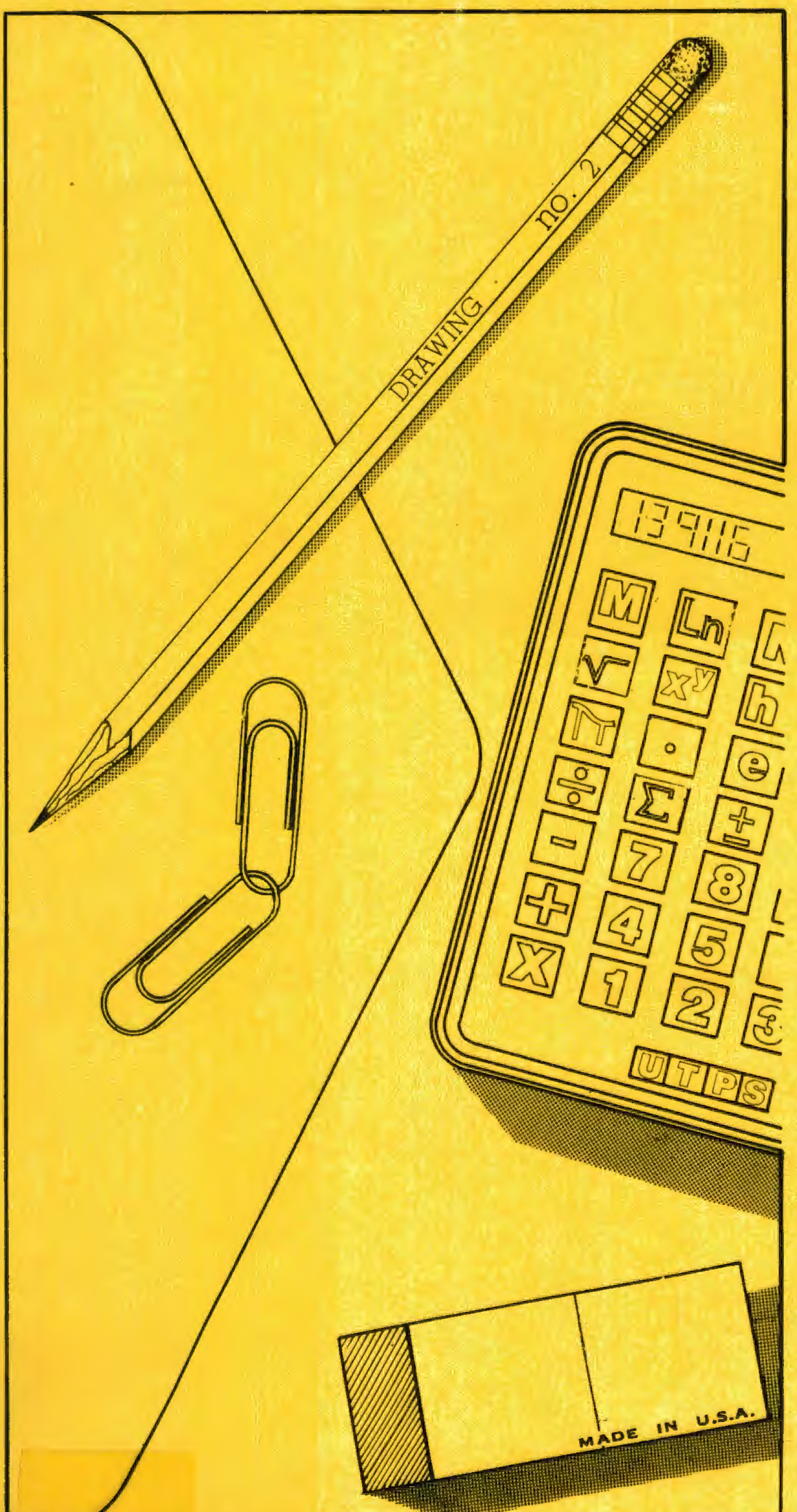

simplified aids for transportation analysis

estimating parking accumulation

Jeff Carpenter

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16. Abstract

The analytical aid described in this report provides a method for estimating the accumulation of parked vehicles within a study area over the course of a typical weekday. Parking accumulation and utilization of parking facilities may be estimated for all parkers, long-term parkers, and/or short-term parkers, based on an estimate of daily automobile trip destinations, an inventory of available parking supply, and a set of parking "accumulation factors" (which may be derived from a parking survey within the study area or from default values provided in this report).

The primary use of the parking accumulation estimation method is to analyze the adequacy of available parking supply in relation to expected parking demand. The method may also be used to monitor and suggest revisions to automobile travel impedance values used in transportation planning models.

Modifications, embellishments, and improvements to the procedures suggested in this report are encouraged should local data or previous analyses suggest a more appropriate method.

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SIMPLIFIED AIDS FOR TRANSPORTATION ANALYSIS

Methodology for Estimating Parking Accumulation

Prepared by

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1025 Conn. Ave., N.W. Washington D.C. 20036

JANUARY 1979

Prepared for

U.S. Department of Transportation
Urban Mass Transportation Administration
Office of Planning Methods and Support

FOREWORD

Today's transportation planner confronts ever-changing issues within a variety of work environments. To assist him, UMTA's Planning Methods and Support Program researches, develops and distributes planning aids, including novel planning studies, and new design and forecasting techniques.

This is one of a series of six reports describing simplified aids to improve transportation decisions without resorting to computers or extensive data collection. The series, titled Simplified Aids for Transportation Analysis, presently includes the following titles:

1. Annotated Bibliography (UMTA-IT-06-9020-79-1)

2. Forecasting Auto Availability and Travel (UMTA-IT-06-9020-79-2)

3. Estimating Ridership and Cost (UMTA-IT-06-9020-79-3)

4. Transit Route Evaluation (UMTA-IT-06-9020-79-4)

5. Estimating Parking Accumulation (UMTA-IT-06-9020-79-5)

6. Fringe Parking Site Requirements (UMTA-IT-06-9020-79-6)

All are the work of recognized experts. They clearly present usable planning concepts, and add to the growing set of manual and computerized techniques comprising the UMTA/FHWA Urban Transportation Planning System (UTPS).

More important than the production and dissemination of new tools is the experience and opinion of their user. Local issues change. Better methods evolve. Or, realistically errors may appear in the final product. We depend on you, the transportation planner, to alert us to any of the above. We need your comments and your ideas. Please let us hear them, so we can continually improve our products.

You may obtain copies of any of the above reports from the National Technical Information Service (NTIS), Springfield, VA, 22161. On your request, please include the reference number in parenthesis.

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Washington, DC 20590

ABSTRACT

In January 1976, the U.S. Department of Transportation issued a Technical Notice (DOT-1-76) requesting transportation planners, engineers, and transit operators to submit useful but not widely known manual techniques that could be developed and distributed as simplified aids for transportation analysis. Over 70 analytical aids were submitted in response to this request.

Based on an evaluation process conducted to determine the most useful, easily applied, and generally applicable techniques, several of these analytical aids have been selected and documented in sufficient detail to permit their immediate use. In addition to these techniques, three additional analyttical aids were developed as part of the Short-Range Transportation Planning project, and an annotated bibliography of each analytical aids reviewed was prepared. These individual analytical aids and the annotated bibliography have been prepared as separate reports and have been brought together in this manual of simplified aids for transportation analysis.

The analytical aid described in this report provides a method for estimating the accumulation of parked vehicles within a study area over the course of a typical weekday. Parking accumulation and utilization of parking facilities may be estimated for all parkers, long-term parkers, and/or short-term parkers, based on an estimate of daily automobile trip destinations, an inventory of available parking supply, and a set of parking "accumulation factors" (which may be derived from a parking survey within the study area or from default values provided in this report).

The primary use of the parking accumulation estimation method is to analyze the adequacy of available parking supply in relation to expected parking demand. The method may also be used to monitor and suggest revisions to automobile travel impedance values used in transportation planning models.

Modifications, embellishments, and improvements to the procedures suggested in this report are encouraged should local data or previous analyses suggest a more appropriate method.

SOURCE

Peat, Marwick, Mitchell & Co., 1025 Connecticut Avenue, N.W., Washington, D.C. 20036

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I. INTRODUCTION

This report describes one of a collection of useful but not widely known manual techniques employed by local transportation planners, engineers, and transit operators. The technique presented in this report provides a method for estimating the demand for and utilization of parking facilities, within a local area, over the course of a typical weekday. This technique permits the analyst to identify the parking space requirements necessary to accommodate estimated parking demand. The information provided in this report, which is sufficient to permit the immediate use of the analytical aid, is presented in five sections and an appendix:

- I. Introduction. This section describes the analytical aid and its applicability as a simplified aid for transportation analysis, provides an overview of the application procedure, identifies the data and information required to use the aid, and illustrates the analysis output.

- II. Data and Information Needed. This section provides a detailed description of the data and information required to use the analytical aid and identifies the most likely data sources.

- III. Using the Parking Accumulation Estimation Method. This section describes the step-by-step procedures for calculating parking accumulation, determining the utilization of existing or planned parking facilities, and estimating the required new or additional parking spaces.

- IV. Application Example. This section illustrates the analysis procedure with a hypothetical case study.

- V. Shortcomings and Limitations. This section describes the method's shortcomings to make the user aware of the limits of its applicability.

- Appendix. The Appendix describes the derivation of the accumulation factors presented in this report. The analyst can use the accumulation factors shown in this Appendix or can use the derivation method directly to develop locally applicable accumulation factors.

The technique reported here is oriented to the practical planner who requires a specific analytical technique but who has limited data and time to perform an in-depth analysis. The soundness of the method described in this report, however, must be considered independently by the potential user for each specific application. The section on shortcomings and limitations is provided to assist the potential user in making this assessment. Modifications, embellishments, and improvements to this technique are encouraged should local data or past analyses suggest a more appropriate procedure.

DESCRIPTION AND APPLICABILITY

The technique presented in this report was developed by Peat, Marwick, Mitchell & Co. (PMM&Co.), based on data collected from parking surveys conducted in the Bethesda and Silver Spring, Maryland, central business districts (CBDs).[1] Its basic output is an estimate of the accumulation of parked cars within a study area for each time period during the day. Accumulation can be estimated for shortterm parkers, long-term parkers, or all parkers in the study area.[2]

This analysis output has two important uses. Its primary use is to assess the utilization of the existing parking system and to indicate the need for additional capacity for each type of parker (long-term and short-term). The output can also be used to monitor and suggest revisions to impedance values used in locally calibrated travel demand forecasting models. Both of these applications are explained below in more detail.

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[1]See Recommended Capital Improvement Program for the Bethesda Parking Lot District and Recommended Capital Improvement Program for the Silver Spring Parking Lot District, prepared for Montgomery County Department of Transportation, Division of Parking, by Peat, Marwick, Mitchell & Co. (July 1976).

[2]Parking facilities are typically designed to accommodate short-term parkers only, long-term parkers only, or a specific proportion of each group. Parking accumulation in an area of interest for a given time period is measured as the number of parked cars present at the end of the previous period plus the cars entering the area in the current period minus the cars leaving in the current period. The area of interest may be a single parking facility, a group of facilities, a traffic analysis or transportation planning zone, a group of such zones, or an entire study area. For the methodology presented in this report, the area of interest is an entire local study area.

The technique may be applied to any study area for which the necessary input data are available. Typical study areas include urban CBDs of any size, suburban CBDs, regional business districts, or neighborhood business districts.

CHARACTERISTICS OF PARKING FACILITY USAGE

Before considering the specific applications of this analytical aid, the user must be aware of certain characteristics of parking facility usage which influence parking demand and facility utilization. These characteristics are summarized below.

Relation Between Parking Demand and Facility Utilization

The estimated number of daily automobile trip-ends in a particular study area equals the total number of parkers requiring vehicle storage in a day. However, because parkers arrive and depart at different times of day and parking spaces may, therefore, be used by more than one parker, the number of parkers requiring space does not equal the number of required spaces. The required number of spaces is determined by estimating parker accumulation over the course of the day.

Stratification of Parkers

Parkers in a study area may be stratified into groups according to ex pected arrival and departure times and duration of stay.

Long-term parkers typically include drivers making a work trip and, therefore, parking for a duration of at least eight hours on the majority of weekdays. Since parking prices are normally directly related to duration, price becomes an important factor in the parking location choice for these parkers. While all parkers will attempt to minimize the walking distance between parking location and destination, long-term parkers will trade longer walks for lower parking costs.

Short-term parkers, on the other hand, are generally drivers making trips for shopping, personal business, or a medical or dental appointment. Typical parking durations for these trip purposes range from 15 minutes to three hours. For short-term parkers, the price of parking has less influence on the parking location choice because of the small amount of money involved and the infrequency of the trips. The short-term parker will generally consider alternative destinations before tolerating a walk of more than two or three blocks from parking location to destination.

Because each type of parking demand is important, parking space needs are frequently estimated for each type as well as for the total. Accordingly, the method described in this report provides a total estimate of space requirements over the course of a typical weekday for each type of parker.

Practical Capacity

The practical capacity of the parking system is different from the total supply of parking spaces within a study area for two reasons:

- time is wasted in parking and unparking maneuvers as the available supply of spaces approaches zero; and
- parkers do not have complete knowledge of space availability (in particular, a parker may not be aware that a space is available under conditions where most spaces are occupied).

Furthermore, parkers who must circulate repeatedly through an area to find find a parking space may become discouraged and choose to conduct their business in locations where adequate parking is available. For these reasons, "practical capacity" is normally defined as 85 percent of the available supply of parking spaces.[1]

The preparation of this analytical aid was based on the consideration of each of these characteristics of parking facility usage. The use of this method in parking analysis is described below.

USE OF THE METHOD'S OUTPUT

The parking accumulation estimation output can be used in two ways. In each application, the method represents one element in a complete transportation planning process. In the first application, the process is conducted at a micro-level of analysis; in the second, it is conducted at a macro-level.

The Method as an Element in Micro-Level Analysis

At the micro-level of analysis, the parking accumulation estimation method can be used as a substitute for the traditional parking study approach that is normally used to determine the performance of the existing parking

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[1]Parking Principles, Special Report 125, Highway Research Board, Washington, D.C., 1971.

system.[1] The traditional approach requires an inventory of existing parking demand and supply in the study area, generally involving extensive field survey procedures. Based on this inventory, an evaluation and description is prepared of the level of service being provided parkers by the parking system. Such measures as average walking distance by trip purpose, parking facility cost schedules (including redemption programs), access/egress times for selected parking facilities, and utilization of the available parking capacity are used to define a systemwide level of performance. Parker attraction rates[2] (or similar measures of parking demand) are used to project future space needs on a block or zonal basis, from relations developed as part of the overall parking study. The projection of these space needs identifies probable future parking capacity deficiencies (total, short-term, and long-term parking) within the study area. This information is then used to formulate a parking system operating policy and a multi-year capital improvement program designed to upgrade the efficiency and effectiveness of parking service in the area.

Virtually the same level of analysis can be conducted for small study areas (e.g., small urban area CBDs, suburban area CBDs, and neighborhood business districts) at minimal cost and effort using only the parking accumulation estimation method.

The Method as an Element in Macro-Level Analysis

Parking analysis is sometimes included at a macro-level in areawide transportation planning analysis for an urban area. The parking analysis in these areawide studies usually does not provide a detailed assessment of the area's parking system and future parking capacity requirements. Broader, multi-modal transportation planning issues are the central concern of these studies, not the details of parking facility site selection and design. However, parking analysis can be included to ensure that, in future years, there is a balance between the capacity of the highways on which automobiles travel to a particular activity center and the parking space available at that activity center.

Parking analysis can be used to influence the urban transportation process in two ways. First, certain characteristics of the parking system (such as parking charges and walking distances) contribute to the overall level of

[1]A comprehensive traditional parking study approach is described in detail in the Manual of Traffic Engineering Studies, 4th Edition, Institute of Transportation Engineers, Arlington, Virginia, 1976, Chapter 10, "Parking Studies."

[2]For example, parkers attracted to a commercial area at a rate of x parkers per 1,000 square feet of commercial floor space.

travel impedance or disutility associated with using the automobile as a mode of transportation to a particular destination or zone. The higher the parking charges and the longer the walking distances from the parking facility to the destination, the greater the travel impedance associated with automobile use. Similarly, the absence of parking charges or long walking distances can influence the attractiveness of the automobile in relation to other modes.

Second, the treatment of parking capacity can affect the ability of urban transportation planning models to estimate travel patterns accurately; particularly significant is the manner in which available parking space represents a constraint on the ability of the roadway network to convey automobiles to a particular destination. The transportation modeling process typically assumes some measure of capacity restraint on the highway network, but none on the facilities where vehicles must be stored. Forecasts of travel demand, particularly the modal split estimates, are not accurate unless parking supply is considered as a capacity constraint on automobile travel. Parking supply may also impose a capacity constraint on transit usage, as in the case of park and ride lots for line haul transit service.

Within the urban transportation planning process, the analysis of the parking system should logically follow trip generation, trip distribution, modal split, and other travel forecasting steps, but should precede the traffic assignment element of the process. To complete the trip generation, trip distribution, and modal split sequences of the process, the analyst must initially assume certain values of travel impedance for each mode being examined. These travel impedance values should include the "costs" or disutilities (such as parking cost, walking distance, parking and unparking time) that are attributable to the terminal portion of the trip. It has not been common practice, however, for the analyst to review the model's results following these travel forecasting steps and to determine if the travel impedances initially assumed produced realistic projections of automobile driver trip-ends to particular destination zones (realistic in relation to the corresponding parking supply for that location). The parking accumulation estimation method provides a means of comparing the parking supply to the parking demand associated with projected travel demand to a destination (measured in terms of the number of automobile driver trip-ends to the destination). If the available parking supply for a set of destination zones is then found to be insufficient to meet the projected demand for parking, the analyst has two options:

- to assume an increased parking supply to accommodate the projected automobile driver trip-ends; or
- to assume that the parking supply will not be increased and estimate the increased travel impedance represented by the parking capacity constraint.

Increasing the impedance for auto travel because of a parking capacity constraint could shift the automobile driver to other modes of transportation (such as public transit and automobile passenger), to other destinations, or to foregoing some trips entirely. Increasing the travel impedances because of this condition would most likely result in a more accurate travel simulation and, in turn, a better evaluation of future transportation facility needs.

ANALYSIS OUTPUT

The outputs of the parking accumulation estimation method include a temporal profile of the maximum accumulation of parkers[1] within a study area over the course of a typical weekday.

From these accumulations, the practical capacity required to service the demand can be determined. Knowing the available supply of spaces, the net or incremental parking space needs can be defined and/ or the performance of the existing parking supply can be determined.

Finally, a set of parking accumulation curves, as shown in Figure 1, can be prepared. Note the following outputs illustrated in this figure:

- Maximum accumulation of total, long-term, and short-term parking is the maximum point on the respective curves.
- Maximum accumulation is adjusted by the "practical capacity adjustment factor" (0.85) to obtain a total practical capacity space requirement.
- "Net practical capacity requirements" are equal to the difference between total practical capacity space requirements and parking supply for each type of parking.[2] Practical capacity space requirements equal zero if the parking supply exceeds the adjusted maximum accumulation.

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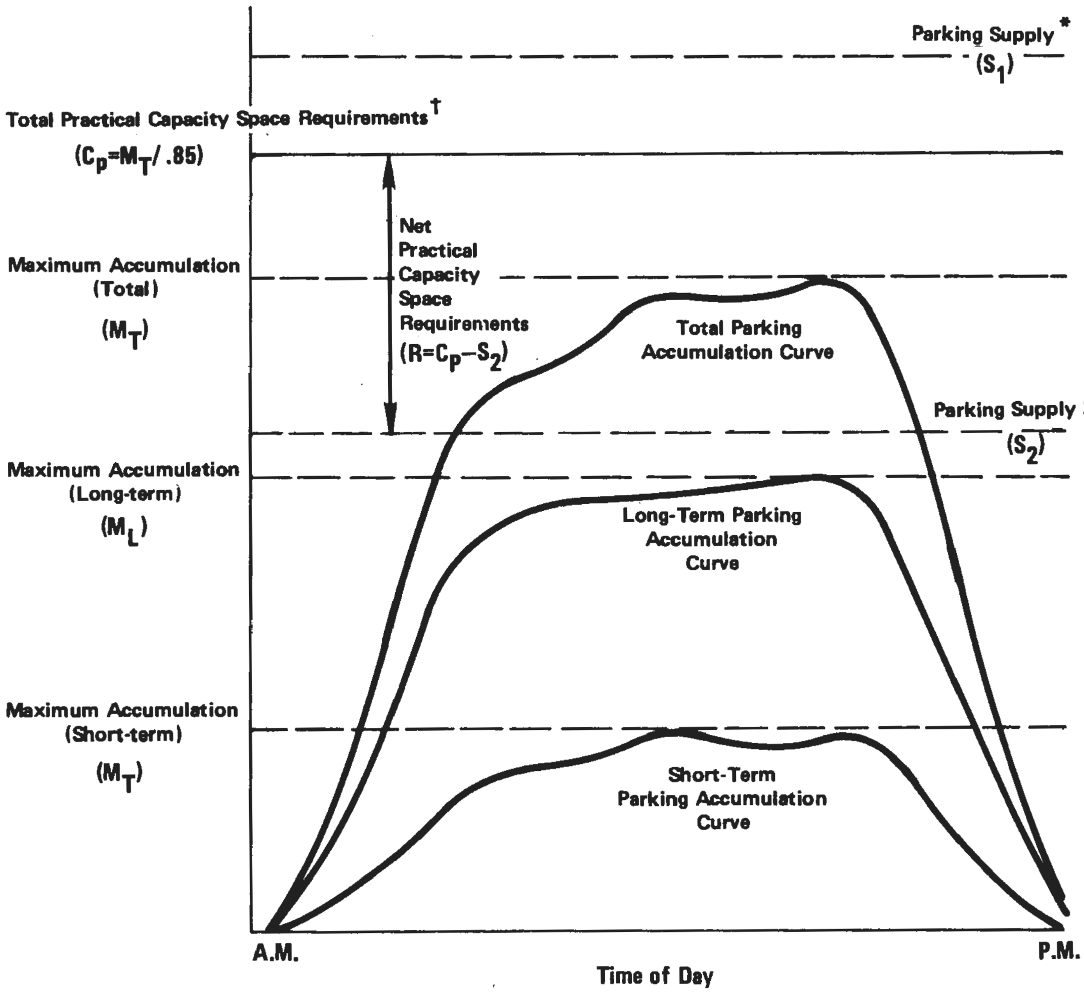
[1]Total for all parkers and subtotals for long-term and short-term parkers.

[2]Figure 1 shows only total practical capacity and total practical capacity requirements. The respective capacities and space requirements can also be developed for long-term and short-term parking.



* If parking supply for study area is as shown by "Parking Supply 1" line, and total parking accumulation is as shown by "Total" curve, parking supply is underutilized.

** If parking supply for study area is as shown by "Parking Supply 2" line and total parking accumulation is as shown by "Total" curve, parking supply is inadequate or inefficiently used.

† Total Practical Capacity Space Requirements = Maximum Accumulation ÷ .85.

FIGURE 1: PARKING ACCUMULATION METHOD OUTPUT

each time period by adding the appropriate column entries for each time period (i.e., calculate total for each row). As a rule, the accumulation of work-trip parkers will provide a rough estimate of the demand for long-term parking spaces, and accumulation of the non-work-trip parkers will provide a rough estimate of the demand for short-term spaces. Enter the individual row totals on the worksheet in the appropriate column, as follows:

- For long-term parking accumulation, no addition is necessary; Column 2 represents long-term parkers accumulated for each time period.
- For short-term parking accumulation, add the entries in Columns 4, 6, and 8 for each time period; enter the results in Column 9.
- For total parking accumulation, add the entries in Columns 2 and 9 for each time period; enter the results in Column 10.

STEP 5: DETERMINE MAXIMUM ACCUMULATION OF PARKERS

Examine the parker accumulations for each type in Columns 10, 2, and 9, respectively, and determine the maximum number of parkers present in any single time period (i.e., row) for each type of parker. This figure represents the maximum accumulation of parkers for the study area for each type of parker.

STEP 6: ADJUST MAXIMUM ACCUMULATION TO DETERMINE PRACTICAL CAPACITY SPACE REQUIREMENTS

Divide each maximum accumulation of parkers determined in Step 5 by the appropriate practical capacity factor to adjust for the practical capacity of the parking supply. This figure indicates the total number of parking spaces which are required to accommodate each type of anticipated parking demand.

STEP 7: COMPARE PRACTICAL CAPACITY SPACE REQUIREMENTS AND AVAILABLE PARKING SUPPLY

Compare the practical capacity requirements developed in Step 6 with the corresponding parking supply to determine which of the following conditions exists:

- The parking supply can accommodate the estimated parking demand, but it does not significantly exceed practical capacity space requirements; no further adjustments or actions are required. For a transportation planning application, auto travel impedances need not be modified.
- The parking supply cannot accommodate the estimated parking demand, and thus either parking capacity must be increased or disincentives must be imposed on the use of the automobile. For transportation planning applications, this condition indicates that auto travel impedance values have been underestimated and should be increased.
- The parking supply can accommodate the estimated demand, and parking capacity is significantly underutilized. For transportation planning applications, auto travel impedances need not be modified.

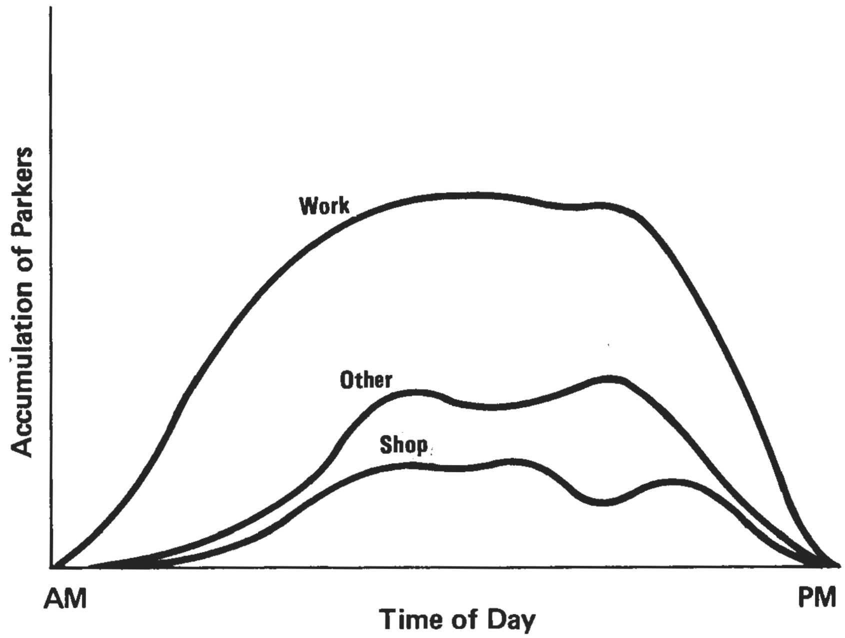
STEP 8: PLOT PARKING ACCUMULATION CURVES AS REQUIRED

Construct parking accumulation curves by plotting the estimated accumulations for various time periods over the course of a day. Possible accumulation curves are listed in Table 2. These curves can be constructed by plotting the points in the columns indicated in the table. They will result in graphs such as those illustrated in Figure 3.

TABLE 2

LIST OF PARKING ACCUMULATION CURVES

PARKING ACCUMULATION CURVE	SOURCE OF DATA (COLUMN NUMBER ON PARKER ACCUMULATION WORKSHEET-TABLE 1)
TOTAL:	
Total Parkers	10
BY PARKER DURATION:	
Long-Term Parkers	2
Short-Term Parkers	9
BY TRIP PURPOSE:	
Work-Trip Parkers	2
Shop-Trip Parkers	4
Other Parkers	6+8



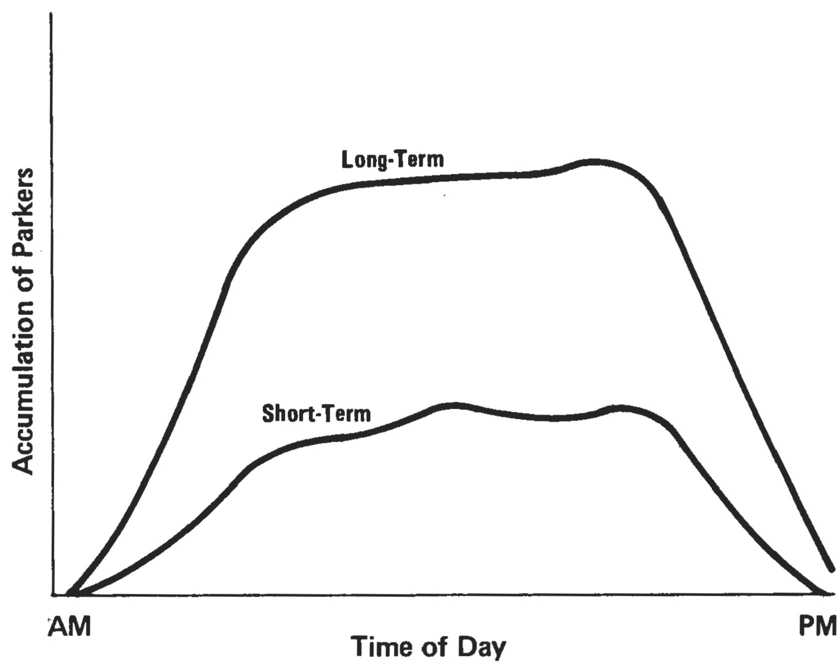


FIGURE 3: ILLUSTRATIVE PARKING ACCUMULATION CURVES

IV. EXAMPLE APPLICATION

This section illustrates the parker accumulation analysis procedure with a hypothetical case study. The case study illustrates the analysis of parking facility requirements for a small urbanized area central business district with eight CBD traffic zones. Each step in the parker accumulation analysis procedure is detailed below for this hypothetical example.

STEP 1: DEVELOP PARKING DEMAND AND PARKING SUPPLY INPUT AND PREPARE PARKING ACCUMULATION WORKSHEET (See Table 3).

Automobile driver trip-ends to CBD zones have been estimated by trip purpose as follows:

TRIP-PURPOSE	TRIP-ENDS	
	Number	Percent
Home-Based Work	840	21
Home-Based Shop	1,600	40
Home-Based Other	760	19
Non-Home-Based	800	20
Total	4,000	100

Enter number of automobile driver trip-ends in appropriate column, line A of parking accumulation worksheet (See Table 3).

Supply Inputs

On-Street Parking Spaces:	475	Long-term	740
Off-Street Parking Spaces:	625	Short-term	360
Total	1,100	Total	1,100

Enter accumulation factors on worksheet (factors derived in Appendix used).

STEP 2: ADJUST FOR DAYTIME TRAVEL (7:00 AM to 6:00 PM)

Enter daytime-to-total daily travel proportions on worksheet (line B) for each trip purpose; use 0.70 for all trip purposes.

Multiply automobile driver trip destinations (line A) times daytime-to-daily travel proportion (line B) for each trip purpose. Enter result in line C (See Table 3).

TABLE 3

PARKING ACCUMULATION WORKSHEET, EXAMPLE APPLICATION

	HOME-BASED WORK		HOME-BASED SHOP		HOME-BASED OTHER		NON-HOME-BASED		SHORT-TERM PARKERS ACCUMULATED col. 4 + col. 6 + col. 8	TOTAL PARKERS ACCUMULATED col. 2 + col. 9
A. Daily Study Area Auto Trip Destinations	840		1600		760		800			
B. Daytime/Total Daily Travel Proportions	.70		.70		.70		.70			
C. Daytime Study Area Auto Trip Destinations	588		1120		532		560			
TIME PERIOD	Accumulation Factor (1)	Parkers Accumulated (Long-Term Parkers) (2)	Accumulation Factor (3)	Parkers Accumulated (4)	Accumulation Factor (5)	Parkers Accumulated (6)	Accumulation Factor (7)	Parkers Accumulated (8)	(9)	(10)
1	(.728)	428	(.041)	46	(.121)	64	(.098)	55	165	593
2	(.754)	443	(.067)	75	(.131)	70	(.112)	63	208	651
3	(.752)	442	(.073)	82	(.122)	65	(.108)	60	207	649
4	(.754)	443	(.125)	140	(.136)	72	(.132)	74	286	729
5	(.746)	439	(.103)	115	(.159)	85	(.142)	80	280	719
6	(.754)	443	(.109)	122	(.195)	104	(.170)	95	321	764
7	(.778)	457	(.113)	127	(.193)	103	(.170)	95	325	782
8	(.762)	448	(.132)	148	(.175)	93	(.163)	91	332	780
9	(.762)	448	(.154)	172	(.179)	95	(.171)	96	363	811
10	(.788)	463	(.183)	205	(.173)	92	(.175)	98	395	858
11	(.765)	450	(.145)	162	(.147)	78	(.146)	82	322	772
12	(.750)	441	(.133)	149	(.160)	85	(.152)	85	319	760
13	(.736)	433	(.103)	115	(.149)	79	(.136)	76	270	703
14	0	0	0	0	0	0	0	0	0	0

STEP 3: STRATIFY AUTO DRIVER TRIP-ENDS BY TIME PERIOD

Multiply daytime auto driver trip destinations (line C) by each accumulation factor. Enter result in appropriate row and column as shown:

TIME PERIOD	Trips (Line B)	Accumulation Factor (Column 1)	Parkers Accumulated in Period (Column 2)
1	588	0.728	428
2	588	0.754	443
3	588	0.752	442
.	.	.	.
.	.	.	.
.	.	.	.

STEP 4: DETERMINE PARKING ACCUMULATION BY TIME PERIOD

TIME PERIOD	Home-Based Work (Column 2)	Home-Based Shop (Column 4)	Home-Based Other (Column 6)	Non-Home Based (Column 8)	Short-term Parkers Accumulated (Column 9) col.4+col.6 + col. 8	Total (Column 10) col. 2 + col. 4 + col. 6 + col. 8
1	428	46	64	55	165	593
2	443	75	70	63	208	651
3	442	82	65	60	207	649
.	.	.	.	.	.	.
.	.	.	.	.	.	.
.	.	.	.	.	.	.

The completed example is shown in Table 3.

STEP 5: DETERMINE MAXIMUM ACCUMULATION OF PARKERS BY TYPE

Search each accumulation column to determine maximums, as follows (See Table 3):

PARKING TYPE	MAXIMUM ACCUMULATION	TIME PERIOD
Total (Column 10)	858	10
Long-term parkers (Column 2)	463	10
Short-term parkers (Column 9)	395	10

STEP 6: ADJUST MAXIMUM ACCUMULATION TO DETERMINE PRACTICAL CAPACITY REQUIREMENTS

PARKING TYPE	MAXIMUM ACCUMU-LATION	PRACTICAL CAPACITY FACTOR	PRACTICAL CAPACITY REQUIREMENTS
Total	858	0.85	1009
Long-term	463	0.85	545
Short-term	395	0.85	465

STEP 7: COMPARE PRACTICAL CAPACITY REQUIREMENTS AND PARKING SUPPLY

Total:

$$\frac{\text{Total Practical Capacity Requirements}}{\text{Total Parking Supply}} = \frac{1{,}009}{1{,}100} = \text{95\% Utilization of Practical Capacity}$$

Long term:

$$\frac{\text{Long-term practical capacity requirements}}{\text{Long-term parking supply}} = \frac{545}{740} = \text{74\% Utilization of Practical Capacity}$$

Short-term:

$$\frac{\text{Short-term practical capacity requirements}}{\text{Short-term parking supply}} = \frac{465}{360} = \text{129\% Utilization of Practical Capacity}$$

Conclusion: Total parking capacity appears adequate to accommodate total projected demand. However, the proportion between short- and long-term available parking supply does not match the proportion between short- and long-term demand. Since long-term parking supply is just sufficient to accommodate long-term demand, the recommendation should be to increase short-term parking supply by at least 105 spaces to accommodate short-term demand.

STEP 8: PLOT PARKING ACCUMULATION CURVES AS REQUIRED

Accumulation curves (see Figure 4) for:

. Total Study Area Parking Demand (Column 10);
. Long-term Parking Demand (equals home-based work trips, Column 2);
. Short-term Parking Demand (equals home-based shop trips + other home-based trips + non-home-based trips, Column 9).

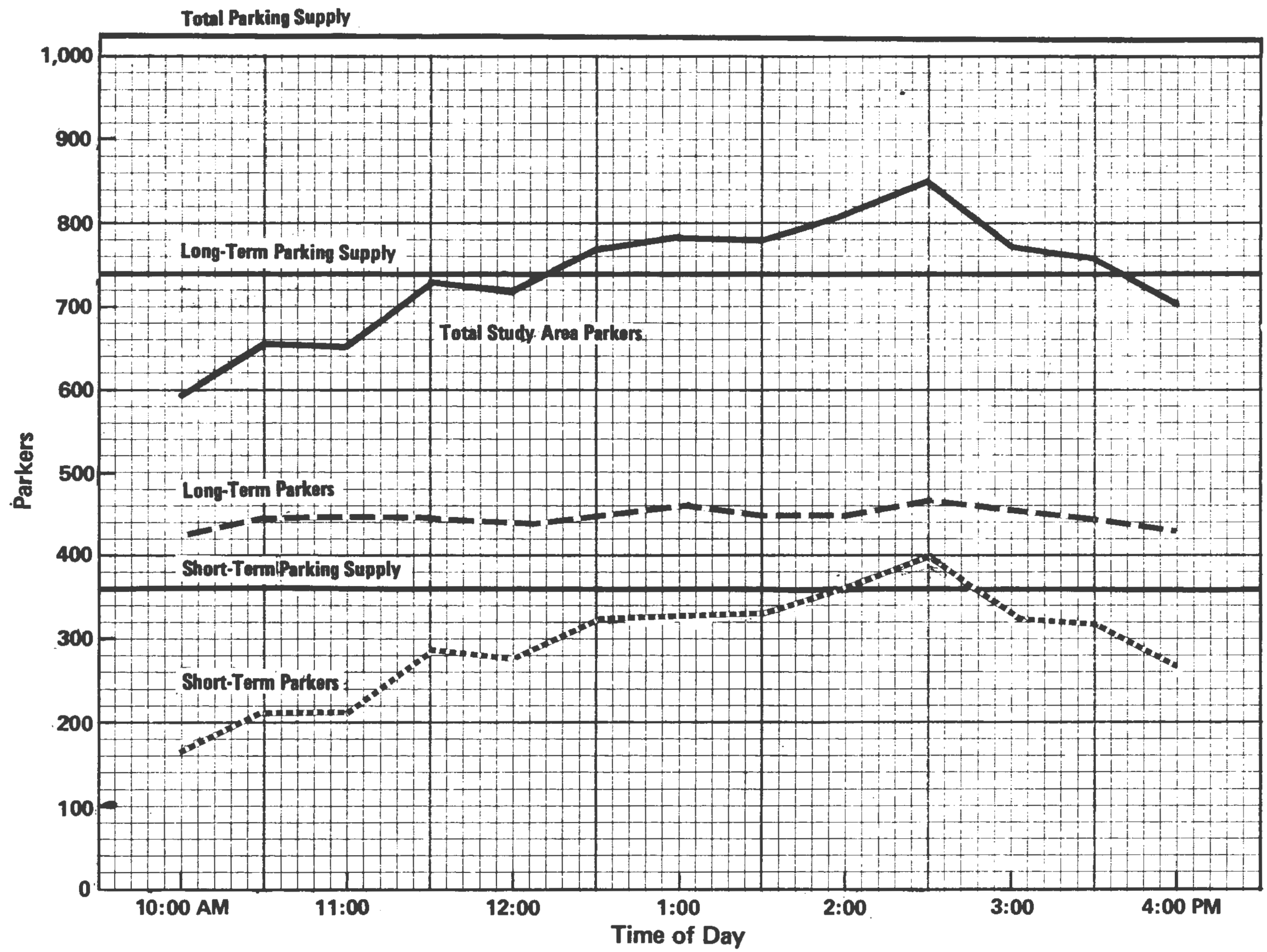


FIGURE 4: PARKING ACCUMULATION CURVES FOR EXAMPLE

V. SHORTCOMINGS AND LIMITATIONS

This section outlines the shortcomings of the parking accumulation estimation method to make the user aware of the limits of the method's applicability. The technique presented is generally applicable in any study area. However, the reliability of the results is clearly dependent on the reliability of the input data. The limitations associated with specific input data items are described below.

PARKING DEMAND INPUT

The number of automobile driver trip-ends is the most critical input data item. The demand input data may be derived from a number of possible data sources. The reliability of this data is a function of the sophistication and validity of the modeling procedure used to produce it, the reliability of the input to the modeling procedure, and the age of the data itself.

PARKING SUPPLY INPUT

Parking accumulation estimation, itself, does not require parking supply input data. However, policy decisions are often based on estimates of parking space requirements calculated by comparing estimated parking demand with available parking supply. These policy decisions can be made wisely only if the parking supply inventory is reliable. The total space inventory is the most important parking supply item. Frequently, this inventory does not differentiate between short-term and long-term parking; in many cases therefore estimates must be used to determine space availability for types of parkers. Policy decisions based on such information must be made recognizing that the actual short-term and long-term parking supply inventory could vary significantly from these estimates.

ACCUMULATION FACTORS

The development and use of locally derived parking accumulation factors is recommended, where possible. Although the parking arrival and departure time matrices and consequent accumulation factors provided in this report appear to be reasonably general, their transferability to another study area cannot be assured.

OTHER FACTORS

The practical capacity factor and daytime-to-total daily travel ratios could possibly vary from city to city. The factors suggested in this report have been observed in data from more than one location and may be considered applicable for most applications.[1]

IMPACT OF PARKING LOT PLACEMENT AND RATE STRUCTURES

This estimation method allows the analyst to assess the overall performance of a parking system with little regard to the spatial distribution of parking facilities in relation to major travel generators or with little consideration of the impacts of different price structures on parking facility usage. A a first step in a site analysis for parking space needs, this technique may be used. A more detailed analysis of parking needs will however most likely require a more comprehensive technique, incorporating the variables of price, spatial distribution, and capacity on parking space choice. The analyst is referred in these cases to more detailed procedures for performing a parking systems analysis.[2]

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[1] Parking in the City Center, Wilbur Smith and Associates, New Haven Connecticut, May 1965.

[2] A Guide to Parking Systems Analysis, prepared for U.S. Department of Transportation, Federal Highway Administration, prepared by Peat, Marwick, Mitchell & Co., October 1972.

APPENDIX

DEVELOPMENT OF PARKING ACCUMULATION FACTORS

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DEVELOPMENT OF PARKING ACCUMULATION FACTORS

This appendix describes the data source and procedure used to develop the accumulation factors provided in this analytical aid.

DATA SOURCE

The data used to develop the parking accumulation factors were collected from parker surveys conducted in the Bethesda and Silver Spring, Maryland, CBDs. These surveys were a principal work element in the Comprehensive Systems Analysis of the Bethesda and Silver Spring Parking Lot Districts (studies undertaken by Peat, Marwick, Mitchell & Co. for the Montgomery County Division of Parking[1,2]). Surveys were conducted between October 1974 and January 1975, although questionnaires were not distributed during peak holiday shopping periods at Thanksgiving and Christmas or on days of inclement weather.

The parker surveys involved the distribution of mail-back postcard questionnaires on the windshields of vehicles parked within each study area. The postcards were filled out and mailed back to the Division of Parking by each parker. A total of 22,297 and 19,676 questionnaires were distributed in the Silver Spring and Bethesda study areas, respectively. In Silver Spring, 17 percent (3,795 forms) of the questionnaires were returned; 19 percent (3,790 forms) of the questionnaires distributed in Bethesda were returned.

All publicly owned (i.e., Montgomery County Division of Parking) and privately owned on-street and off-street parking was surveyed in each study area (excluding new and used car lots and off-street parking facilities available solely for the use of residents of each area [i.e., those facilities operated by apartments and/or condominiums for use of their residents]). Residential parking facilities were excluded from

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<u>Recommended Capital Improvement Program for the Silver Spring Parking Lot District</u>, prepared for the Montgomery County Department of Transportation, Division of Parking by Peat, Marwick, Mitchell & Co., July 1976.

<u>Recommended Capital Improvement Program for the Bethesda Parking Lot District</u>, prepared for the Montgomery County Department of Transportation, Division of Parking by Peat, Marwick, Mitchell & Co., July 1976.

the parking survey because parking in these facilities is restricted to residents and parking in these facilities generally peaks during non-work hours rather than during the normal peak parking accumulation periods for public and commercial parking facilities.

At short-term parking facilities, parker survey forms were distributed at least once each hour. To minimize the number of parkers not counted and sampled, surveys were performed every half-hour at those short-term facilities where a high turnover rate had been observed in the past. In the long-term parking facilities (where turnover during the day is generally low), parker survey forms were distributed only at 9:30 a.m., 1:30 p.m., and 4:30 p.m.

CALCULATION OF ACCUMULATION FACTOR

The accumulation factors presented on the Parker Accumulation Worksheet represent the proportion of the total daytime automobile trip-ends that accumulated within each time period (i.e., the proportion that arrived within the study area up to and including a particular time period and departed in a subsequent time period). These factors were calculated from an arrival time/departure time matrix prepared for each of the four trip purposes in the Montgomery County parker survey (see Figure A-1).

The arrival time/departure time matrix displays the proportional distribution of parkers for each trip purpose by arrival time and departure time. Each entry (or cell) of the matrix indicates the proportion of parkers within each trip purpose group arriving in Period i and departing in Period j. To generate the arrival time/departure time matrices, the parker survey data were stratified into 14 arrival time/departure time periods as follows:

- Period 1 = 7:00 a.m. to 10:00 a.m.
- Period 2 = 10:00 a.m. to 10:30 a.m.
- Period 3 = 10:30 a.m. to 11:00 a.m.
- Period 4 = 11:00 a.m. to 11:30 a.m.
- Period 5 = 11:30 a.m. to 12:00 noon
- Period 6 = 12:00 noon to 12:30 p.m.
- Period 7 = 12:30 p.m. to 1:00 p.m.

Trip Purpose Categories	Arrival Period	Departure Period													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Home-Based Work	1	.0165	.0109	.0072	.0145	.0096	.0162	.0110	.0148	.0072	.0071	.0089	.0146	.0126	.5931
	2		.0006	.0006	.0026	.0005	.0034	–	.0021	.0002	.0034	.0002	.0043	.0007	.0168
	3			–	.0003	.0005	–	–	.0004	–	.0011	.0003	.0011	.0005	.0020
	4				–	–	.0040	–	.0013	–	.0011	–	.0037	.0004	.0057
	5					–	.0012	.0014	.0003	.0007	–	–	–	–	.0024
	6						–	.0011	.0026	.0009	.0022	.0017	–	.0007	.0200
	7							–	.0006	–	–	.0049	.0064	.0003	.0125
	8								.0003	.0003	.0012	.0004	.0032	.0004	.0138
	9									–	.0005	.0018	.0009	.0005	.0052
	10										.0011	.0012	.0022	.0003	.0219
	11											.0006	–	–	.0137
	12												.0023	.0059	.0152
	13													.0004	.0088
	14														.0307
Home-Based Shop	1	.0251	.0108	.0060	.0067	.0082	–	.0006	.0005	.0021	–	–	–	–	.0058
	2		.0049	.0135	.0134	.0037	.0058	.0002	–	–	–	–	–	–	–
	3			.0072	.0105	.0094	.0036	.0002	.0015	.0011	–	–	–	–	–
	4				.0127	.0284	.0207	.0088	.0071	.0030	.0102	.0018	.0018	–	–
	5					.0164	.0092	.0110	–	.0011	–	.0059	.0014	–	–
	6						.0093	.0119	.0198	.0063	.0046	.0008	.0019	–	–
	7							.0094	.0157	.0065	.0012	.0079	.0012	.0012	.0022
	8								.0241	.0240	.0235	.0114	.0040	–	.0009
	9									.0045	.0192	.0306	.0041	.0074	.0053
	10										.0093	.0386	.0321	.0078	.0092
	11											–	.0279	.0177	.0129
	12												.0162	.0240	.0381
	13													.0221	.0290
	14														.1759
Home-Based Other	1	.0484	.0280	.0235	.0191	.0110	.0038	.0025	.0036	.0006	.0011	.0023	.0010	.0012	.0236
	2		.0050	.0113	.0126	.0059	.0032	.0002	.0016	–	.0006	.0007	.0010	.0005	.0004
	3			.0030	.0091	.0067	.0039	.0033	.0006	.0013	–	–	.0002	–	.0005
	4				.0058	.0150	.0137	.0096	.0072	.0023	.0011	–	.0020	.0010	.0023
	5					.0075	.0260	.0166	.0056	.0056	.0026	.0008	.0023	–	.0021
	6						.0014	.0211	.0313	.0186	.0097	.0012	.0011	.0022	.0021
	7							.0030	.0166	.0129	.0040	.0095	.0040	–	.0042
	8								.0096	.0072	.0241	.0115	.0037	.0003	.0018
	9									.0017	.0147	.0202	.0033	.0048	.0088
	10										.0182	.0161	.0200	.0027	.0131
	11											.0056	.0087	.0134	.0146
	12												.0102	.0158	.0447
	13													.0074	.0308
	14														.1547
Non-Home-Based	1	.0418	.0231	.0185	.0156	.0102	.0027	.0019	.0027	.0011	.0008	.0016	.0007	.0008	.0185
	2		.0050	.0119	.0128	.0048	.0040	.0002	.0011	–	.0004	.0005	.0007	.0004	.0003
	3			.0042	.0095	.0075	.0038	.0024	.0009	.0012	–	–	.0001	–	.0003
	4				.0078	.0188	.0157	.0094	.0072	.0025	.0037	.0005	.0019	.0007	.0016
	5					.0100	.0212	.0150	.0040	.0043	.0018	.0022	.0021	–	.0015
	6						.0036	.0184	.0281	.0151	.0083	.0011	.0013	.0016	.0015
	7							.0048	.0163	.0111	.0032	.0091	.0032	.0003	.0036
	8								.0137	.0120	.0239	.0115	.0038	.0002	.0016
	9									.0025	.0159	.0232	.0035	.0056	.0078
	10										.0157	.0225	.0234	.0041	.0120
	11											.0040	.0142	.0147	.0141
	12												.0119	.0181	.0428
	13													.0116	.0303
	14														.1607

FIGURE A-1: BETHESDA-SILVER SPRING ARRIVAL-DEPARTURE PATTERN SUMMARY PROPORTION

- Period 8 = 1:00 p.m. to 1:30 p.m.
- Period 9 = 1:30 p.m. to 2:00 p.m.
- Period 10 = 2:00 p.m. to 2:30 p.m.
- Period 11 = 2:30 p.m. to 3:00 p.m.
- Period 12 = 3:00 p.m. to 3:30 p.m.
- Period 13 = 3:30 p.m. to 4:00 p.m.
- Period 14 = 4:00 p.m. to 6:00 p.m.

Of the home-based work-trip parkers, for example, approximately 59.31 percent arrived between 7:00 a.m. and 10:00 a.m. and departed between 4:00 p.m. and 6:00 p.m. (i.e., arrived in Period 1 and departed in Period 14). Similarly, approximately 3.07 percent of the home-based work-trip parkers arrived between 4:00 p.m. and 6:00 p.m. (Period 14) and departed between 4:00 p.m. and 6:00 p.m. (Period 14).

An accumulation factor for each of the 14 time periods was calculated on the basis of the sum of the proportion of parkers present at the beginning of the time period (who had arrived in a previous time period), plus the proportion of parkers arriving in that time period, minus the proportion of parkers departing within that time period. Mathematically, this may be stated as follows:

$$A_{kp} = \sum_{i=1}^{k-1} \sum_{j=k}^{N} P_{ijp} + \sum_{j=k}^{N} P_{kjp} - \sum_{i=1}^{k} P_{ikp} \qquad (1)$$

where:

A_{kp} = accumulation factor for parkers at end of period k for trip purpose p.

P_{ijp} = proportion of parkers arriving in period i and leaving in period j for trip purpose p.

N = highest time period index (14 for this example).

This is equivalent to the following alternative formulation:

$$A_{kp} = \sum_{i=1}^{k} \sum_{j=k+1}^{N} P_{ijp} \qquad (2)$$

The following example illustrates this calculation mathematically and graphically. Using the home-based work table in Figure A-1, the accumulation factor for time period 5 may be calculated according to Equation 1 as follows:

K = 5
p = home based work trips (HBW)
N = 14

A =	.0096 + .0162 + .0110 + .0149		
	+ .0072 + .0071 + .0089 + .0146	1st term	
	+ .0126 + .5931 + .0005 + .0034		i = 1; j = 5, 6, . . . 14
			i = 2; j = 5, 6, . . . 14
			i = 3; j = 5, 6, . . . 14
	+ 0 + .0021 + .0002 + .0034		i = 4; j = 5, 6, . . . 14
	+ .0003 + .0043 + .0007 + .0188		
	+ .0005 + 0 + 0 + .0004 + 0		
	+ .0011 + .0003 + .0011		
	+ .0005 + .0020 + 0 + .0040		
	+ 0 + .0013 + 0 + .0011 + 0		
	+ .0037 + .0004 + .0057		
	+ 0 + .0012 + .0014 + .0003	2nd term	
	+ .0007 + 0 + 0 + 0 + 0 + .0024		i = 5; j = 5, 6, . . . 14
	- (.0096 + .0005 + .0005	3rd term	
	+ 0 + 0)		i = 1, 2, 3, 4, 5; j = 5
=	.6952 + .0337 + .0059 + .0162	1st term	
	+ .0060	2nd term	
	- .0106	3rd term	
=	.7470 + .0060 - .0106		
=	.7464		

This estimate is illustrated by the shaded area in Figure A-1.

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