings of land in downtowns if a people mover is installed can be expressed in terms of threshold criteria also. At about 3 million annual place-miles per line-mile a DPM pre-empting the space of an urban arterial will have more people-carrying capacity in the peak hour, assuming typical auto occupancies. If the requirement were to use land more efficiently than an auto facility for a 24-hour period, the threshold would be much higher, given the peaking characteristics of both the auto and transit users. Such a requirement would be unnecessarily stringent, however, since there is generally unused space for travel in offpeak hours.

For capital investment requirements, the analysis for determining threshold criteria is accomplished by assuming two possible levels of investment: the median value of recent fixed guideway investment, $1500 per daily passenger-mile (1977 dollars), or $2250 per daily passenger-mile, the 75 percentile level for recent investments. Assuming that three-quarters of the structure length is elevated and one-quarter is at grade the threshold criteria convert to 12 and 8 million annual place-miles per line-mile, respectively.

In sum, the threshold criteria for DPMs in millions of annual place-miles per line-mile are:

Land savings	3 in place of arterials
Capital investment	(1) 12 using median investment criteria
	(2) 8 using 75 percentile investment criteria
Labor savings	(1) 5 for a one-mile system
	(2) 10 for a three-mile system
Energy savings	(1) 80 in snowy climates with half the amortization period
	(2) 50 in snowy climates with the full amortization period,
	(3) 45 in warm climates or in snowy climates with a steel-wheeled DPM, and with half the amortization period
	(4) 28 in warm climates or in snowy climates with a steel-wheeled DPM, and the full amortization period

It is clear from this array of criteria that energy savings will always be the highest value. If the savings of energy is not included, recognizing the limited scale of DPM energy consumption as compared to all urban travel, the range of demand volumes worthy of consideration would expand substantially.

6.3.2 Capacity Constraints

Aside from meeting demand threshold criteria the feasibility of any particular DPM system depends on whether the capacity is available to accommodate the estimated demand. The passenger carrying capacity of the vehicles must be examined in both time and space, i.e., the peak period at the maximum load point. The peak hour capacity for a given comfort standard can be calculated from the maximum service frequency and the gross floor area of the vehicle, or for those systems with entraining possibilities, the floor area of the train. For example, if a system is capable of operating every twenty seconds with vehicles of 118 square feet (10 m^2) operating in two-car trains, it would have a comfortable capacity of 7,200 passenger places in one direction (40 passengers each occupying 5.4 square feet (0.5 m^2) of a 236 square feet (20 m^2) train in each of 180 trains.) Using the minimum space standard, the capacity would be about 11,300 one-way passenger places per peak hour. Currently, the Boeing people mover at the University of West Virginia in Morgantown has a comfortable capacity of 4,600 places per direction per hour, and that of Airtrans at the Dallas-Ft.Worth Airport, with two-car trains has 11,880 places per direction in the peak hour. Each of these capacity figures assumes the ability to sustain the minimum headways for a full hour.

A system intended to serve mostly internal trips is likely to have its peak period in midday. Extensive cyclical counts of pedestrians indicate that the peak hour for pedestrians occurs in the 12:00 - 1:30 pm period and averages about 15 percent ranging from about 12.5 to 17.5 percent of the 12-hour period from 7:30 am to 7:30 pm. Areas with more retail land uses tend to be near the upper end of the range. However, these counts include people walking as part of trips external to the CBD, i.e., travelling to or from commuting facilities. The true peak of purely internal trips is likely to be considerably higher. In the absence of data, perhaps 20 percent or more would be a reasonable estimate. Because these internal trips during midday are generally split about 50-50 by direction, a reasonable assumption is that about 10 percent of the two-way DPM daily passenger traffic diverted from internal trips occurs in the peak hour in one direction. It can be expected that the link on the system with the maximum load point will be attached to the station with the largest concentration of activities in its vicinity. The location of this is probably best obtained using the more detailed demand estimation techniques in Section 7.

For DPM systems with sizable demand attracted from regional trips to and from the CBD, the peak hour may shift to either the morning or evening. The morning peak hour as a percent of daily CBD cordon entries for 18 fixed guideway systems averages 26.3 percent. For auto travel, peak hour CBD entries generally falls below 10 percent of daily entries, but this peaking factor is somewhat deflated by traffic passing through the CBD. It is reasonable to conclude that the passengers diverted from auto to the DPM will be considerably more peaked because of the greater attraction of the DPM for the all day parker. Twenty percent might be a reasonable estimate. The location of the maximum load point resulting from those entering or leaving the DPM at the fringe in the morning or evening peak hour will obviously occur on one of the links connected to the fringe DPM stations.

This discussion of peak hour capacity at the maximum load point is necessarily crude. More precise link loadings on the system are called for. Nevertheless, a rough notion as to whether line capacity will be a constraint can be gained. Suppose, for example, a DPM attracts only internal trips, say 50,000 daily two-way trips. Twenty percent will occur at a midday hour, or 10,000 in both directions, 5,000 in one direction. Of course, all of these trips will not occur on one link in the system; more precise link loadings will be required to determine that. However, the 5,000 represents an absolute maximum; if a DPM technology comfortably handles that volume per hour in one-direction, it will be sufficient to handle the internal trips.

For DPM systems which must handle many passengers delivered to the CBD's fringe, the analysis follows similarly. Consider a system that attracts 25,000 two-way trips per day from transit at the fringe and the same number from auto at the fringe, in addition to the internal trips. If the half of the 12,500 one-way transit-diverted trips (25,000 two-way) are delivered to each of the two DPM stations, the one-way peak hour load from this component would be some 1650 passengers (12,500 x 0.5 x .263) where 0.263 is the peak hour factor. Similarly, if two DPM fringe parking areas are provided, the auto-diverted component in the peak hour would be some 1250 passengers (12,500 x 0.5 x .20). If the transit and auto passengers are delivered to the same fringe DPM station, these two components can be added giving 2900 passengers in the peak hour in one direction on a link connecting the fringe DPM station. In this example, the internal trip volumes, up to 5,000 one-way in the peak hour, would still be the controlling factor.

Aside from the line capacity constraints, additional constraints may occur if stations are not designed with enough space. For waiting and circulation areas on station platforms, at least 5 square feet per person are recommended. Similarly, standards have been suggested for escalators and stairways. The standard for escalators to avoid queue build-up is 60 persons per minute for the standard 48-inch escalator. If the peaks are very short and only a few consecutive minutes are highly peaked, a 90 persons per minute standard is acceptable. On stairways, the prevention of queues requires less than 6 persons per minutes per foot of stairway width. However, flow rates up to 12 persons per foot per minute are acceptable if no reverse flow exists on the stairway. Station design configurations to meet these standards, while not resulting in intolerable queues or dangerous conditions, await analysis by station simulation techniques.

6.3.3 Testing the System

To compare the threshold criteria with the scale of demand estimated in the aggregate demand analysis the steps are:

1) Decide whether the DPM will be designed to attract regional auto trips and regional transit trips (either deposited at the fringe or delivered to the center of the CBD) in addition to internal CBD trips

2) Decide what proportion of regional trips will be susceptible to DPM diversion. For auto trips this depends on the highway system's configuration and the provision of adequate park-and-ride facilities at fringe DPM stations. For transit trips this depends on the proportion of line-haul transit passengers whose routes are re-aligned to deliver passengers to fringe DPM stations or, in the case of central CBD delivery, what proportion of the passengers are delivered to the center.

3) From Tables 6-17, 18, and 19 determine the number of trips to be diverted based on the assumptions in 1 and 2 above.

4) Multiply each component of trips, regional transit from either Table 6-17 or 18 regional auto from Table 6-19, and internal walk, transit, and auto from Tables 6-20, 21, and 22, respectively, by average trip length, obtaining daily passenger-miles for each component. (The results of this step are shown in Tables 6-23 through 6-28.)

5) Sum the selected passenger_mile components to get total passenger-miles. For example, if only internal trips are to be diverted, the components will be taken from Tables 6-26, 27, and 28.

6) Multiply daily passenger-miles by 283, the ratio of annual to daily passengers, obtaining annual passenger-miles.

7) Divide by 0.233 reflecting the assumption that, on the average over the year, 23.3 percent of places will be occupied by passengers.

8) Divide by the route length in miles to obtain annual place-miles per line-mile.

TABLE 6-23

DAILY PASSENGER-MILES DIVERTED TO DPM ASSUMING 50 PERCENT OF TRANSIT RIDERS DELIVERED TO FRINGE DPM STATIONS FROM REGIONAL CBD TRANSIT TRIPS AS A FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)	CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	63	115	109	115	114	118	n.a	n.a	110	n.a	n.a.	n.a
200	69	37	67	71	76	67	70	n.a	n.a	65	n.a	n.a.	n.a
100	39.5	14	26	27	29	25	26	n.a	n.a	24	n.a.	n.a	n.a.
75	31.5	9	16	17	19	17	17	n.a.	n.a	16	n.a	n.a	n.a
50	22.5	5	9	9	10	9	9	n.a	n.a	8	n.a	n.a	n.a
30	15	1	3	3	3	3	3	n.a.	n.a	3	n.a	n.a	n.a
20	10	1	2	2	2	2	2	n.a.	n.a	2	n.a.	n.a	n.a
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	50	129	135	140	124	122	n.a.	n.a	115	n.a	n.a	n.a
200	69	29	75	79	82	73	72	n.a.	n.a	68	n.a	n.a.	n.a
100	39.5	11	29	30	31	27	27	n.a	n.a	26	n.a	n.a.	n.a
75	31.5	7	18	20	20	18	18	n.a.	n.a.	17	n.a.	n.a.	n.a.
50	22.5	4	10	10	11	10	10	n.a	n.a	9	n.a	n.a.	n.a
30	15	1	3	4	4	3	3	n.a	n.a	3	n.a	n.a	n.a
20	10	1	2	2	2	2	2	n.a	n.a	2	n.a.	n.a	n.a
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	45	87	107	118	110	120	118	121	108	110	n.a.	n.a.
200	69	27	51	63	69	65	70	70	71	63	65	n.a	n.a
100	39.5	10	19	24	26	24	27	26	27	24	24	n.a	n.a
75	31.5	7	13	15	17	16	17	17	17	15	16	n.a.	n.a.
50	22.5	3	6	8	9	8	9	9	10	8	8	n.a.	n.a.
30	15	1	2	3	3	2	3	3	3	3	3	n.a.	n.a.
20	10	--	1	1	2	2	2	2	2	2	2	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	49	109	127	130	116	124	122	119	115	115	n.a	n.a
200	69	29	64	74	76	68	73	72	70	68	68	n.a.	n.a
100	39.5	11	24	28	29	26	28	27	27	25	26	n.a	n.a
75	31.5	7	16	18	19	17	18	18	17	17	17	n.a.	n.a.
50	22.5	4	9	10	10	9	10	10	10	9	9	n.a.	n.a.
30	15	2	3	3	3	3	3	3	3	3	3	n.a.	n.a
20	10	1	1	2	2	2	2	2	2	2	2	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	16	33	43	67	76	110	117	115	112	113	111	110
200	69	10	19	26	39	44	65	69	68	66	66	66	65
100	39.5	4	7	9	15	17	24	26	26	25	25	24	24
75	31.5	3	5	6	10	11	16	17	17	16	16	16	16
50	22.5	1	2	4	6	6	9	9	9	9	8	8	9
30	15	-	1	1	2	2	3	3	3	3	3	3	3
20	10	-	1	1	1	1	2	2	2	2	2	2	2
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	19	47	65	84	90	111	126	124	110	108	106	106
200	69	11	27	38	50	52	65	74	73	66	63	62	62
100	39.5	4	11	14	19	20	25	27	28	24	24	23	23
75	31.5	3	7	10	12	13	16	18	18	16	16	15	15
50	22.5	2	4	5	7	7	9	10	9	8	8	8	8
30	15	1	2	2	2	3	3	3	3	3	3	3	3
20	10	1	1	1	1	1	2	2	2	2	2	2	2

* Assumes a shuttle system where route length = station spacing times number of stations minus one.
n.a. – Not applicable
Note: All Passenger-Miles in thousands
Dash Indicates Less than 500 Passenger-Miles

TABLE 6-24

DAILY PASSENGER-MILES DIVERTED TO DPM ASSUMING TRANSIT RIDERS DELIVERED TO CENTER DPM STATION FROM REGIONAL TRANSIT TRIPS AS A FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,800	2,000	800	1,200	1,600	2,000	800	1,200	1,800	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)	CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	3	25	50	94	38	76	n.a.	n.a.	65	n.a.	n.a.	n.a.
200	60	3	15	30	55	23	44	n.a.	n.a.	39	n.a.	n.a.	n.a.
100	30.5	1	6	11	21	9	17	n.a.	n.a.	15	n.a.	n.a.	n.a.
75	31.5	1	4	7	14	6	11	n.a.	n.a.	10	n.a.	n.a.	n.a.
50	22.5	-	2	4	7	3	6	n.a.	n.a.	5	n.a.	n.a.	n.a.
30	15	-	-	1	3	1	2	n.a.	n.a.	2	n.a.	n.a.	n.a.
20	10	-	-	1	2	1	1	n.a.	n.a.	1	n.a.	n.a.	n.a.
		CBD Area = 0.5 sq. miles, Concnetrated Activity Distribution											
300	96	1	9	24	52	16	35	n.a.	n.a.	36	n.a.	n.a.	n.a.
200	60	1	5	14	31	9	21	n.a.	n.a.	21	n.a.	n.a.	n.a.
100	30.5	-	2	5	12	4	8	n.a.	n.a.	8	n.a.	n.a.	n.a.
75	31.5	-	1	3	8	2	5	n.a.	n.a.	5	n.a.	n.a.	n.a.
50	22.5	-	-	2	4	1	3	n.a.	n.a.	3	n.a.	n.a.	n.a.
30	15	-	-	1	1	-	1	n.a.	n.a.	1	n.a.	n.a.	n.a.
20	10	-	-	-	1	-	1	n.a.	n.a.	-	n.a.	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	4	18	36	60	25	62	112	170	46	89	n.a.	n.a.
200	60	2	10	21	35	15	36	66	100	26	53	n.a.	n.a.
100	30.5	1	4	8	13	6	14	25	38	10	20	n.a.	n.a.
75	31.5	-	3	5	9	4	9	16	24	6	13	n.a.	n.a.
50	22.5	-	1	3	5	2	5	9	13	3	7	n.a.	n.a.
30	15	-	-	1	2	1	2	3	5	1	2	n.a.	n.a.
20	10	-	-	1	1	-	1	2	3	1	2	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	3	12	18	32	9	29	46	114	25	57	n.a.	n.a.
200	60	2	7	11	19	5	17	28	67	15	33	n.a.	n.a.
100	30.5	1	3	4	7	2	6	10	25	6	13	n.a.	n.a.
75	31.5	-	2	3	5	1	4	7	16	4	8	n.a.	n.a.
50	22.5	-	1	2	2	1	2	3	9	2	5	n.a.	n.a.
30	15	-	-	1	1	-	1	1	3	1	2	n.a.	n.a.
20	10	-	-	-	-	-	1	1	2	-	1	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	1	7	18	51	16	47	108	143	39	80	116	200
200	60	-	4	11	30	10	27	64	84	23	47	68	118
100	30.5	-	2	4	11	4	10	24	32	9	18	26	44
75	31.5	-	1	3	7	2	7	16	21	6	11	17	29
50	22.5	-	-	2	4	1	4	9	11	3	6	9	16
30	15	-	-	1	1	-	1	3	4	1	2	3	5
20	10	-	-	-	1	-	1	2	2	1	1	2	3
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	1	7	16	42	11	27	40	74	21	49	77	144
200	60	1	4	9	25	6	16	28	43	12	28	46	84
100	30.5	-	2	3	9	2	6	11	16	5	11	17	32
75	31.5	-	1	2	6	2	4	7	11	3	7	11	21
50	22.5	-	-	1	3	1	2	4	6	2	4	6	11
30	15	-	-	-	1	-	1	1	2	-	1	2	4
20	10	-	-	-	1	-	1	1	1	-	1	1	2

* Assumes a shuttle system where route length = station spacing times number of stations minus one.

n.a.– Not applicable

Note: All Passenger-Miles in thousands

Dash indicates less than 500 Passenger-Miles

TABLE 6-25

DAILY PASSENGER-MILES DIVERTED TO DPM ASSUMING NO FRINGE PARKING CONSTRAINTS, FROM REGIONAL CBD AUTO TRIPS AS A FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	72	72	72	72	77	77	n.a	n.a	89	n.a	n.a	n.a
200	69	65	65	65	65	69	69	n.a	n.a	80	n.a	n.a	n.a
100	39.5	38	41	42	41	35	31	n.a.	n.a	43	n.a	n.a	n.a.
75	31.5	28	31	34	31	28	24	n.a	n.a	33	n.a	n.a	n.a.
50	22.5	17	18	20	19	15	13	n.a.	n.a.	19	n.a	n.a	n.a
30	15	8	8	8	8	6	5	n.a.	n.a	8	n.a	n.a	n.a.
20	10	2	2	1	1	2	1	n.a.	n.a	1	n.a	n.a.	n.a.
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	71	71	71	71	77	78	n.a.	n.a	90	n.a.	n.a	n.a.
200	69	64	64	64	64	68	68	n.a.	n.a.	72	n.a.	n.a.	n.a.
100	39.5	38	40	41	42	32	35	n.a	n.a	35	n.a.	n.a.	n.a
75	31.5	28	32	33	32	26	28	n.a.	n.a.	28	n.a.	n.a.	n.a
50	22.5	16	16	17	15	13	15	n.a.	n.a.	13	n.a.	n.a.	n.a.
30	15	8	7	7	6	6	10	n.a.	n.a.	6	n.a.	n.a.	n.a.
20	10	3	2	2	1	2	1	n.a.	n.a.	2	n.a.	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	34	70	110	160	155	153	155	153	221	181	n.a.	n.a.
200	69	30	62	95	128	128	130	128	123	183	152	n.a	n.a.
100	39.5	17	33	46	60	59	68	57	52	87	70	n.a.	n.a.
75	31.5	13	25	36	43	45	53	40	35	66	53	n.a.	n.a.
50	22.5	7	15	22	25	25	30	21	17	36	26	n.a.	n.a.
30	15	3	7	11	12	6	14	8	6	14	10	n.a.	n.a.
20	10	1	1	2	2	1	1	-	-	2	1	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	42	83	125	164	150	148	150	148	221	181	n.a.	n.a.
200	69	36	66	106	145	120	119	119	117	164	144	n.a.	n.a.
100	39.5	19	34	80	74	57	68	63	62	87	53	n.a.	n.a.
75	31.5	14	25	43	51	43	52	43	40	63	35	n.a.	n.a.
50	22.5	8	14	25	30	31	36	23	18	37	15	n.a.	n.a.
30	15	3	5	7	8	22	17	6	-	15	4	n.a.	n.a.
20	10	1	1	2	1	2	1	-	-	2	1	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	18	34	65	81	88	195	303	365	203	275	433	510
200	69	17	30	49	69	76	162	236	267	159	217	326	389
100	39.5	9	18	25	36	36	74	76	89	66	80	117	108
75	31.5	7	13	19	27	25	52	51	60	45	53	67	58
50	22.5	4	9	11	20	11	23	21	26	23	22	20	19
30	15	1	4	4	8	4	8	6	7	7	5	-	-
20	10	-	1	1	1	1	2	-	-	2	1	-	-
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	26	40	74	101	105	207	265	326	207	275	433	524
200	69	22	44	62	82	82	150	184	214	146	200	306	360
100	39.5	12	20	30	32	38	62	75	86	58	80	130	114
75	31.5	8	15	22	24	27	44	50	56	43	55	94	67
50	22.5	4	7	15	12	13	18	18	19	21	21	42	26
30	15	2	3	6	5	5	4	3	4	6	4	10	4
20	10	1	1	1	1	1	1	-	-	2	1	-	-

* Assumes a shuttle system where route length = station spacing times number of stations minus one.

n.a. – Not applicable

Note: All Passenger-Miles in thousands

Dash indicates less than 500 Passenger-Miles

TABLE 6-26

DAILY PASSENGER-MILES DIVERTED TO DPM FROM INTERNAL CBD WALK TRIPS AS A FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

Number of stations		4				8				12			
Station spacing feet		800	1,200	1,800	2,000	800	1,200	1,800	2,000	800	1,200	1,800	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	21	40	42	20	48	61	n.a.	n.a.	57	n.a.	n.a.	n.a.
200	69	14	33	29	14	30	40	n.a.	n.a.	38	n.a.	n.a.	n.a.
100	39.5	7	16	14	6	15	20	n.a.	n.a.	19	n.a.	n.a.	n.a.
75	31.5	5	12	11	5	11	15	n.a.	n.a.	14	n.a.	n.a.	n.a.
50	22.5	3	7	7	3	7	10	n.a.	n.a.	10	n.a.	n.a.	n.a.
30	15	2	4	4	2	4	6	n.a.	n.a.	5	n.a.	n.a.	n.a.
20	10	1	2	2	1	2	3	n.a.	n.a.	3	n.a.	n.a.	n.a.
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	40	59	53	28	56	69	n.a.	n.a.	64	n.a.	n.a.	n.a.
200	69	25	37	39	23	37	45	n.a.	n.a.	37	n.a.	n.a.	n.a.
100	39.5	14	19	20	13	19	22	n.a.	n.a.	20	n.a.	n.a.	n.a.
75	31.5	10	14	15	9	14	16	n.a.	n.a.	16	n.a.	n.a.	n.a.
50	22.5	7	9	10	6	9	11	n.a.	n.a.	11	n.a.	n.a.	n.a.
30	15	4	5	5	3	5	6	n.a.	n.a.	6	n.a.	n.a.	n.a.
20	10	2	3	2	2	2	3	n.a.	n.a.	3	n.a.	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	7	25	23	7	21	40	47	24	31	54	n.a.	n.a.
200	69	5	13	15	5	6	29	29	14	20	35	n.a.	n.a.
100	39.5	4	7	8	3	7	15	15	6	10	18	n.a.	n.a.
75	31.5	4	6	6	2	5	11	11	5	8	13	n.a.	n.a.
50	22.5	2	4	3	1	3	7	7	3	5	8	n.a.	n.a.
30	15	1	2	2	1	2	4	4	2	3	4	n.a.	n.a.
20	10	1	1	1	-	1	2	2	1	1	2	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	19	22	21	7	20	34	37	22	28	46	n.a.	n.a.
200	69	13	12	13	5	16	25	24	14	16	31	n.a.	n.a.
100	39.5	5	9	10	4	11	16	13	10	13	18	n.a.	n.a.
75	31.5	4	8	9	4	10	13	10	9	12	14	n.a.	n.a.
50	22.5	3	5	6	3	6	8	7	8	8	9	n.a.	n.a.
30	15	2	3	3	2	4	5	4	3	4	5	n.a.	n.a.
20	10	1	2	1	1	2	2	2	2	2	3	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	4	10	11	4	17	31	29	13	19	46	38	15
200	69	2	7	8	3	6	18	20	8	12	29	29	10
100	39.5	1	4	4	1	4	10	11	4	7	15	14	5
75	31.5	1	3	3	1	3	7	7	3	5	11	11	4
50	22.5	1	2	2	1	2	5	6	2	3	7	7	2
30	15	-	1	1	-	1	3	3	1	2	4	4	1
20	10	-	1	1	-	-	1	1	-	1	2	2	1
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	10	23	21	11	25	44	40	26	38	56	48	26
200	69	8	17	16	7	15	29	28	16	25	46	34	18
100	39.5	4	8	8	3	8	13	13	8	14	20	16	10
75	31.5	3	6	6	3	5	10	10	6	10	13	11	6
50	22.5	2	3	3	2	4	7	7	4	7	9	8	4
30	15	1	2	2	1	2	4	4	2	4	5	4	2
20	10	-	1	1	-	1	2	2	1	2	2	2	2

* Assumes a shuttle system where route length = station spacing times number of stations minus one.

n.a. – Not applicable

Notes: All Passenger-Miles in thousands

Dash indicates less than 500 Passenger-Miles

TABLE 6-27

DAILY PASSENGER-MILES DIVERTED TO DPM FROM INTERNAL TRANSIT TRIPS AS A FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

	Number of stations	4				8				12			
	Station spacing, feet	800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
	Route length, feet*	2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,000	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	4	5	6	6	10	10	n.a	n.a	16	n.a	n.a	n.a
200	69	2	2	2	3	4	5	n.a.	n.a	7	n.a.	n.a	n.a
100	39.5	2	2	2	2	4	5	n.a.	n.a.	6	n.a.	n.a	n.a.
75	31.5	2	2	2	2	4	5	n.a	n.a	6	n.a	n.a	n.a
50	22.5	1	2	2	2	3	4	n.a	n.a	6	n.a.	n.a	n.a
30	15	1	1	1	1	2	3	n.a.	n.a	4	n.a.	n.a	n.a
20	10		-	-	-	-	-	n.a	n.a	-	n.a	n.a.	n.a
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	9	10	11	11	17	18	n.a.	n.a.	22	n.a	n.a.	n.a.
200	69	4	4	4	5	8	8	n.a	n.a	10	n.a.	n.a	n.a
100	39.5	1	2	2	2	3	3	n.a	n.a	4	n.a.	n.a	n.a
75	31.5	1	1	1	1	2	2	n.a.	n.a	2	n.a	n.a	n.a.
50	22.5	1	1	1	1	1	1	n.a.	n.a	2	n.a	n.a.	n.a.
30	15	-	1	1	1	1	1	n.a.	n.a.	1	n.a.	n.a.	n.a.
20	10		-	-	-	-	-	n.a	n.a	-	n.a	n.a	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	2	4	4	4	6	8	8	8	10	13	n.a.	n.a.
200	69	1	1	1	1	2	3	3	4	4	5	n.a	n.a.
100	39.5	1	1	1	1	1	1	1	1	1	2	n.a.	n.a.
75	31.5	-	-	-	-	1	1	1	1	1	1	n.a.	n.a.
50	22.5	-	-	-	-	1	1	1	1	1	1	n.a	n.a.
30	15	-	-	-	-	-	-	-		-	-	n.a.	n.a.
20	10	-	-	-	-	-	-	-		-	-	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	6	8	8	8	13	15	15	17	19	24	n.a.	n.a.
200	69	3	3	3	4	5	6	6	7	8	10	n.a.	n.a.
100	39.5	1	1	1	1	2	2	2	3	3	4	n.a.	n.a.
75	31.5	1	1	1	1	1	1	1	1	1	2	n.a.	n.a
50	22.5	1	1	1	1	1	1	1	1	1	1	n.a.	n.a.
30	15	-	-	-	-	-	-	-	1	1	1	n.a.	n.a.
20	10	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	2	3	3	3	5	8	8	8	10	13	14	15
200	69	1	1	1	1	2	2	3	3	4	5	5	5
100	39.5	-	-	-	-	1	1	1	1	1	2	2	2
75	31.5	-	-	-	-	-	1	1	1	1	1	1	1
50	22.5	-	-	-	-	-	-	-	-	-	-	1	1
30	15	-	-	-	-	-	-	-	-	-	-	-	-
20	10	-	-	-						-	-	-	-
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	7	8	8	8	12	18	18	18	21	26	27	28
200	69	2	3	3	3	5	6	6	7	8	10	11	11
100	39.5	1	1	1	1	2	2	2	3	3	4	4	4
75	31.5	1	1	1	1	1	1	1	1	2	2	2	2
50	22.5	-	-	-	-	1	1	1	1	1	1	1	1
30	15	-	-	-	-	-	-	-	1	1	1	1	1
20	10	-	-	-	-	-	-	-	-	-	-	-	-

* Assumes a shuttle system where route length = station spacing times number of stations minus one.

n.a. – Not applicable

Dash indicates less than 500 Passenger-Miles

Note: All Passenger-Miles in thousands

TABLE 6-28

DAILY PASSENGER-MILES DIVERTED TO DPM FROM INTERNAL CBD AUTO TRIPS AS A FUNCTION OF AMOUNT AND DISTRIBUTION OF CBD ACTIVITIES, CBD SIZE, NUMBER OF STATIONS AND STATION SPACING

Number of stations		4				8				12			
Station spacing, feet		800	1,200	1,600	2,000	800	1,200	1,600	2,000	800	1,200	1,600	2,000
Route length, feet*		2,400	3,600	4,800	6,000	5,600	8,400	11,200	14,000	8,800	13,200	17,600	22,000
CBD Employ. (000's)	CBD Floorsp. (mil.sq.ft.)												
		CBD Area = 0.5 sq. miles, Spread Activity Distribution											
300	96	2	3	3	3	5	6	n.a.	n.a.	9	n.a.	n.a.	n.a.
200	69	2	2	2	2	4	4	n.a.	n.a.	6	n.a.	n.a.	n.a.
100	39.5	1	1	1	1	2	2	n.a.	n.a.	3	n.a.	n.a.	n.a.
75	31.5	1	1	1	1	2	2	n.a.	n.a.	2	n.a.	n.a.	n.a.
50	22.5	-	-	-	-	1	1	n.a.	n.a.	1	n.a.	n.a.	n.a.
30	15	-	-	-	-	1	1	n.a.	n.a.	1	n.a.	n.a.	n.a.
20	10	-	-	-	-	-	-	n.a.	n.a.	-	n.a.	n.a.	n.a.
		CBD Area = 0.5 sq. miles, Concentrated Activity Distribution											
300	96	5	5	6	6	9	10	n.a.	n.a.	12	n.a.	n.a.	n.a.
200	69	4	4	4	5	7	8	n.a.	n.a.	10	n.a.	n.a.	n.a.
100	39.5	2	2	2	3	4	4	n.a.	n.a.	4	n.a.	n.a.	n.a.
75	31.5	2	2	2	2	3	3	n.a.	n.a.	3	n.a.	n.a.	n.a.
50	22.5	1	1	1	2	2	2	n.a.	n.a.	2	n.a.	n.a.	n.a.
30	15	1	1	1	1	1	1	n.a.	n.a.	1	n.a.	n.a.	n.a.
20	10	-	-	-	-	-	-	n.a.	n.a.	1	n.a.	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Spread Activity Distribution											
300	96	1	1	1	1	4	4	4	4	6	7	n.a.	n.a.
200	69	1	1	1	1	2	3	3	4	4	5	n.a.	n.a.
100	39.5	-	-	-	-	1	1	1	1	2	1	n.a.	n.a.
75	31.5	-	-	-	-	1	1	1	1	1	1	n.a.	n.a.
50	22.5	-	-	-	-	-	1	1	1	1	1	n.a.	n.a.
30	15	-	-	-	-	-	-	-	-	1	1	n.a.	n.a.
20	10	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
		CBD Area = 1.0 sq. miles, Concentrated Activity Distribution											
300	96	3	4	4	4	6	8	8	8	10	13	n.a.	n.a.
200	69	2	2	3	4	5	6	6	6	7	10	n.a.	n.a.
100	39.5	1	1	1	1	2	3	3	3	4	4	n.a.	n.a.
75	31.5	1	1	1	1	1	2	2	2	2	2	n.a.	n.a.
50	22.5	1	1	1	1	1	1	1	1	1	1	n.a.	n.a.
30	15	-	-	-	-	1	1	1	1	1	1	n.a.	n.a.
20	10	-	-	-	-	-	-	-	-	-	-	n.a.	n.a.
		CBD Area = 1.5 sq. miles, Spread Activity Distribution											
300	96	1	1	1	1	2	4	5	6	5	7	8	8
200	69	1	1	1	1	1	2	3	3	4	5	5	5
100	39.5	-	-	-	-	-	1	1	1	2	2	2	2
75	31.5	-	-	-	-	-	1	1	1	1	1	1	1
50	22.5	-	-	-	-	-	1	1	1	1	1	1	1
30	15	-	-	-	-	-	-	-	-	-	-	-	-
20	10	-	-	-	-	-	-	-	-	-	-	-	-
		CBD Area = 1.5 sq. miles, Concentrated Activity Distribution											
300	96	2	3	3	3	5	9	9	9	10	13	14	14
200	69	1	1	1	2	4	5	6	6	7	8	8	8
100	39.5	-	-	1	-	2	2	2	2	2	3	3	3
75	31.5	-	-	1	-	1	1	1	1	1	2	2	2
50	22.5	-	-	1	-	1	1	1	1	1	1	1	1
30	15	-	-	-	-	-	-	-	-	-	1	1	1
20	10	-	-	-	-	-	-	-	-	-	-	-	-

* Assumes a shuttle system where route length = station spacing times number of stations minus one.

n.a. — Not applicable

Note: All Passenger-Miles in thousands

Dash indicates less than 500 Passenger-Miles

9) Compare to threshold criteria.

These steps have been carried out for the complete array of CBD activities, CBD area (0.5, 1.0 and 1.5 square miles), both spread and concentrated CBDs, and 12 station spacing-number of stations combinations. The calculated daily passenger-miles estimates (Tables 6-23 through 6-28), correspond to the six trip components, in Tables 6-17 through 6-22. These exhibits can be used to obtain the average trip length used in calculating passenger-miles by dividing the estimate of daily trips for any one component of DPM demand into the estimate of daily passenger-miles for the corresponding component.

This process can be carried out for any combination of assumptions about the groups of travellers susceptible to DPM diversion. For purposes of illustration three such options will be pursued here. Option A assumes that only internal CBD trips will be diverted. (This is the sum of the trips from Tables 6-20, 21, and 22.) Option B includes all the trips from Option A plus the diversion from 25 percent of the regional transit trips delivered to the fringe and from 25 percent of the regional auto trips delivered to the fringe. Option C includes all the trips from Option A plus the diversion from 25 percent of the regional auto trips and from 100 percent of the regional transit trips delivered to the CBD center. As described, Option A represents a minimum condition of sorts, while B and C represent conditions closer to maximum, B probably for a bus oriented, and C for a rapid transit oriented regional transit system.

In Figure 6-13 sets of curves of annual place-miles per line-mile versus CBD nonresidential floorspace are shown for each of these options. For simplicity of presentation, for each CBD area and activity distribution combination, only the system combination (spacing and number of stations) that produces the highest annual place-miles per line-mile is shown for each of the three options.* The array of threshold criteria are shown by a series of horizontal lines. For the labor thresholds, value lines for one and three-mile systems are given.

Figure 6-13 suggests that DPM's <u>attracting only internal trips</u> (Option A) will exceed all criteria in CBD's of 60 to 100 million square feet (msf) of non-residential floorspace and confined to an area of 1/2 square mile. For CBD's of about one square mile all criteria would be exceeded only if non-residential floorspace approached 100 msf. If the CBD were not subject to snow conditions all criteria would be exceeded for smaller CBDs; 40 msf would be sufficient if the CBD areas were smaller (0.5 sq. miles), 80 to 100 msf if the CBD were larger

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*Often other station spacing-number of station combinations have annual place-miles per line-mile almost as high. To obtain these, the reader must convert the sum of the daily passenger-miles components obtained by converting the selected combinations to annual place-miles per line-mile, as described.

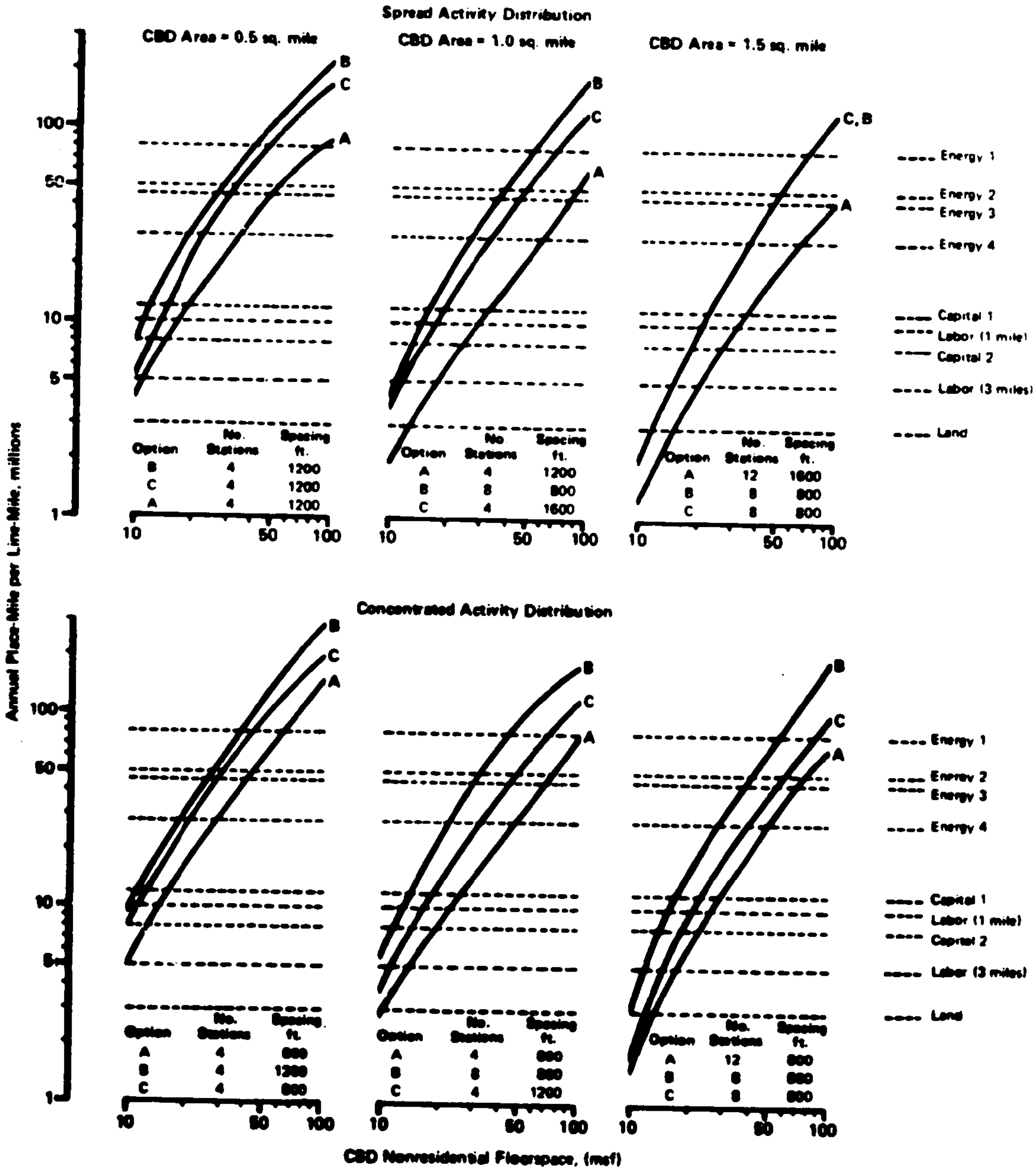

FIGURE 6-13

PEOPLEMOVER DEMAND AND THRESHOLD CRITERIA AS A FUNCTION OF CENTRAL BUSINESS DISTRICT CHARACTERISTICS

(1.5 sq. miles). Totally ignoring any energy criteria, 20 msf might be enough for CBDS of small area, 35 to 40 msf, for a large sized CBD.

The inclusion of substantial numbers of regional trips (Options B and C) would broaden the range of possible DPM applications exceeding all criteria; 40 msf would be enough to exceed all criteria in a small-area CBD; 80 msf would be required in a large one. In snowy climates all criteria would be exceeded for CBDS in the 25 to 40 msf range, the upper end for CBDs of large area (1.5 sq. miles). Removal of snow as a criterion would expand the range of DPM possibilities still further to as little as 15 msf for CBDs of 0.5 sq. miles and 20 msf for CBDs of 1.5 sq. miles.

From the viewpoint of the local planner, the proper way to view this exhibit is to examine the set of curves that most closely describes his CBD. For example, if the CBD is approximately one square mile in area, with 20 million square feet of nonresidential activities rather evenly spread, then if it is designed as an internal circulator only it will exceed only the land savings criterion, and possibly the labor criterion. The optimum but not necessarily the only system (among those examined) that would accomplish this would be one of 4 stations and 1200 foot station spacing. Redesigning to attract 25 percent of the regional CBD transit and auto traffic would push DPM demand above all the capital, labor and land criteria, but the DPM would still fall short of saving energy. The optimum DPM system then would have 8 stations and 800 foot station spacing.

Similarly, an 80 million square foot, 1.5 square mile, spread CBD would clear all but the energy threshold if only internal trips (Option A) were handled. Twelve stations, 1600 feet apart would be optimum. Structured to capture a substantial portion of regional trips (Options B or C), the energy criteria would be exceeded also, even if snow melting were required.

It should be re-emphasized that exercises such as these should be performed only for the purpose of yielding general implications of design options and not for decision-making or justification purposes.