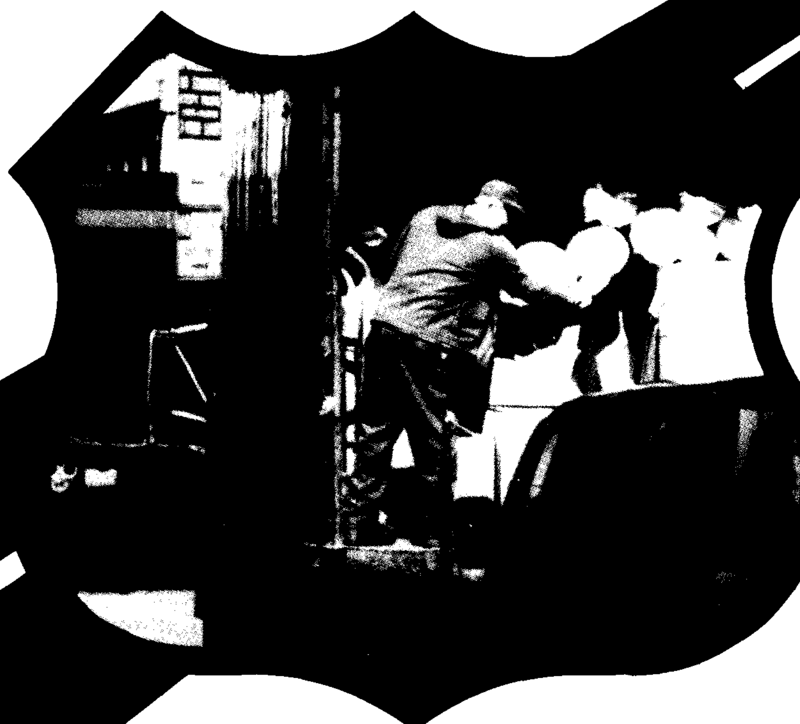
PB81225914

Report No. FHWA/RD-80/020

CURBSIDE PICKUP AND DELIVERY OPERATIONS AND ARTERIAL TRAFFIC IMPACTS

February 1981
Final Report



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Prepared for
FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Traffic Systems Division
Washington, D.C. 20590

FOREWORD

This report describes the results and conclusions from the observation of more than 12,000 pickups and deliveries that were made from curbside (excluding pickups and deliveries that were made directly to loading docks). This research was conducted by the Polytechnic Institute of New York under contract DOT-FH-11-9373 to the Federal Highway Administration.

The purpose of the research was to determine what characteristics of the pickup and delivery process cause the most traffic impacts and to propose strategies for ameliorating those impacts.

The results indicate that the number of trips generated, the amount of space marked for loading, and the location on the blockface are among the critical elements. Restaurants tend to generate the most truck trips and locations near the downstream stopline have the most sensitive traffic impacts. A restaurant near the stopline with little loading space can be expected to have pronounced adverse effect on traffic flow. Tables are provided for the amount of loading space which must be provided in order to achieve given levels of traffic service and six strategies are proposed for the amelioration of traffic impacts due to the shipment of goods.

Sufficient copies of the report are being distributed by FHWA Bulletin to provide a minimum of two copies to each FHWA regional office, one copy to each FHWA division office and two copies to each State highway agency. Direct distribution is being made to the Division offices.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

NOTICE

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/RD-80/020		PB81 225914

4. Title and Subtitle	5. Report Date / 6. Performing Organization Code
Curbside Pickup and Delivery Operations and Arterial Traffic Impacts	February 1981
7. Author(s): Philip A. Habib	8. Performing Organization Report No.
9. Performing Organization Name and Address: Transportation Training & Research Center, Polytechnic Institute of New York, 333 Jay Street, Brooklyn, N.Y. 11201	10. Work Unit No. (TRAIS): FCP 32K5-012; 11. Contract or Grant No.: DOT-FH-11-9373
12. Sponsoring Agency Name and Address: Federal Highway Administration	13. Type of Report and Period Covered: Final Report; 14. Sponsoring Agency Code: T-0389

15. Supplementary Notes

Contract Manager: Dr. Paul Ross, FHWA, HRS-31

16. Abstract

This report presents an analysis of curbside pickups and deliveries (PUD) of freight in urban areas. Portions of six cities-San Francisco, Boston, St. Paul, Oklahoma City, Dallas, Phoenix-were studied as part of this effort. Data was collected on the characteristics of the PUD trip, the parking of the vehicle, the type and size of the generator and the impact that double parking has on arterial traffic performance.

Analysis was conducted to develop tools to predict PUD demand, parking patterns and resultant traffic impact under families of conditions. These tools were used to test various traffic engineering strategies to improve arterial-traffic performance. Level of service was used as this performance measure.

The final chapter recommends the most practical strategies for demonstration. These strategies include improved management of curbspace utilization, improved signing and striping, signal-timing adjustments and enforcement.

17. Key Words	18. Distribution Statement
Urban Goods Movement, Trucks, Freight, Capacity, Level of Service, Traffic	This 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		

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

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EXECUTIVE SUMMARY

The distribution of freight in urban areas is done almost exclusively by vehicles using the road system. These vehicles vary from large tractor-trailers handling unit loads to bicycles handling documents.

The principal 'zones' of goods-movement activity in the urban area are: (1) the central business district (CBD), (2) the industrial/warehousing district and (3) the terminal (and port) district. Although the amount of total freight moved outside of the CBD is usually greater than that of the CBD, the high level of competition for space between people and goods movements in the CBD makes that district the most sensitive to congestion-causing conflicts.

The purpose of this study is to develop the tools necessary to better quantify the relationships between curbside pickup and delivery (PUD) of freight and surface traffic measures of effectiveness, and, to use these tools to evaluate alternate strategies for reducing congestion-causing conflicts on the road system.

DATA COLLECTION METHODS

The data necessary to quantify PUD demand, parking patterns and traffic impact of curbside PUD operations was collected from various cities nationwide. The study was limited to six 'typical' cities of over 250,000 population. The data collected (over 12,000 trips) was for on-street PUD operations at typical blocks in the downtown, fringe and residential areas of the various cities.

SURVEY CITIES CHARACTERISTICS

City	1970 Population (1000)	Density	Economic* Function	Part of Megalopolis	Port Facilities
Boston	641	High	Balanced	Yes	Yes
Dallas	844	Low	Manufacturing	No	No
Oklahoma City	367	Low	Balanced	No	No
Phoenix	581	Low	Balanced	No	No
San Francisco	716	High	Consuming	Yes	Yes
St. Paul	310	Medium	Manufacturing	Twin Cities	Minor

*Represents the proportion of total employment in manufacturing.

Curbside PUD Operations

Data on each pickup and delivery trip was recorded by field personnel directly observing the curbside operation. This data included: time of vehicle arrival, dwell time, shipment characteristics and parking characteristics. In addition, field personnel also recorded the characteristics of the establishments (land use, size, em-

U. S. DEPARTMENT OF TRANSPORTATION

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SUBJECT FHWA/RD-80/020, "CURBSIDE PICKUP AND DELIVERY OPERATIONS AND ARTERIAL TRAFFIC IMPACTS"	FHWA BULLETIN

Distributed with this Bulletin is the subject Research and Development report intended for traffic engineers and researchers in urban goods movement. This is the complete report of a research study conducted by the Polytechnic Institute of New York in six United States cities.

Data were collected on more than 12,000 pickups and deliveries that were made from the curb (excluding pickups and deliveries made directly to loading docks). Twenty-six different types of businesses were observed but the results indicated that segregation into only six classes is adequate. The report gives the number and duration of trips, as a function of the type and size of each establishment and the number of pieces and weight of shipment for each trip. Regression equations predict the amount of traffic blockage on each block as a function of traffic engineering variables. Tables are given which indicate how much loading space must be provided in order to achieve given levels of traffic service. Finally, six traffic engineering strategies are proposed for reducing the impacts of pickups and deliveries on traffic flow.

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ployment) and parking regulations and enforcement on each blockface. The survey was predominantly conducted in the downtown area of each city. However, residential, light industry and warehousing land uses were surveyed in the fringes as well as outlying residential zones.

Data on each establishment were used as variables in PUD generation equations. Employment was collected for all land uses except residential, office buildings and hotels. Floor area was collected for all generators except residential and hotels, for which the number of units (dwelling or rental) was hypothesized to be the best independent variable for generation.

Each site (establishment, building), with the exception of some special generators, was observed for a period of five days, from Monday through Friday. Daily coverage, using the full crew, extended from before 8 AM to after 4 PM, as dictated by the goods movement activity.

San Francisco was selected as the pilot city on which to test the various survey methods. This pilot study was conducted in March of 1978 to test the various survey methods. In September 1978 the main data collection effort began in Boston, and then St. Paul, Oklahoma City, Dallas and Phoenix followed in succession. The field effort was concluded in early December 1978.

DISTRIBUTION OF PUD SAMPLES BY CITY

City (Survey dates)	Number of PUD Records
San Francisco (March 1978)	3,044
Boston (September 1978)	2,618
Dallas (Oct/Nov 1978)	2,321
Oklahoma City (October 1978)	1,904
Phoenix (Nov/Dec 1978)	1,513
St. Paul (Sept/Oct 1978)	761
Total	12,161

Traffic Impact Data

In addition to the goods movement data, traffic operations data were also collected. The purpose of this traffic operations data was to calibrate NETSIM (a discrete traffic simulation model) before using NETSIM to produce traffic impact data for a variety of conditions.

Twenty-five (25) lane blockage conditions (by a PUD vehicle) were filmed throughout the country. However, most were not usable because the arterial traffic at the time of the blockage was too low to cause any visible effect on performance. Ten (10) cases that had sufficient volume (volume to capacity ratio from 0.5 to 0.9) were selected for NETSIM calibration.

TRAFFIC CONDITIONS USED FOR NETSIM CALIBRATION

City	Lanes per Direction	Direction	Vehicles/ Hour of Green/Lane*
Dallas	3	one-way	1100
San Francisco	2	one-way	1000
San Francisco	2	one-way	1100
San Francisco	2	one-way	1000
San Francisco	2	one-way	800
White Plains, N.Y.	2	two-way	700
White Plains, N.Y.	2	two-way	650
New York	3	one-way	800
New York	2	two-way	950
New York	2	two-way	1000

* represents volume conditions without blockage

CURBSIDE PICKUP AND DELIVERY DEMAND

The demand for freight is a function of land use. The type of freight is also dependent on land use. The data collected for this study was based on dissaggregated land use categories. Employment (except office and hotel/residential), size (area or dwelling units) and location were collected for 503 individual generators. These generators included large office buildings and hotels, as well as small specialty shops. After examination of the data for individual land uses, six new 'aggregate' land use classes were identified for separate analysis. These are: office, residential, hotel, light industry/warehousing, retail/prepared foods, retail/services. The PUD trip generation equations for these aggregate land uses are presented below. It should be noted that the demand equations presented represent 'Fall' (or peak) goods movement conditions for an entire work-week.

PUD DEMAND EQUATIONS

Land Use	Equation	Samples	R^2
Office	WG = 0.80xFA+2.0	48	.93
Residential	WG = 0.15xDU+2.3	87	.94
Hotels	WG = 0.30xRU-12.0	11	.96
Retail & Prepared Foods	WG = 1.65xFA+1.21xE+5.20	44	.25
Industry/ Warehousing	WG=1.28xFA+0.31xE+11.96	31	.64
Retail & Services	WG=0.30xE+8.2	219	.74

where WG is average peak weekly generaton of PUD demand, FA is floor area in hundreds of square meters, E is employment, DU is dwelling units and RU is rental units.

The distributions of shipment weight and size at the various land uses are presented in the following tables.

DISTRIBUTION OF SHIPMENT WEIGHTS (KG) FOR PUD OPERATIONS

Weight per Shipment	Office	Residen-tial	Hotel	Foods	Light Ind.& Warehousing	Retail & Service
Under 2 kg	29%	34%	8%	6%	16%	22%
2 - 5	16	13	10	16	12	14
5 - 25	27	34	24	34	21	26
25 - 50	11	9	12	16	12	13
50 - 250	14	5	32	22	22	18
250 - 500	2	2	7	4	7	3
Over 500 kg	1	3	7	2	10	4
	100%	100%	100%	100%	100%	100%
Mean Weight	44kg	39kg	120kg	61kg	265kg	95kg

DISTRIBUTION OF SHIPMENT SIZES (PIECES) FOR PUD OPERATIONS

Pieces per Shipment	Office	Residen-tial	Hotel	Foods	Light Ind.& Warehousing	Retail & Service
Under 4	70	79	45	51	53	60
4 - 5	11	10	13	14	12	12
6 - 10	10	7	19	17	13	13
11 - 50	8	4	20	16	15	12
Over 50	1	0	3	2	7	3
	100%	100%	100%	100%	100%	100%
Mean Size	5.2	3.8	9.1	8.0	22.6	11.8
# of Sample Trips	2873	472	535	1098	1333	3970
Avg. Weight per piece	8.5kg	10.3kg	13.2kg	7.6kg	11.7kg	8.1kg

PARKING CHARACTERISTICS

The 'parked' PUD vehicle on a downtown arterial is the principal element influencing goods-movement related traffic delays. The needs of the generator to receive/ship goods, the need to use the curbside (and sometimes a traffic lane) for goods distribution and the need tc use all available street space to efficiently move traffic all combine tc produce 'the goods-movement problem.' During periods of the day when the individual needs are not all peaked simultaneously (or nearly so), the 'problem' is lessened or non-existent. During the periods of the day when all demands for curb space simultaneously peak, severe congestion can and usually does result.

The results show that 90% of curbside PUD activity occurred on the non-alley system. For blocks studied which did have alley access, 38% parked on the alley and 62% parked on another blockface including main arterials. The table below shows how all non-alley PUD vehicles parked in the CBD.

NON-ALLEY PARKING PATTERNS

Curbside-legal	52
Curbside-illegal	22
Double Parked-in Moving Lane	17
Curbside-in Moving Lane	9
	100%

"Curbside legal" represents space in which PUD vehicles park with no risk of a summons (no "pressure"), including meters, loading zones and unregulated curbspace. 'Curbside illegal' represents parking at bus stops, hydrants, in driveways, etc. About 9% of the vehicles parked in a curbside designated travel lane, and about one of six vehicles double parked on the non-alley systems.

The dwell time of PUD vehicles is a key element affecting curb space demand as well as duration of blockages. The table below shows the frequency distribution of dwell times for the main parking modes for all data collected in six cities.

DWELL TIME DISTRIBUTION BY PARKING MODE

Period	Double Parked in Moving Lane	Legally Parked at Curbside	Illegally Parked at Curbside
Under 1 minute	8.3	4.1	9.0
1-3	19.2	9.8	13.9
3-5	17.6	12.5	16.6
5-10	22.0	21.0	23.5
10-30	26.1	34.4	26.1
30-60	4.6	11.7	7.8
60-90	1.6	4.4	2.5
Over 90 minutes	0.6	2.1	0.5
	100%	100%	100%
Mean	11.5 min	19.5 min	13.8 min
Median	5.5	11.0	7.0

Double-parked PUD vehicles have the shortest dwell times. The vehicles parked at a hydrant, bus stop and in a no-parking zone had dwell characteristics substantially shorter than the PUD vehicles that were in a 'non-pressurized' parking mode at curbside. However, the mode of parking is not the only variable influencing dwell time. The land use where the PUD operation is being made has a significant effect on dwell time. The following table was prepared to show the dwell time distribution at each land use for all parking modes combined. It should be noted that all are curbside PUD and do not reflect longer dwell times at buildings where off-street loading facilities are used.

CURBSIDE PUD DWELL TIME
DISTRIBUTIONS BY LAND USE

Dwell Time (Minutes)	Office	Residential	Hotel	Light Industry/ Warehousing	Foods	Retail/ Service
Under 1	3.2	15.0	4.3	4.1	3.9	4.3
1-3	11.4	22.2	15.4	10.0	11.2	11.4
3-5	16.9	14.7	16.9	10.2	17.3	13.0
5-10	24.5	14.0	22.3	19.6	23.6	21.3
10-30	29.0	24.0	31.8	31.8	33.3	31.5
30-60	9.2	4.7	5.9	11.7	6.7	10.9
60-120	4.6	3.6	3.0	8.4	2.6	5.5
Over 120	1.2	1.8	0.3	4.2	1.4	2.1
	100%	100%	100%	100%	100%	100%
Mean Dwell (minutes)	18	15	15	27	16	21

Theoretically, for a given hourly demand, the double parking incidence should decrease as 'available' PUD space increases and as enforcement increases. In several cities, double parking is tolerated by enforcement agents as long as the PUD operation seems to be in progress. The preliminary results indicated that there were too many site specific situations (alleys, no non-PUD curbspace demand, other) to conduct the general analysis of parking patterns. Therefore, a sub-set of 13 'classical' blockfaces was defined for analysis. This subset had auto parking, bus stops, hydrants, loading zones, and the other elements usually associated with the typical urban arterial blockface. The results of the analysis of double parking showed that lane blockages can be predicted with moderate accuracy with the principal variable being available curb space.

BLOCKAGE ANALYSIS

It is hypothesized that at a certain low volume level, a lane blockage does not impact flow speed. Also, at very high volume levels (near capacity), the intersection so controls the flow that a blockage (except right at the intersection) does not affect speed.

NETSIM simulations were designed and run for each test case, and relationships were developed between simulated and actual field conditions. As NETSIM was not created to simulate lane blockages by trucks, the development of linear relationships between simulated and actual conditions was essential in interpreting the simulations to be made for the various volume levels, street sizes and types, and lane blockage configurations.

The analysis process defined six lane-blockage configurations on a one-way street and three lane-blockage configurations for a two-way street to which all possible lane blockage configurations could be reduced for traffic impact purposes. These configurations were simulated with NETSIM under varied volume levels and the results adjusted as per the field data test cases. A standard block length of 122 meters was used and typical arterial street progression, traffic composition and turning conditions assumed. The figure on the following page shows the developed speed reduction relationships for the various possible blockage configurations.

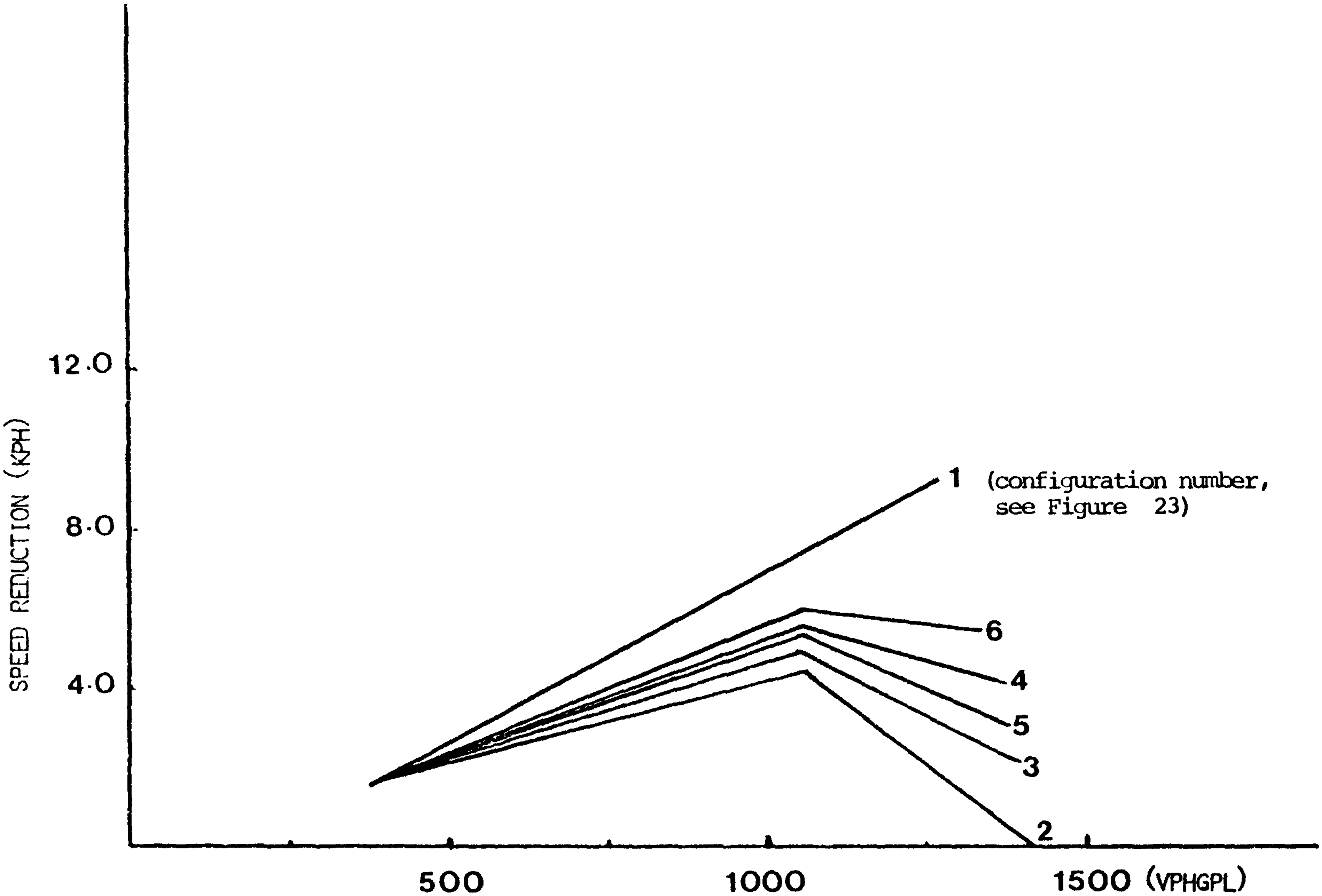
The figure on the subsequent page shows the expected resultant level of service on the arterial street for various traffic volumes and PUD double parking demand conditions. These levels of service are more appropriate descriptors of a segment (several blocks) of arterial than for an individual block, as a random PUD arrival pattern based on a uniform distribution along the block was assumed in the analysis process. That is, if a block has a very large downstream generator and little or no generation elsewhere, the figure shown would underestimate the impact. On the other hand, should that major generator be at mid block, an underestimate would be expected.

The level of service was determined by combining the no-blockage volume-speed curve from the NETSIM simulations with a general volume/ level of service relationship from the Transportation Research Circular 212, January 1980: 'Interim Materials on Highway Capacity'. To find the resultant level of service caused by PUD blockages the hypothetical volume was used to find the no-blockage speed, which in turn was reduced by appropriate values to determine the resultant level of service.

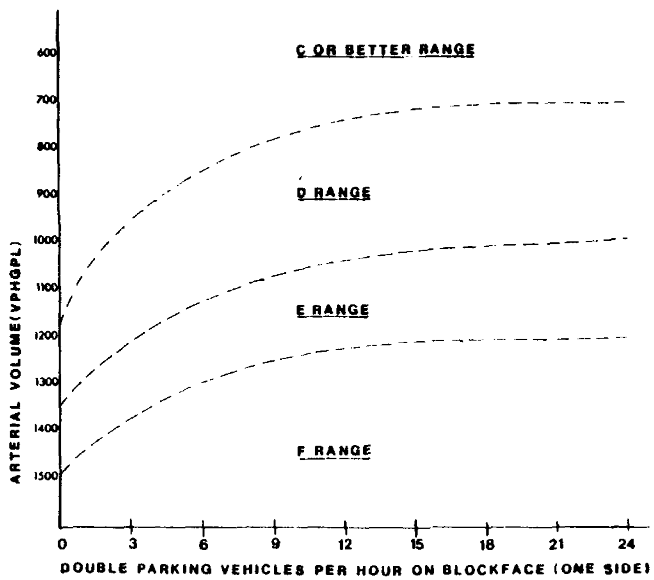
Under a very small amount of PUD activity, the maximum throughput of an arterial street will be reduced from about 1500 VPHGPL to about 1325 VPHGPL. This reduction must be viewed as the minimum effect of PUD operations on throughput of the system. The range of effects grows larger as PUD demand increases.

STRATEGIES FOR IMPROVING ARTERIAL FLOW

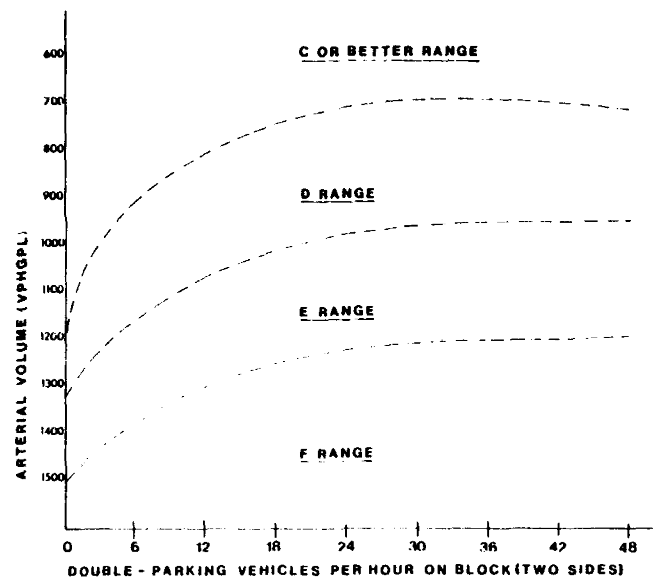
Initially, it becomes necessary to define the analysis objectives. For this type of analysis, a target level of service for the arterial is that objective. The recognition of curbside goods movement as a 'problem' related to traffic flow occurs when the traffic state is approaching or at capacity. An arterial with freely flowing traffic does not appear (to the traffic engineer) to represent a problem even though there is some speed reduction due to double-parked vehicles. Therefore, the strategy objectives for testing are:



TRAFFIC FLOW SPEED REDUCTION
FOR VARIOUS BLOCKAGE CONFIGURATIONS



LEVEL OF SERVICE FOR LANE BLOCKAGES ON TWO-WAY ARTERIALS



LEVEL OF SERVICE FOR LANE BLOCKAGES ON ONE WAY ARTERIALS

o upper limit level of service C (C/D boundary)
or o upper limit level of service D (D/E boundary)

Each strategy developed includes: description of the strategy, analysis and variability, and implementation plan. The various strategies presented and evaluated are all low cost, operations oriented options. As such, each (except PUD demand reduction techniques) is an ideal candidate for demonstration. The value of such demonstrations in urban goods movement is expected to be very high as little operations work has yet been done to try to improve arterial flow by specifically identifying and correcting goods-movement related deficiencies.

The strategies recommended for possible demonstration are:

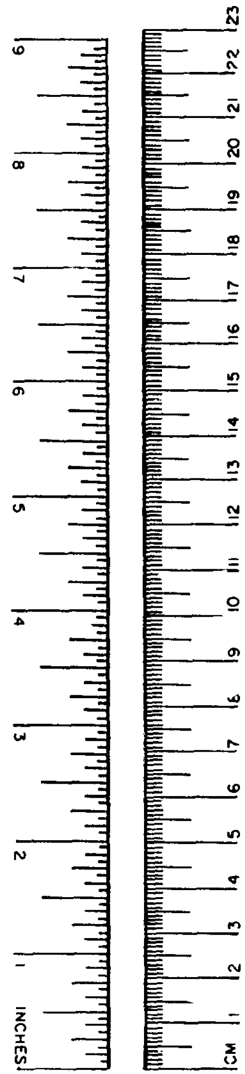
1. Curbspace Management. The allocation of specific amounts of curbspace for PUD operations by time of day to reduce blockages.
2. Pressurized (intended) Signing. The replacement of 'Loading Zone' signs with 'No Parking' signs to increase curbspace efficiency.
3. Signal Timing. Adjusting the major street green to provide additional time to process traffic through a problem block.
4. Double Parking Curblane. The striping of a 'parking' lane on one side of the arterial to accommodate a curbside and a double-parked vehicle
5. Bus Stop Relocation. The relocation of bus stop to near side to reduce the chance of approach lane blockage by PUD vehicles.

This and previous studies have pointed out that problems related to curbside PUD are almost exclusively concentrated in the downtown area. In addition, the Research Team considers that a city which has a population of 500,000 or less usually does not have sufficient PUD problems to warrant strategies related to easing these problems unless unusual site-specific conditions exist.

METRIC CONVERSION FACTORS

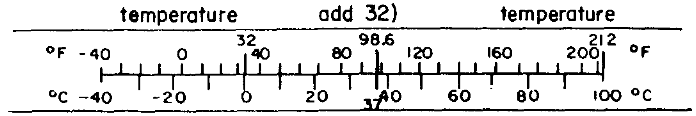
APPROXIMATE CONVERSIONS FROM METRIC MEASURES

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	0.6	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS FROM METRIC MEASURES

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	36	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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CHAPTER I

INTRODUCTION AND STUDY DESCRIPTION

The distribution of freight in urban areas is done almost exclusively by vehicles using the road system. These vehicles vary from large tractor-trailers handling unit loads to bicycles handling documents.

The principal 'zones' of goods-movement activity in the urban area are: (1) the central business district (CBD) and (2) the industrial/warehousing district and(3) the terminal (and port) district. Although the amounts of total freight moved outside of the CBD is usually greater than that of the CBD, the high level of competition for space between people and goods movements in the CBD makes that district the most sensitive to congestion-causing conflicts.

To date, several studies have been conducted in the area of urban goods movement (UGM) and, due to the relative novelty of the study of this 'mode' of transportation, most of these studies have been state-of-the-art research. Only one study (1)* has attempted to address the relationships between UGM and surface traffic performance. No studies to date have been able to quantitatively evaluate alternative strategies for urban goods movement. As traffic engineers/planners progress in their efforts to improve transportation on existing facilities, the ability to identify the congestion-causing effects of PUD operations takes on more importance and urgency. However, the variables controlling the process require identification and documentation before the needed traffic impact tools can be developed.

The scope of this study is to address only curbside pickup and delivery (PUD), and its relationship to arterial traffic impacts. The study of off-street operations is not included in this effort. The data collected for this study was from cities of over 250,000 population, and six such cities are used to represent a nationwide cross-section. The cities considered are: San Francisco, Boston, St. Paul, Oklahoma City, Dallas and Phoenix.

The purpose of this study is to develop the tools necessary to better quantify the relationships between curbside pickup and delivery (PUD) of freight and surface traffic measures of effectiveness, and to use these tools to evaluate alternate strategies for reducing congestion causing conflicts on the road system.

In a simplified way, Figure 1 shows the process of urban curbside PUD and its relationship with surface traffic. The land use generates the PUD vehicles. The PUD vehicle often parks at curbside or double parks. This on-street parking 'mode' is hypothesized to be influenced by curbside parking regulations and enforcement.

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*Underlined numbers in parentheses refer to references at the end of this report

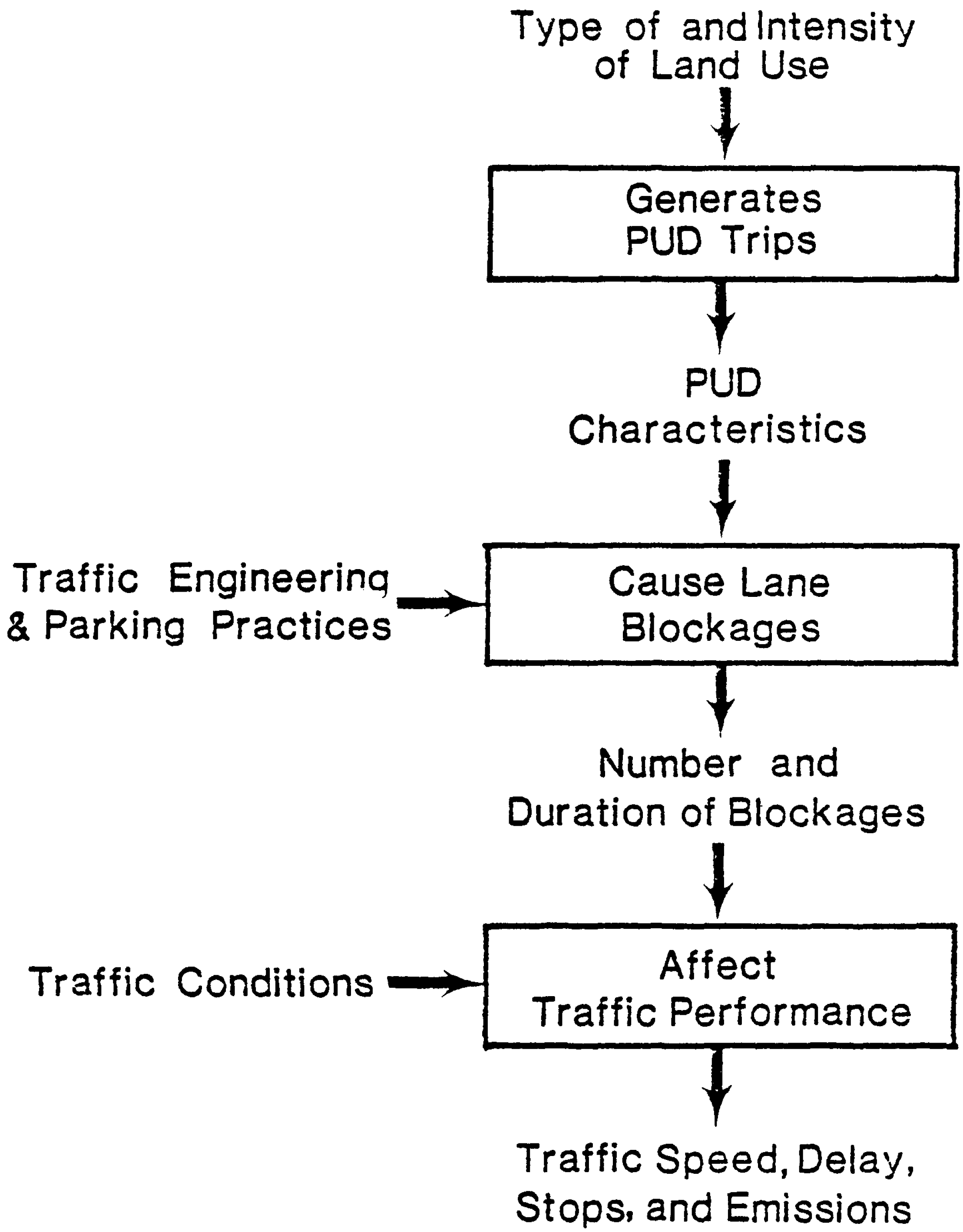


FIGURE I. PUD OPERATIONS PROBLEM DEVELOPMENT

The PUD vehicle will adversely affect traffic if it is parked in a traffic lane for which there is demand. Therefore the specific tools developed herein define:

- How different land uses generate PUD trips
- How frequently traffic blockages are created by PUD vehicles
- What the effects of lane blockages are on surface traffic.

The analyses conducted to develop the above tools are based on data collected for this study. This data, from six cities, includes field recordings of over twelve thousand PUD trips at generators. In addition, descriptive data for each generator was collected, as well as parking regulations and enforcement during the observed PUD operations. Time-lapse photography was used to collect traffic impacts of lane blockages by PUD vehicles.

SUMMARY OF RESULTS

The large data base provided the Research Team with sufficient input to develop the necessary analytic tools. Regression equations for predicting PUD demand and the probability of lane blockages were documented. Simulation, coupled with on-street data, provided the basis for developing relationships between lane blockages and traffic flow speed on the downtown arterial. Methods for determining impact resultant levels of service were also developed (Chapter 5).

Using these developed tools, various operational strategies were tested for their effectiveness for field implementation (Chapter 6). The results of this testing showed that several low-cost options do exist to address goods movement problems on the arterial system. The Research Team recommends selected strategies (Chapter 7) for field demonstration and identifies the scope of such demonstration studies.

CHAPTER 2

DATA COLLECTION METHODS

The data necessary to quantify PUD demand, parking patterns and traffic impact of curbside PUD operations were collected from various cities nationwide. The study were limited to six cities of over 250,000 population. The data collected was for on-street PUD operations at typical blocks in the downtown, fringe and residential areas of the various cities. Off-Street PUD operations were not included in this study.

This chapter consists of sections on city selection, survey procedures for PUD operations, and data collection for traffic impact analysis.

CITY SELECTION

The 1970 Census of Population lists 56 cities of 250,000 persons and over, with six cities of over 1,000,000 persons (New York, Los Angeles, Chicago, Philadelphia, Detroit and Houston). The primary concern in city selection was how many other cities could be 'represented' by the sampled cities. For this reason none of the six largest cities was selected as being representative, not even of each other. The attributes of the remaining cities that were considered in the selection process were:

- Population
- Population density
- Industrialization
- Proximity to ports
- Part of a "Megalopolis"
- Geographic location

The population was that of the city (within city limits) and the density was population per square kilometer. Degree of industrialization of each city was determined by calculating the ratio of manufacturing employment to total employment (the employment data was also from the Bureau of the Census). Then, a mean and a standard deviation were calculated for the distribution of the ratios of all 56 cities. Those cities having their ratios within one standard deviation of the mean were defined as 'balanced'. Those cities having their ratios greater than plus one standard deviation from the mean were defined as 'manufacturing' and those having their ratios less than minus one standard deviation from the mean were defined as 'consuming'.

The first cut reduced the list of candidate cities to Baltimore, Birmingham, Boston, Cincinnati, Dallas, El Paso, Indianapolis, Louisville, Minneapolis, Nashville, Oklahoma City, Omaha, Phoenix, San Francisco, St. Paul, Tampa, Tucson and Tulsa. Subsequently, after a more detailed review of parking, goods-movement programs, city traffic engineer interest, survey logistics and weather considerations, the six cities were selected for survey. These are shown in Table 1 and Figure 2.

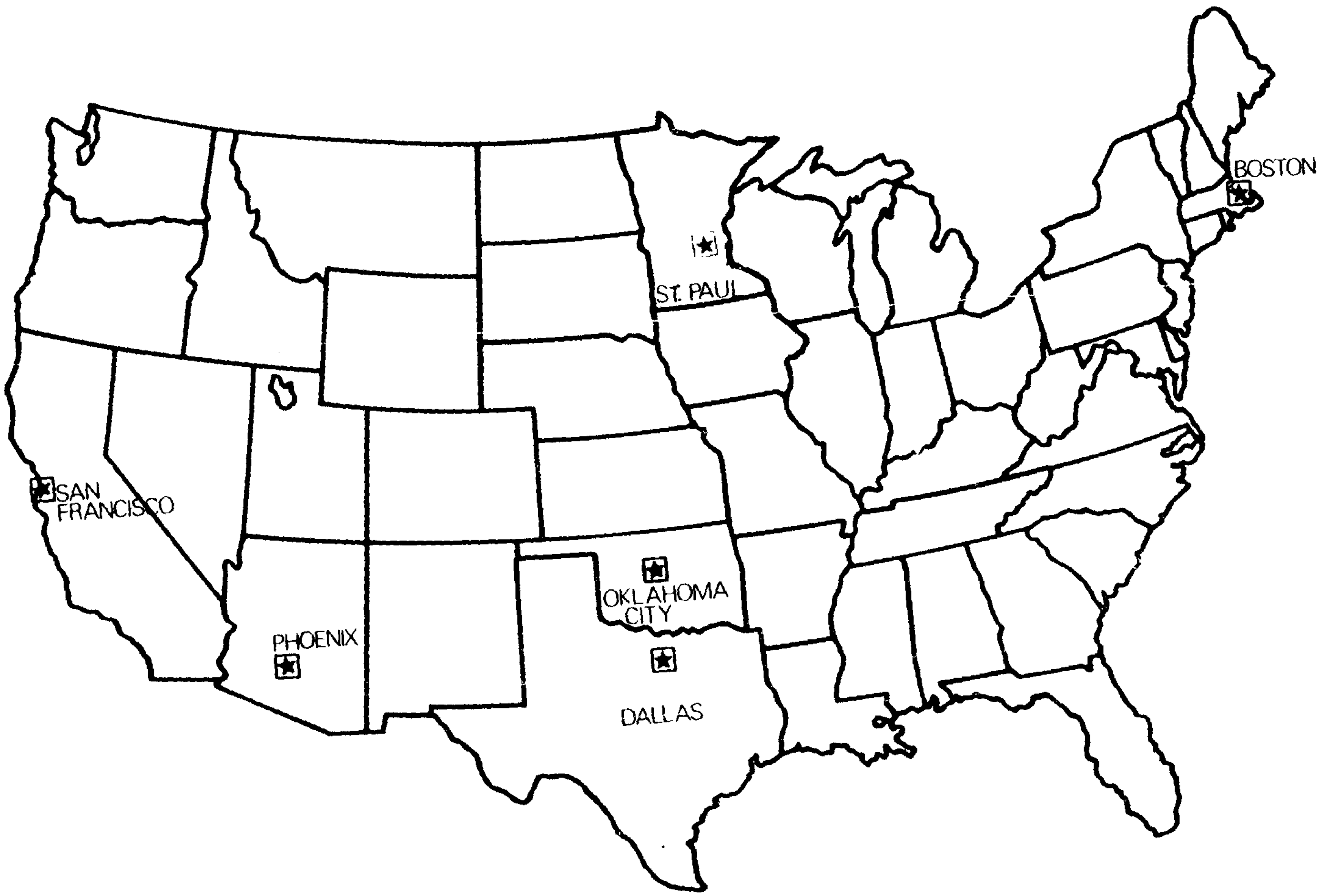


FIGURE 2. CITIES USED FOR DATA COLLECTION

TABLE 1 SURVEY CITIES CHARACTERISTICS

City	1970 Population (1000)	Density	Economic Function	Part of Megalopolis	Port Facilities
Boston	641	High	Balanced	Yes	Yes
Dallas	844	Low	Manufacturing	No	No
Oklahoma City	367	Low	Balanced	No	No
Phoenix	581	Low	Balanced	No	No
San Francisco	716	High	Consuming	Yes	Yes
St. Paul	310	Medium	Manufacturing	Twin Cities	Minor

San Francisco was selected as the city to conduct the pilot study primarily because of its weather (the pilot study was conducted in early March) and its size.

Site Selection for PUD Operations

The method of selecting the blocks and block-faces in each city for observation was done in a manner similar to city selection, by starting with a large population of potential sites and narrowing these down to the most desirable. Factors considered were land use, the number and type of establishments per blockface, street configuration, parking regulations, and presence of designated loading zones. Table 2 shows how the locations were divided among the several cities. Appendix I includes a breakdown of the specific blocks considered in the data collection effort.

TABLE 2 LOCATION DISTRIBUTION BY CITY

City	Opposing Block-Faces	Square Blocks	Special Generators*
Boston	-	3	1
Dallas	1	3	2
Oklahoma City	1	2	-
Phoenix	1	2	2
San Francisco	6	-	1
St. Paul	1	3	2
Total	10	13	8

*Large single-use blocks

Table 2 shows that, in addition to selecting 10 blockfaces that are on either side of an arterial, 13 entire blocks (four faces) were also inventoried in this effort. Special generators were single large establishments such as large department stores, office buildings or hotels which have multiple entries and which, in themselves, may occupy an entire city block.

Data on each pickup or delivery on these blocks were recorded, as well as characteristics of the establishments (land use, size, employment), and parking regulations and enforcement on each blockface. The survey was predominantly conducted in the downtown area of each city. However, residential, light industry and warehousing land uses were surveyed in the fringes as well as outlying residential zones.

TABLE 3 SITES SURVEYED

Land Use	# Surveyed	Land Use	# Surveyed
Bank	10	Novelties	5
Stationery	7	Misc. (Retail)	22
Clothing	46	Shoes	9
Department Store	5	Bar, Tavern	9
Drug Store, Health, Beauty Aid	6	Vacant or Construction	46
Electronic	5	Garage, Station	10
Fabrics	1	Hotel	8
Flowers	2	Light Industry	24
Food (Prepared)	47	Office	52
Food (Retail)	10	Residential	100
Furniture	3	Service	53
Jewelry	13	Warehousing	11
Liquor Store	3	Entertainment	3

Data on each establishment was collected to be used as variables in PUD generation equations. Employment was collected for all land uses except residential, office buildings and hotels. Floor area was collected for all generators except residential and hotels, for which the number of units (dwelling or rental) was hypothesized to be the best independent variable for generation.

SURVEY PROCEDURES

The collection of data was carried out by field crews hired locally and consisted of college students and/or personnel obtained through temporary employment agencies. Before being sent to the field, each crew was required to attend a training seminar where they were familiarized with the study, taught how the observations were to be made, how the information was to be entered on the field forms, and the various traffic oriented terms were defined. The classroom-type training session was followed, where practical, by a dry run on the street under the supervision of study staff personnel.

Each site, with the exception of some special generators, was observed for a period of five days from Monday through Friday. Daily coverage using the full crew extended from before 8 AM to after 4 PM as dictated by the goods movement activity.

Figure 3 shows the data-collection form for PUD operations. Figure 4 shows the data collection form for curbside regulations and enforcement by hour of the day. There was no specific form for the employment and size data for each generation, as these were recorded in a project notebook along with other qualifying information about each site. This additional information included such elements as the diversity of goods sold and the location and type of freight access.

San Francisco was selected as the pilot city on which to test the various survey methods. This pilot study was conducted in March of 1978. In September 1978 the main data collection effort began in Boston, and then St. Paul, Oklahoma City, Dallas and Phoenix followed in succession. The field effort was concluded in early December 1978.

Table 4 summarizes the PUD operations data collected in each city. The computer coding format of the collected data is presented in Appendix I. A copy of the computer tape containing this data can be acquired by potential users from FHWA, Traffic Systems Division (HRS-31).

TABLE 4 DISTRIBUTION OF SAMPLES BY CITY

City	Number of PUD Records
San Francisco	3,044
Boston	2,618
Dallas	2,321
Oklahoma City	1,904
Phoenix	1,513
St. Paul	761
Total	12,161

TRAFFIC IMPACT DATA

In addition to the goods movement data, traffic operations data was also collected. The purpose of this traffic operations data was to validate (or calibrate) NETSIM (a discrete traffic simulation model)(11) before using NETSIM to produce traffic impact data for a variety of conditions.

P.U.D. OPERATIONS SURVEY

A. BLOCK ID ______________________
CITY-BLOCK NO.-BLOCKFACE

B. DATE ______________________
DAY OF WEEK-MONTH-DAY

C. TIME OF ARRIVAL __________ TIME OF DEPARTURE __________
HOURS-MINUTES HOURS-MINUTES

D. PARKING MODE
VEHICLE PARKED IN
1. MOVING LANE ______
2. NON-MOVING LANE LEGALLY ______
3. NON-MOVING LANE ILLEGALLY ______
4. OTHER ______

E. ACTIVITY RECORD

1. NAME OF ESTABLISHMENT __________ OPERATION ______
TYPE OF GOODS ______ NO. OF PARCELS ______ TOTAL WEIGHT ______

NOTE: CONTINUE BELOW ONLY IF ADDITIONAL ESTABLISHMENTS ARE VISITED.

2. NAME OF ESTABLISHMENT __________ OPERATION ______
TYPE OF GOODS ______ NO. OF PARCELS ______ TOTAL WEIGHT ______

3. NAME OF ESTABLISHMENT __________ OPERATION ______
TYPE OF GOODS ______ NO. OF PARCELS ______ TOTAL WEIGHT ______

4. NAME OF ESTABLISHMENT __________ OPERATION ______
TYPE OF GOODS ______ NO. OF PARCELS ______ TOTAL WEIGHT ______

F. NUMBER OF ESTABLISHMENTS VISITED ______

SAMPLE VEHICLE DESCRIPTION:	OPERATION CODES:	1. PICK-UP 2. DELIVERY 3. SERVICE 4. PICK-UP AND DELIVERY 5. UNKNOWN

OBSERVER: ______

CODER: ______

1 | 7 | 12 | 14 | 7 8 | 21 | 30 | 32 | 38 | 42 | 47 | 51 | 57 | 62 | 66 | 72 | 77 | 81 | 87 | 92

FIGURE 3. PUD OPERATIONS SURVEY FORM

POLYTECHNIC INSTITUTE OF NEW YORK
EDWARDS AND KELCEY, INC.

CURB INVENTORY

2

A. BLOCK ID ______ 2
CITY-BLOCK NO.-BLOCKFACE

7

B. DATE ______ 9 [ ][ ][ ][ ] 7 8
DAY OF WEEK-MONTH-DAY

C. BLOCK LENGTH (FEET) ______ 16

D. LOADING ZONE WIDTH (FEET AND TENTH) ______ 21

E. LOADING ZONE TIME LIMIT (MINUTES) ______ 25

F. TIME PERIOD	G. COUNT OF PARKING ENFORCEMENT AGENTS	H. LOADING ZONE EXISTS	I. CURB LANE MOVING	J. CURB LANE STATUS (FEET) LOADING ZONE	K. OTHER LEGAL	L. ILLEGAL
29 06	32	35	36	38	42	46
07						
08						
09						
10						
11						
12						
13						
14						
15						
16						
17						

OBSERVER: ______

FIGURE 4. CURB REGULATION AND ENFORCEMENT SURVEY FORM

INVENTORY BY: ______

Twenty-five (25) lane blockage conditions (caused by PUD vehicles) were filmed throughout the country. Ten (10) cases that had sufficient volume (volume to capacity ratio from 0.5 to 0.9) were selected for validation. The principal reason for rejecting selected filmed cases was that the volume past the blockages was too low to provide measurable impact. The second reason for rejecting cases was that other exogenous factors more controlled arterial flow than did the lane blockage. These exogenous factors included cross-street congestion, auto double-parking, bus breakdown in moving lane, and others.

The cases were recorded with 1 second time lapse photography using a super 8 MM camera mounted on roof-tops, in office buildings, on fire-escapes and other locations. The data deduced from the films for each case was: the travel time of vehicles through a specific section (usually a block) before a blockage occurred and during the entire blockage. While in the field, information was manually collected for each blockage site: signal timing and off-set for adjacent intersections, block lengths, and number of lanes. All other site-descriptive information was deduced from the films. Table 5 shows the description of the ten cases used for NETSIM calibration. The volumes shown in Table 5 are vehicles per hour of green during the blockage divided by the before blockage number of lanes.

TABLE 5 TRAFFIC CONDITIONS USED FOR NETSIM CALIBRATION

City	Lanes per Direction	Direction	Vehicles/ Hour of Green/Lane*
Dallas	3	one-way	1100
San Francisco	2	one-way	1000
San Francisco	2	one-way	1100
San Francisco	2	one-way	1000
San Francisco	2	one-way	800
White Plains, N.Y.	2	two-way	700
White Plains, N.Y.	2	two-way	650
New York	3	one-way	800
New York	2	two-way	950
New York	2	two-way	1000

* represents volume conditions without blockage

CHAPTER 3

CURBSIDE PICKUP AND DELIVERY DEMAND

The demand for curbside pickup and delivery of freight in urban areas is the principal variable governing the potential goods/people conflicts and the severity of these conflicts. The tools to predict PUD demand markedly facilitate the process of developing and evaluating measures to reduce conflicts and improve mobility.

The demand for freight is a function of land use. The type of freight is also dependent on land use. The data collected for this study were for dissaggregated land use categories. Employment (except office and hotel/residential), size (area or dwelling units) and location were collected for 503 individual generators. These generators included large office buildings and hotels, as well as small specialty shops. The demand equations for PUD operations to these generators are presented in this report. Selected arrival patterns and freight characteristics are also presented.

Curbside PUD is not entirely a truck related operation, especially for CBD distribution. The reasons can be categorized into three distinct but interrelated factors. First, the variety of land uses and the different sizes of the generators contribute to the numerous types of vehicles being used to transport freight. Secondly, the downtown street networks limit the flexibility and the size of freight vehicles, and thirdly, the high density characteristics of the urban center make it unique from the freight distribution viewpoint.

Previous studies (2,3,4,5) have attempted to develop equations for truck trips in urban areas. Table 6 below summarizes four related studies on PUD trip generation. As the most commonly available variable is size (floor area), this was primarily used. This study, having acquired employment and size information, builds on these previous studies to advance the state-of-the-art in PUD trip generation.

It should be noted that PUD activity is quite seasonal and this could have resulted in the discrepancies evidenced in Table 6. For this study, data was collected in March (in San Francisco), in September (in Boston and St. Paul), in October (St. Paul and Oklahoma City), in November (In Oklahoma City and Dallas), and in December (in Phoenix). The Fall period, during which five of six cities were surveyed, is the peak PUD activity season in downtown areas, due to the back-to-school, Fall shopping, Thanksgiving sales and the Christmas period. Freight movements of consumer products, and the studies thereof, are primarily a Fall phenomenon in the CBD. Therefore, in order to make the pilot data consistent with the other five cities, a correction factor of 1.15 (1) was applied to all demand data from San Francisco.

TABLE 6 PREVIOUS PUD TRIP GENERATION STUDIES

Ref (2):	Light Industry/Warehousing	DG = .037S
	Retail Area	DG = .011S
	Financial Area (Office)	DG = .011S
Ref (3):	Manufacturing	DG = .082E
	Office	DG = .110E
	Retail	DG = .278E
Ref (4):	Manufacturing	DG = 2.2+057S
	Warehousing	DG = 2.3+045S
	Office	DG = 3.6+017S
Ref (5):	Downtown Retail	DG = .059S
	Downtown Retail	DG = 0.40E
	Wholesale Operations	DG = 0.50E
	Truck Terminals	DG = .335S
	Truck Terminals	DG = 1.40E

Where DG is daily generation, E is employment, and S is floor area in hundreds of square meters.

PUD DEMAND ANALYSIS

Initially, land uses were dissaggregated into 26 categories for sample selection purposes (Table 7 shows these categories). However, several of these uses can be aggregated due to their similar PUD characteristics such as shipment sizes, average dwell times and types of vehicles used. After examination of the data for individual land uses, the following six new 'aggregate' land use classes were identified for separate analysis.

- o Office
- o Residential
- o Hotel
- o Light Industry & Warehousing
- o Retail & Prepared Foods
- o Retail & Services

These aggregate land uses and reasons for selection are described in more detail in the sections to follow. Table 8 shows the resultant linear regression equations developed for estimating PUD demand at curbside. Tables 9 and 10 show the resultant characteristics of shipment weights and sizes for each aggregate land use.

Office

Office land use is clearly definable as office use in office buildings. It does not include the other ground floor uses, such as restaurants and banks. The employment information for office buildings was not acquired, due to the decentralized nature of the tenants, and previous studies (2,6,10) have shown that PUD demand at office buildings is a function of building size.

Table 8 shows the resultant weekly and daily generation equations for office land use. The range of building size was up to 700,000 square meters and therefore the demand equation would be representative of all but the largest office complexes. Figure 5 is a plot of the resultant weekly regression equation for office land use. This figure also shows the size distribution of the samples used in the analysis. Table 9 shows the shipment characteristics of office land use, where the mean shipment weight was found to be 44 kilograms and the mean shipment size was 5.2 packages.

TABLE 7 DISAGGREGATE LAND USE CATEGORIES USED IN DATA COLLECTION

Office	Electronic, Appliances
Residential	Camera
Hotel	Flowers
Light Industry	Furniture
Warehousing	Jewelry
Retail Foods	Liquor
Prepared Foods	Novelties
Banks	Shoes
Stationery	Bars, Taverns
Clothing	Entertainment
Department Stores	Garage, Service Stations
Drug Stores	Service (Locksmith, Shoe Repair)
Health & Beauty Aids	Miscellaneous

TABLE 8 PICKUP AND DELIVERY DEMAND EQUATIONS

Land Use	Weekly Generation	Daily Generation	R^2	Samples
Office	WG=0.80xFA+2.0	DG=0.16xFA+.4	.93	48
Residential	WG=0.15xDU+2.27	DG=0.032xDU+.45	.94	87
Hotels	WG=0.30xRU-12.0	DG=0.06xRU-2.4	.96	11
Retail/ Prepared Foods	WG=1.65xFA+1.21xE+5.2	DG=0.33xFA+.242xE+1.04	.25	44
Light Industry/ Warehouse	WG=1.28xFA+0.31xE+11.96	DG=0.26xFA+.06xE+2.4	.64	31
Retail & Services	WG=0.30xE+8.2	DG=.06xE+1.6	.74	219

where: WG is weekly generation, DG is mean daily generation. E is employment, FA is floor area(hundreds of square meters), DU is dwelling unit , RU is rental units.

OFFICE

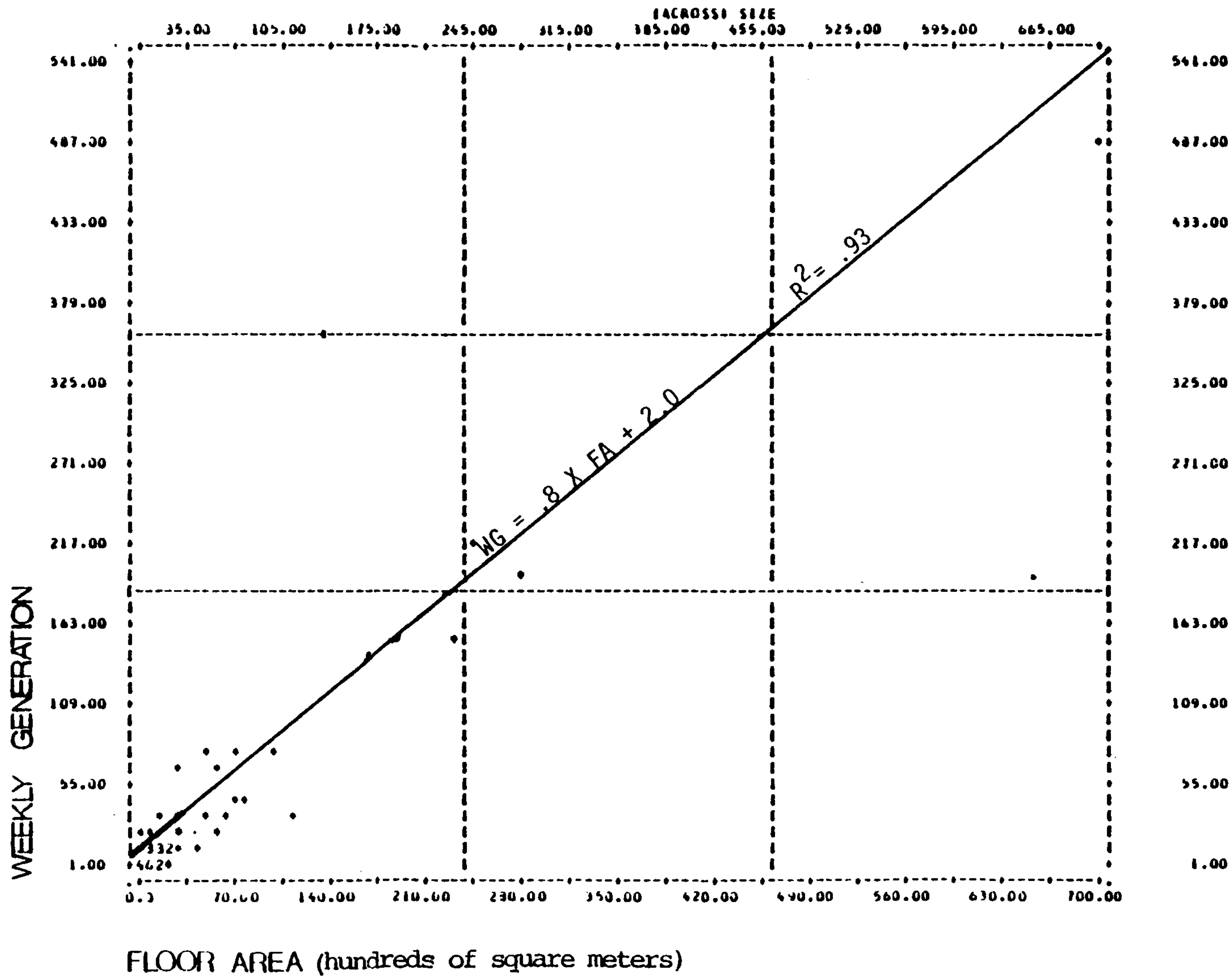


FIGURE 5. PLOT OF WEEKLY PUD GENERATION
VS SIZE FOR OFFICE LAND USE

TABLE 9 PICKUP AND DELIVERY SHIPMENT CHARACTERISTICS

DISTRIBUTION OF SHIPMENT WEIGHTS (KG)-

Weight per Shipment	Office	Residential	Hotel	Foods	Light Ind.& Warehousing	Retail Service
Under 2 kg	29	34	8	6	16	22
2-5	16	13	10	16	12	14
5-25	27	34	24	34	21	26
25-50	11	9	12	16	12	13
50-250	14	5	32	22	22	18
250-500	2	2	7	4	7	3
Over 500 kg	1	3	7	2	10	4
	100%	100%	100%	100%	100%	100%
Mean Weight	44kg	39kg	120kg	61kg	265kg	95kg

DISTRIBUTION OF SHIPMENT SIZES (PACKAGES)-

Pieces per Shipment	Office	Residential	Hotel	Foods	Light Ind.& Warehousing	Retail & Service
Under 4	70	79	45	51	53	60
4-5	11	10	13	14	12	12
6-10	10	7	19	17	13	13
11-50	8	4	20	16	15	12
Over 50	1	0	3	2	7	3
	100%	100%	100%	100%	100%	100%
Mean Size	5.2	3.8	9.1	8.0	22.6	11.8
# of Sample Trips	2873	472	535	1098	1333	3970
Avg. Weight per piece	8.5kg	10.3kg	13.2kg	7.6kg	11.7kg	8.1kg

Residential

Single family dwelling units were the predominant type of residential land use surveyed. However, several small and large residential building are also represented. Figure 6 shows a plot of weekly demand versus dwelling units and Table 8 contains the developed weekly and daily generation equations. Dwelling units (DU) was the variable used in the demand equations. Table 9 shows the shipment characteristics. The mean shipment weight was 39 kilograms and the mean shipment size was 3.8 packages.

RESIDENTIAL

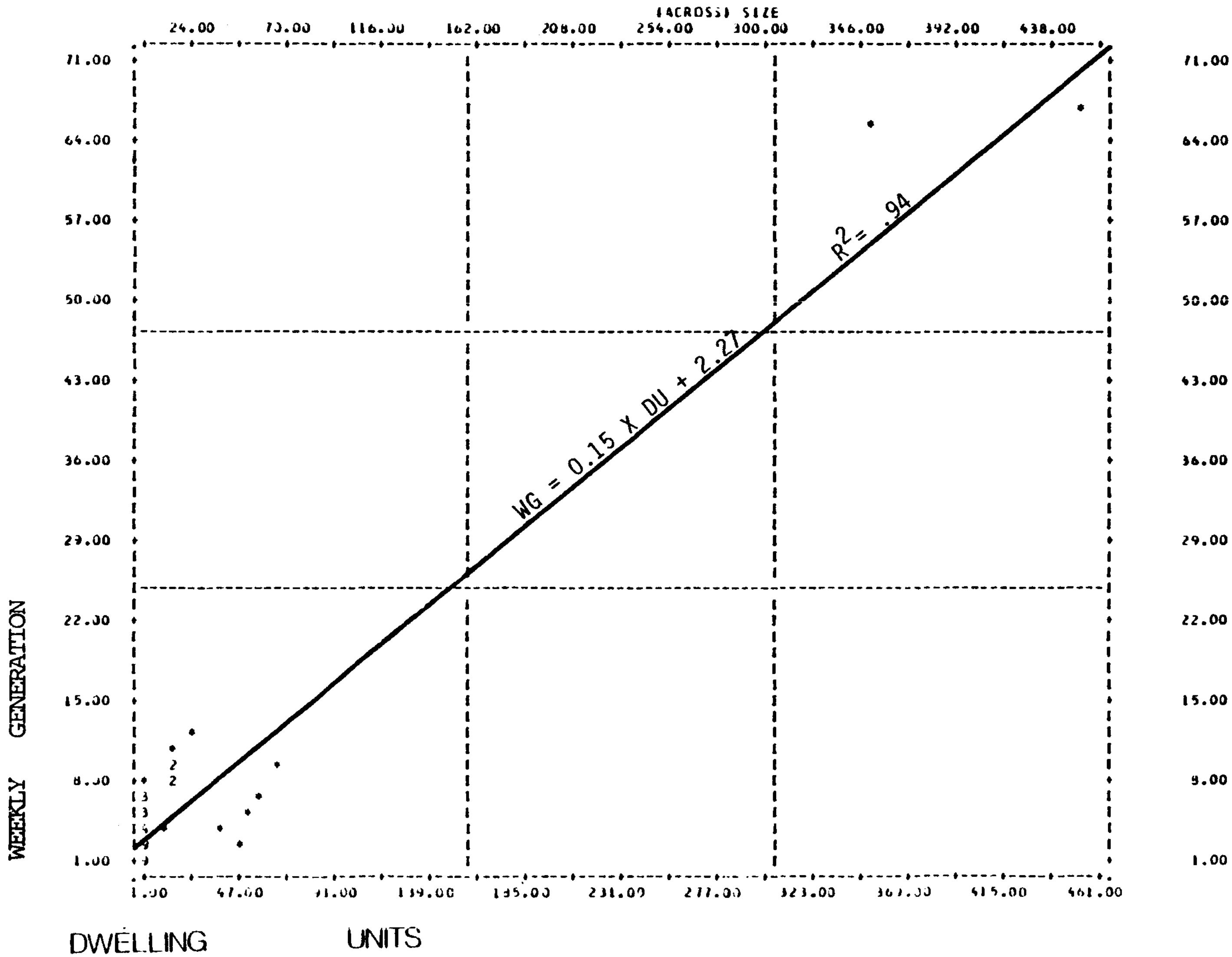


FIGURE 6. PLOT OF WEEKLY PUD GENERATION
VS DWELLING UNITS FOR RESIDENTIAL LAND USE

Hotels

The downtown area of the various cities surveyed have both old and new hotels. As the hotels grow old, the type of tenant generally becomes longer term and the PUD characteristics become similar to those of a residential apartment building. However, most functioning downtown hotels are an aggregate of rooming and support (restaurant, shop, etc.) activities and are, therefore, quite dissimilar to residential development. As such, the hotel samples shown in this section are functioning hotels, and the 'rooming houses' have been grouped with the residential samples.

Figure 7 shows a plot of the weekly generation of PUD operations versus the number of rental units. Table 8 contains the resultant demand equations. The negative constant indicates that the equation should only be applied to generators in excess of 100 rooms.

The shipment characteristics are shown in Table 9. The average shipment weight was 120 kg and the average size was 9.1 packages.

Retail and Prepared Foods ('Foods')

'Foods' land use (retail and prepared) is dominant in downtown areas. Approximately 15% to 20% of CBD establishments are either (or contain) retail or prepared foods. Retail and prepared foods land uses are treated separately from retail and service establishments because their demand characteristics by time of day are unique (this is presented later in this chapter), with a high percentage of arrivals before 9 AM (the time when most other establishments are still closed). Figure 8 shows a plot of weekly generation versus employment, and Figure 9 shows a plot of weekly generation versus size for 'Foods' establishments.

Table 8 shows the best resultant demand equations which are based on a combination of generator size and employment. The developed equations for 'Foods' land use have the lowest R^2 of all demand equations done for this study. This is primarily because of the very high concentration of small establishments (under 200 square meters). However, the equations do produce values that are consistent with previous studies.

The shipment characteristics are shows in Table 9. The mean weight transferred per trip was 61 kilograms and the mean size was 8.0 packages.

Light Industry and Warehousing

This combination of manufacturing and warehousing land uses resulted because (1) only 13 warehousing samples were surveyed in the central areas, (2) several of the manufacturing samples also did some warehousing and (3) the arrival patterns were quite similar. Figure 10 shows the plot of weekly generation versus employment, and Figure 11 shows weekly generation versus floor area in hundreds of square meters. The best weekly generation equation, which com-

HOTEL

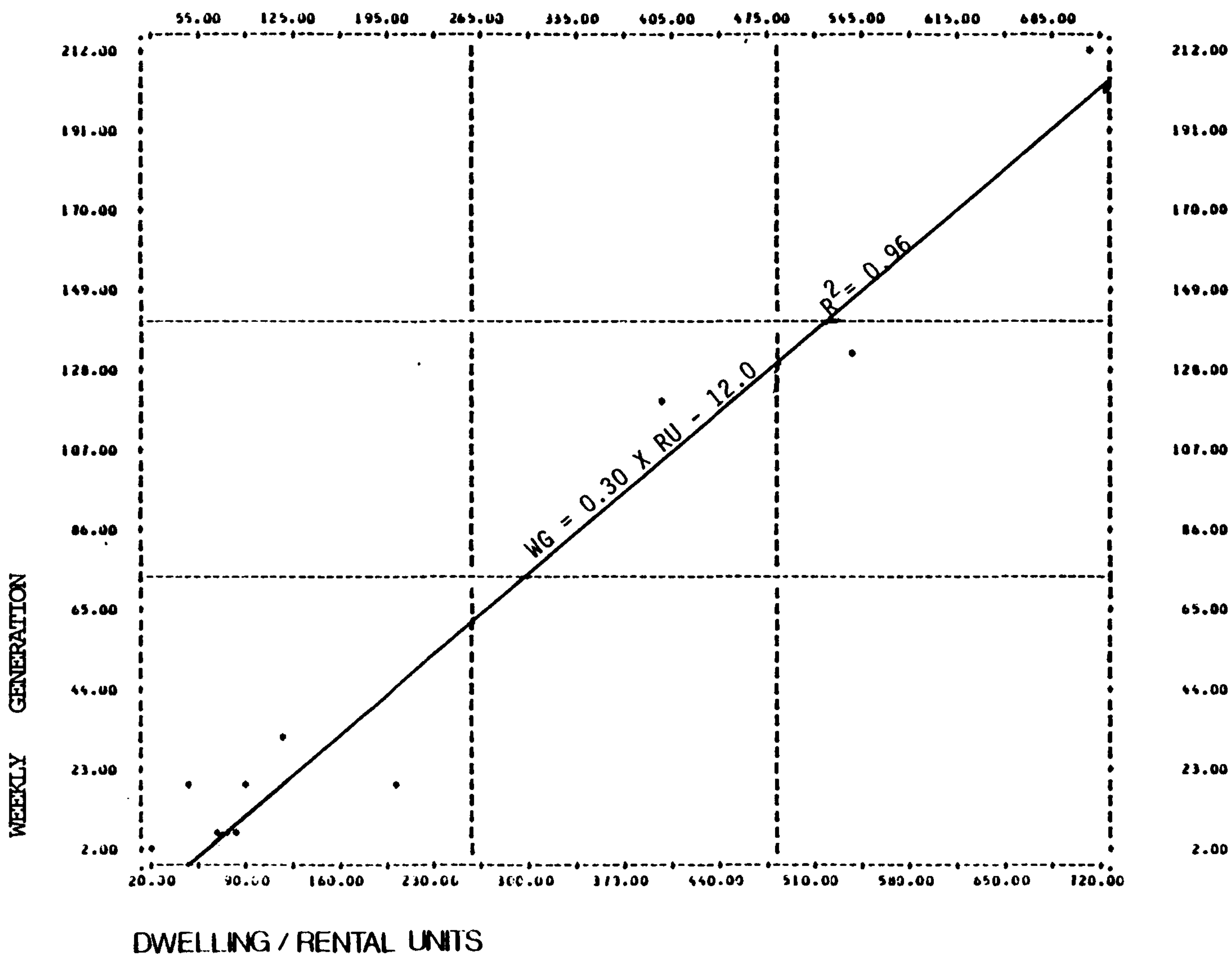


FIGURE 7. PLOT OF WEEKLY PUD GENERATION
VS RENTAL UNITS FOR HOTEL LAND USE

RETAIL & PREPARED FOODS

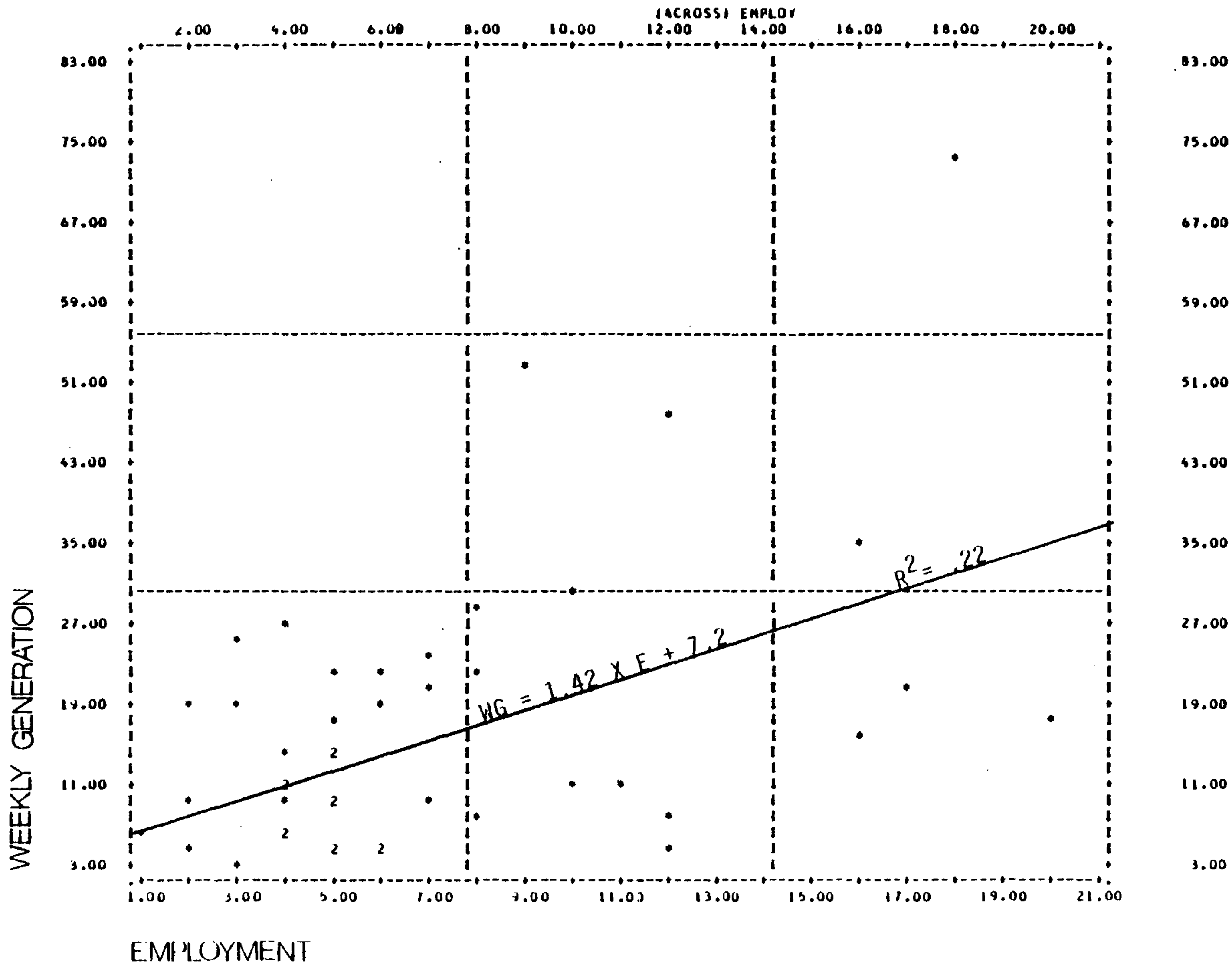
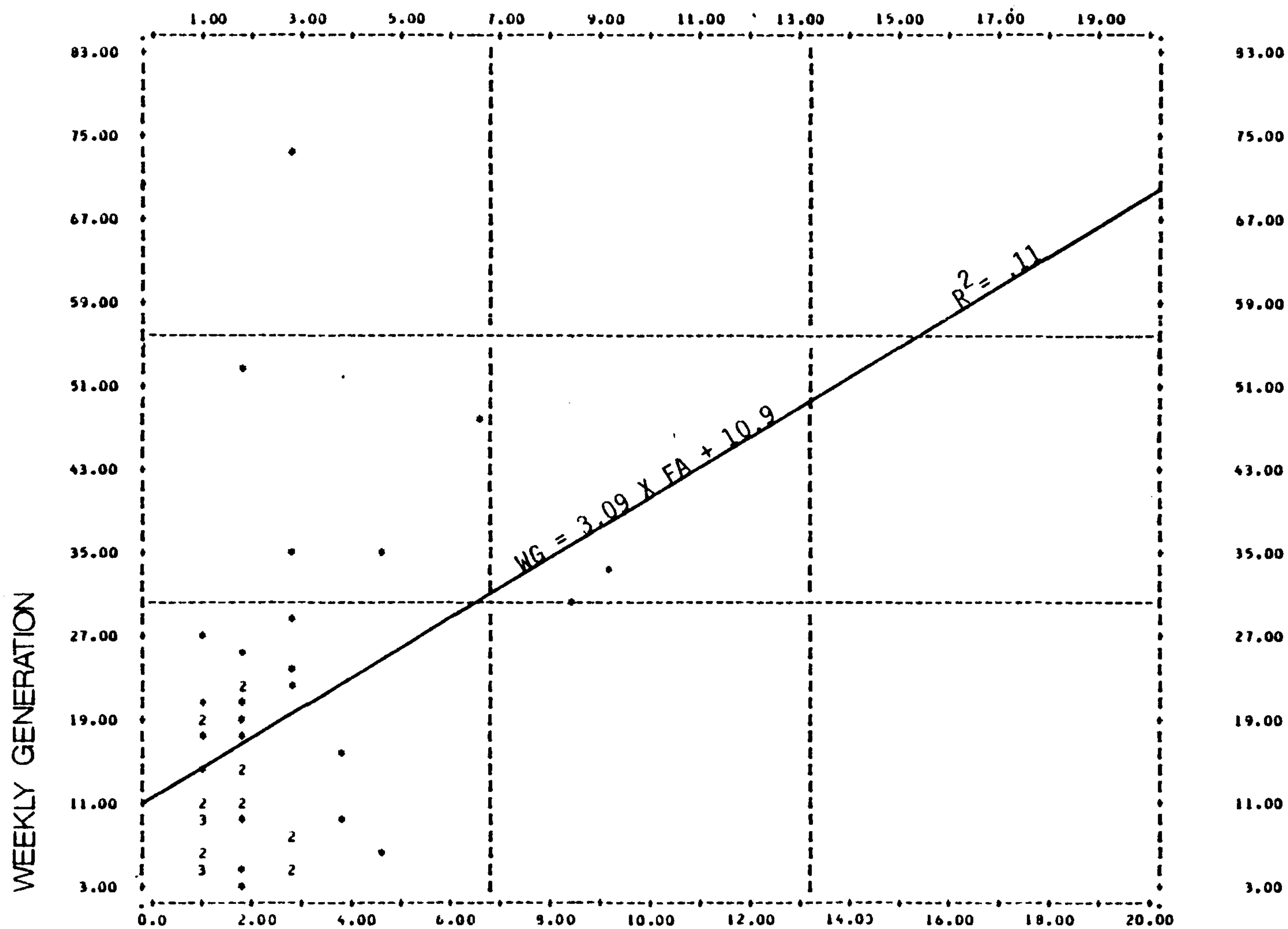


FIGURE 8. PLOT OF WEEKLY PUD GENERATION
VS EMPLOYMENT FOR FOODS LAND USE

FOOD ESTABLISHMENTS



FLOOR AREA (hundreds of square meters)

FIGURE 9. PLOT OF WEEKLY PUD GENERATION VS FLOOR AREA FOR FOODS LAND USE

bines floor area and employment, is shown in Table 8. A review of Figures 10 and 11 shows that the R^2 values for these equations are not substantially different from the regression equation presented in Table 8. This implies that floor area and employment are interdependent variables, and the use of either variable would produce similar accuracy in demand estimation.

The distribution of shipment weight and size is shown in Table 9. The mean shipment weight was 265 kilograms and the mean shipment size was 22.6 packages.

Retail and Service

This aggregated retail and service land use is composed of the various establishment types as shown below.

Banks
Stationery
Clothing
Department Stores
Drug Stores, Health & Beauty Aids
Electronic
Camera
Flowers
Furniture
Jewelry
Liquor
Novelties
Shoes
Bars, Taverns
Entertainment
Garage, Service Stations
Service (locksmith, shoe repairs)
Miscellaneous

They were combined because (1) there were several establishment types with too few samples to analyze independently, (2) the establishment types with large samples all showed similar generation characteristics, and (3) all establishments had similar arrival patterns (primarily due to the fact that the same carriers service all uses). Figure 12 shows a plot of weekly generation versus employment, and Figure 13 shows a plot of weekly generation versus floor area in hundreds of square meters. Combining employment and floor area the PUD generation equation is : $WG=.024xFA+.30xE+8.25(R^2=.75)$. The contribution to R^2 is 99% from E and 1% from FA. Because of this, it is recommended that employment only be adopted for use, by sacrificing a small amount of accuracy for equation simplicity. The resultant demand equations are shown in Table 8.

The distribution of shipment weight and size is shown in Table 9. The mean shipment weight was 95 kilograms and the mean shipment size was 11.8 pieces.

LIGHT INDUSTRIAL & WAREHOUSING

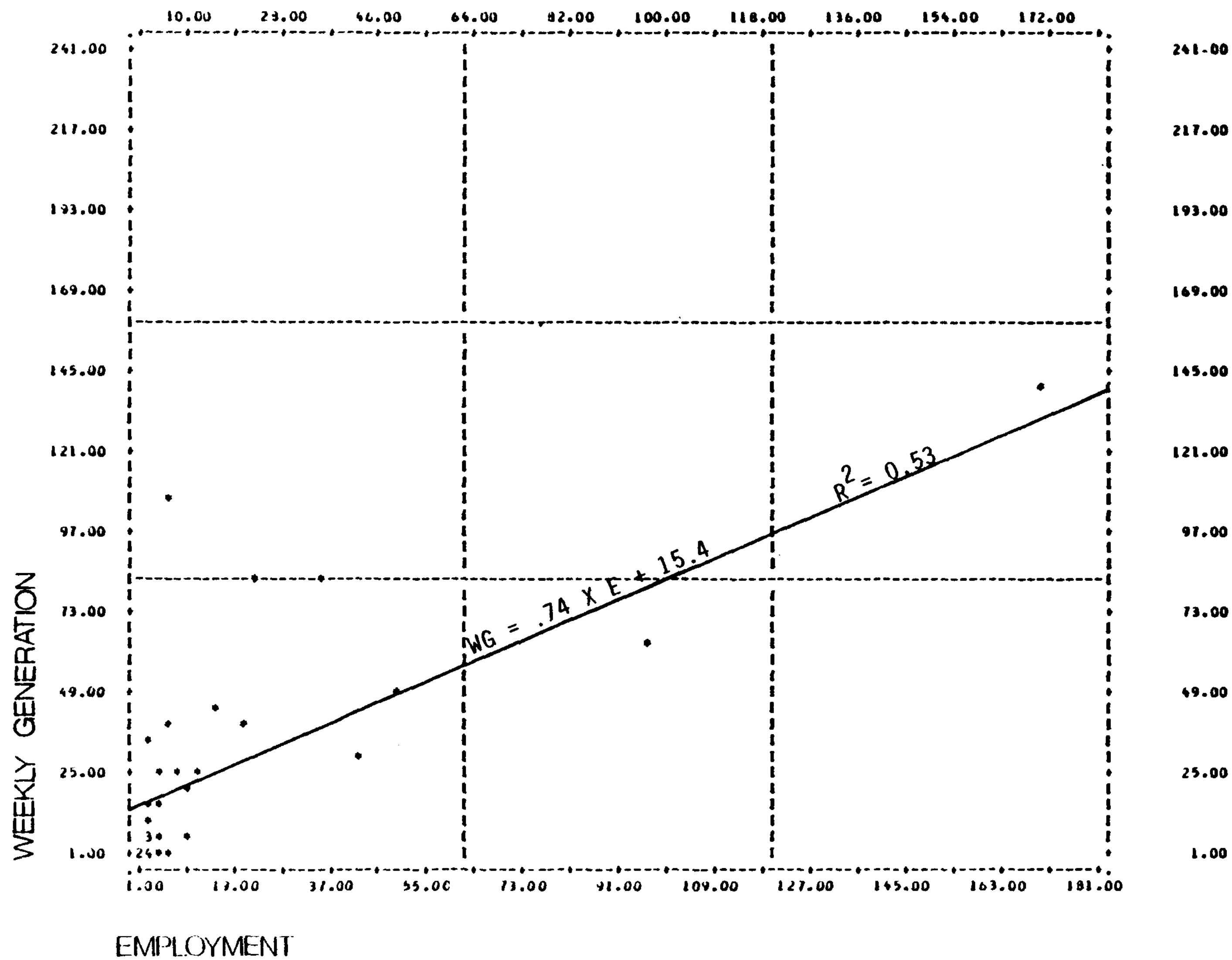


FIGURE 10. PLOT OF WEEKLY PUD GENERATION VS EMPLOYMENT
FOR LIGHT INDUSTRY/WAREHOUSING LAND USE

LIGHT INDUSTRIAL & WAREHOUSING

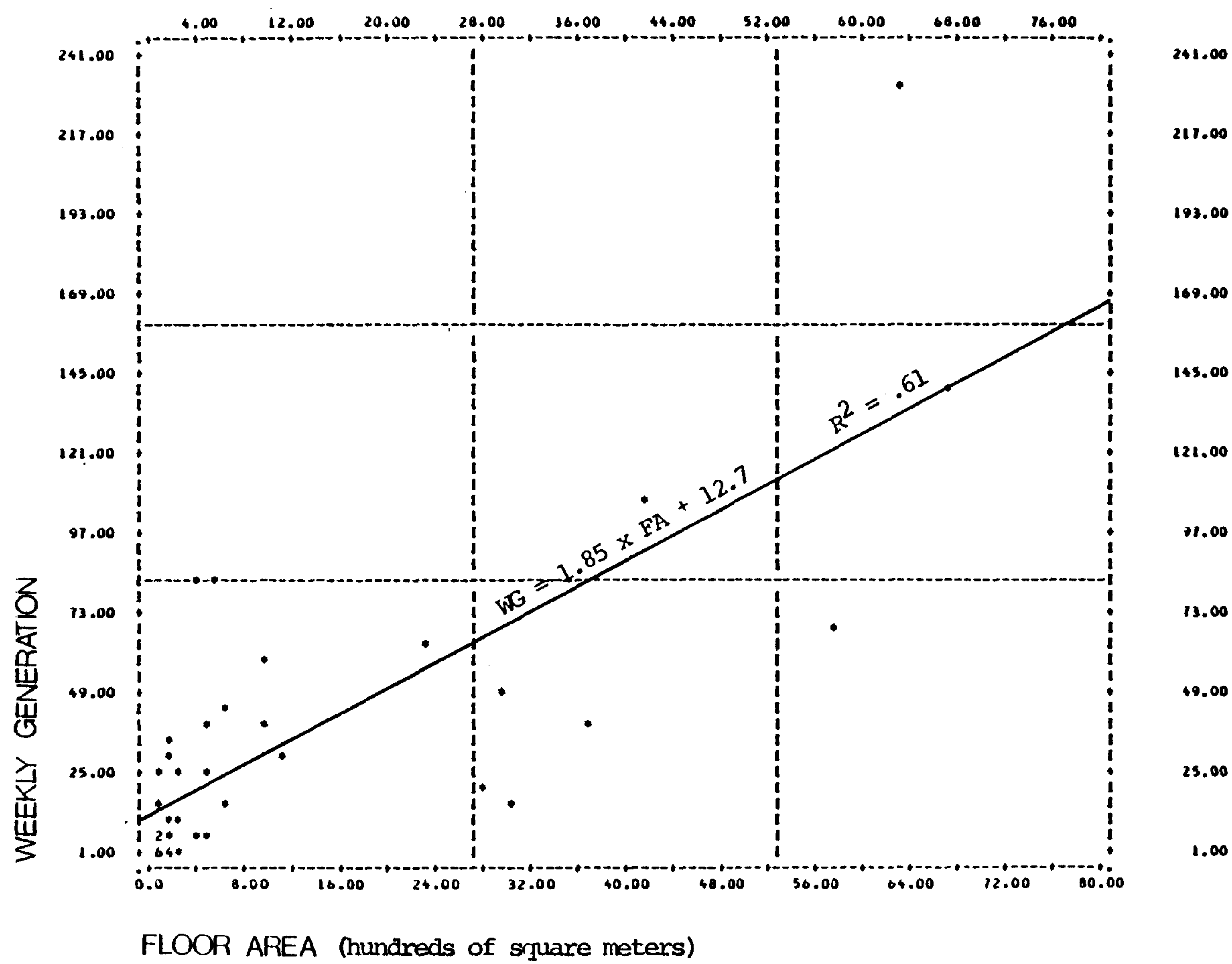


FIGURE II. PLOT OF WEEKLY PUD GENERATION VS FLOOR AREA FOR LIGHT INDUSTRY/ WAREHOUSING LAND USE

RETAIL & SERVICES

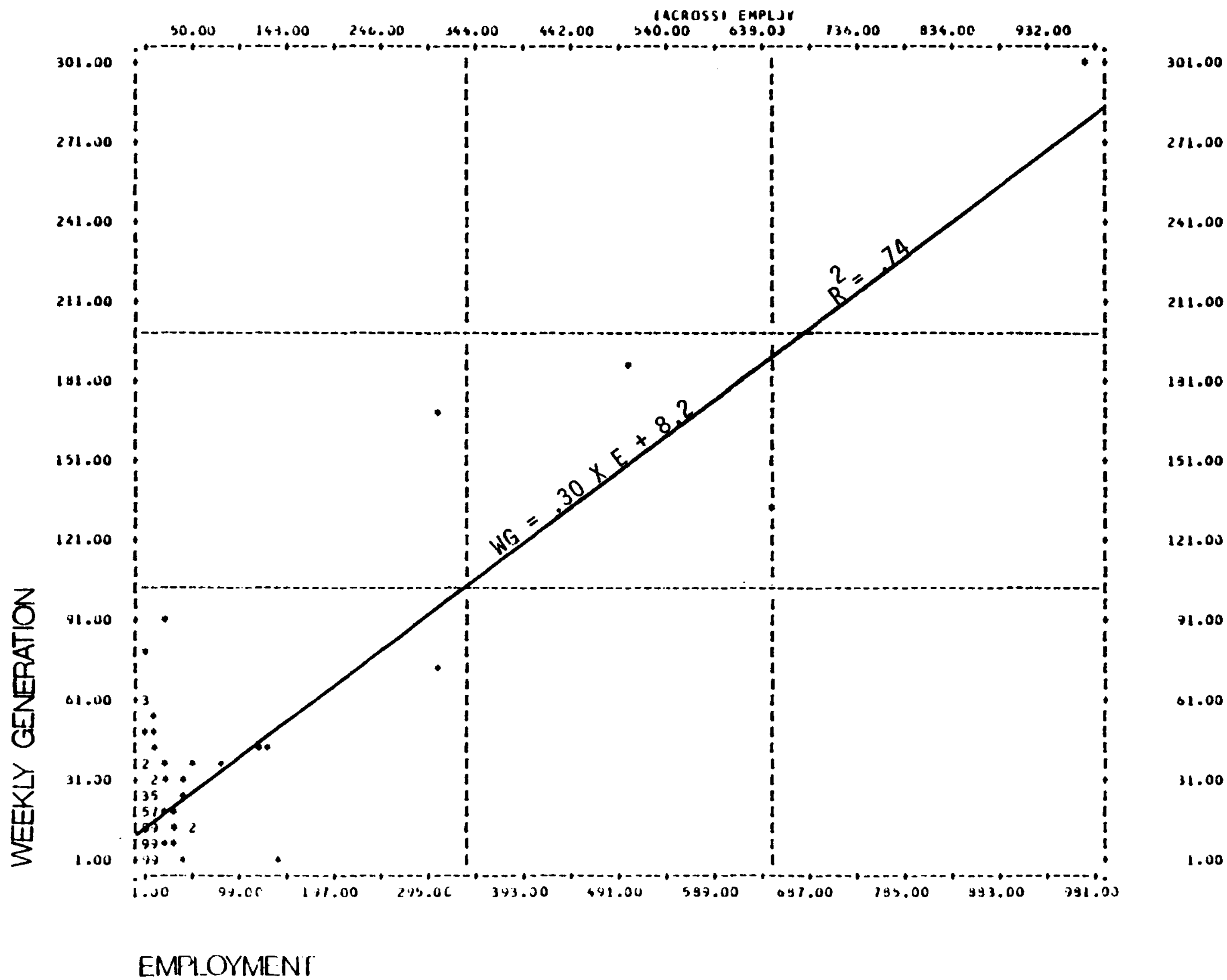


FIGURE I2. PLOT OF WEEKLY PUD GENERATION
VS EMPLOYMENT FOR RETAIL AND SERVICES LAND USE

RETAIL & SERVICES

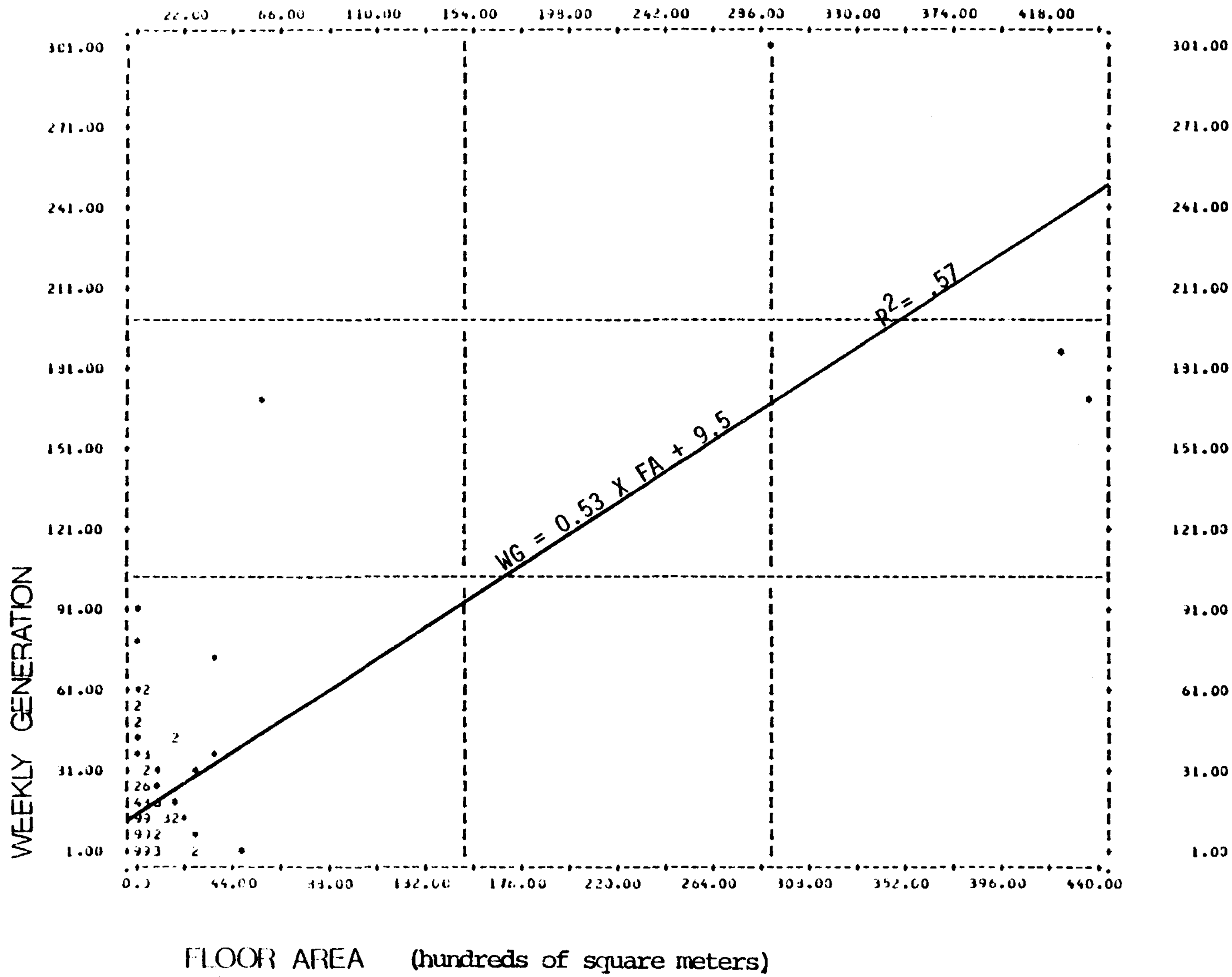


FIGURE I3. PLOT OF WEEKLY PUD GENERATION
VS FLOOR AREA FOR RETAIL AND SERVICES LAND USE

The generation rates produced in this study are derived from a large data base. Several of the equations have high correlation coefficients and are better than those developed previously. The foods-establishment equation has a low R^2 but is consistent with most other studies. Loebl's work (6) essentially concluded that a constant value of generation for prepared foods was usable (his work did not have employment data). For a typical prepared food establishment with 10 employees and three hundred square meters floor area, Loebl's demand equation gives 4 to 6 trips per day. This research predicts a daily generation of 4.3, which is comparable.

It should also be noted here that the data for this study represents Fall PUD operations. Due to the seasonal pattern of freight movement in urban areas (consumer markets), Fall is the peak season. As the data are stratified over the entire Fall period (peaks and valleys), the Research Team considers the demand equations to be average peak conditions for the year, and is representative of conditions that occur for about 4½ months each year.

ARRIVAL PATTERNS

Pickup and delivery arrival patterns change seasonally, as well as by time of day. The seasonal variation is caused by the seasonal demand for consumer products. The hourly variation is caused by (1) the receiver or shipper hours of operation, (2) the use of the truck to first deliver and then pick up freight and (3) drivers union regulations which control the work period.

Seasonal Pattern

Table 10 shows the seasonal pattern for various land uses in downtown areas (1). Figure 14 shows a plot of data collected during this study for a large general-commodity common carrier and for a national small package delivery firm.

Both Table 10 and Figure 14 show that seasonal patterns in PUD activity are: Winter drop, a Spring surge, a Summer low and a Fall peak.

As in the planning and design for other transportation systems, the peak period is the one to be considered, without 'overdesigning'. The four week period between early November and early December is the peak month in PUD, with some peaking within the peak month.

Hourly Arrival Patterns

The hourly demand for curbspace usage by PUD vehicles is primarily a function of land use. However, driver work rules (which fix starting time) and receiver hours also shape the process. The pickup and delivery operations at curbside are carried out either by private carrier or by for-hire carriers. Private carriers are those that own the goods in the vehicle, whereas for-hire carriers transport the goods of others for a fee. The standard mode of operation for a for-hire (common or contract) carrier is to deliver all shipments first

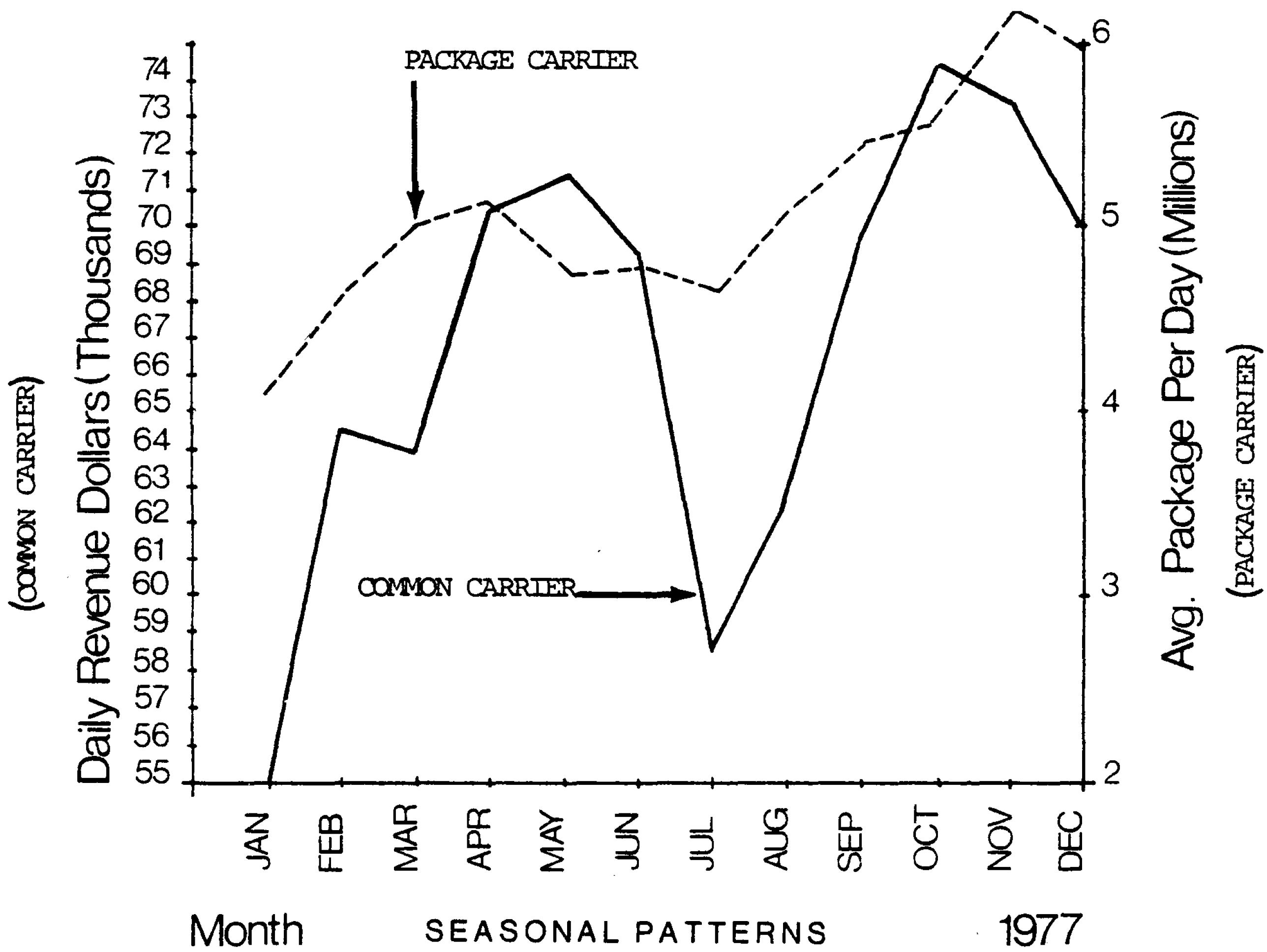


FIGURE I4. PLOT OF MONTHLY VARIATION IN PUD ACTIVITY

TABLE 10 SEASONAL PATTERNS IN PUD DEMAND, BROOKLYN (1)

Month	Prepared & Retail Foods	Retail/ Commercial	Dept. Stores	Office	Resi- dential	Light Industrial
January	8	6	7	8	8	7
February	8	6	8	8	8	8
March	8	8	8	8	8	10
April	9	8	8	8	8	8
May	8	9	8	8	8	8
June	8	7	8	8	7	7
July	8	7	7	7	7	6
August	8	8	8	7	7	8
September	9	9	9	8	8	9
October	8	9	10	9	9	10
November	8	12	10	10	10	10
December	10	11	9	11	12	9
	100%	100%	100%	100%	100%	100%

Source (1)

and then, with the vehicle empty (or almost so), conduct pickups before returning to the terminal. It is expected, therefore, that delivery operations would peak in the morning and pickup operations would peak in the afternoon. For a private carrier, the standard mode of operations is to deliver the product to the retailer/consumer during the work day. Rarely do private carriers need to perform the pickup of freight after the delivery schedule is complete.

Figures 15,16,17,18,19 show the hourly arrival patterns for the land uses in this study. The patterns are all quite similar, except for food establishments, which have earlier trips. Appendix II contains the observed hourly distributions of PUD activity for various dissaggregated land use categories.

The arrival patterns reveal that there are few PUD operations being conducted after 4 in the afternoon and therefore no impact is expected in the PM peak traffic period. The analysis of arrival times by city surveyed showed no statistical variation among cities. This is primarily due to the fact that the temporal pattern in curbside PUD operations in downtown areas is, essentially, a 9 AM to 5 PM business (except for food). The larger the downtown, the farther the PUD operation would go into afternoon hours. As none of the cities surveyed was the size of a New York, a Chicago or a Los Angeles, no appreciable activity progressed late into the afternoon.

ARRIVAL TIME FREQUENCIES

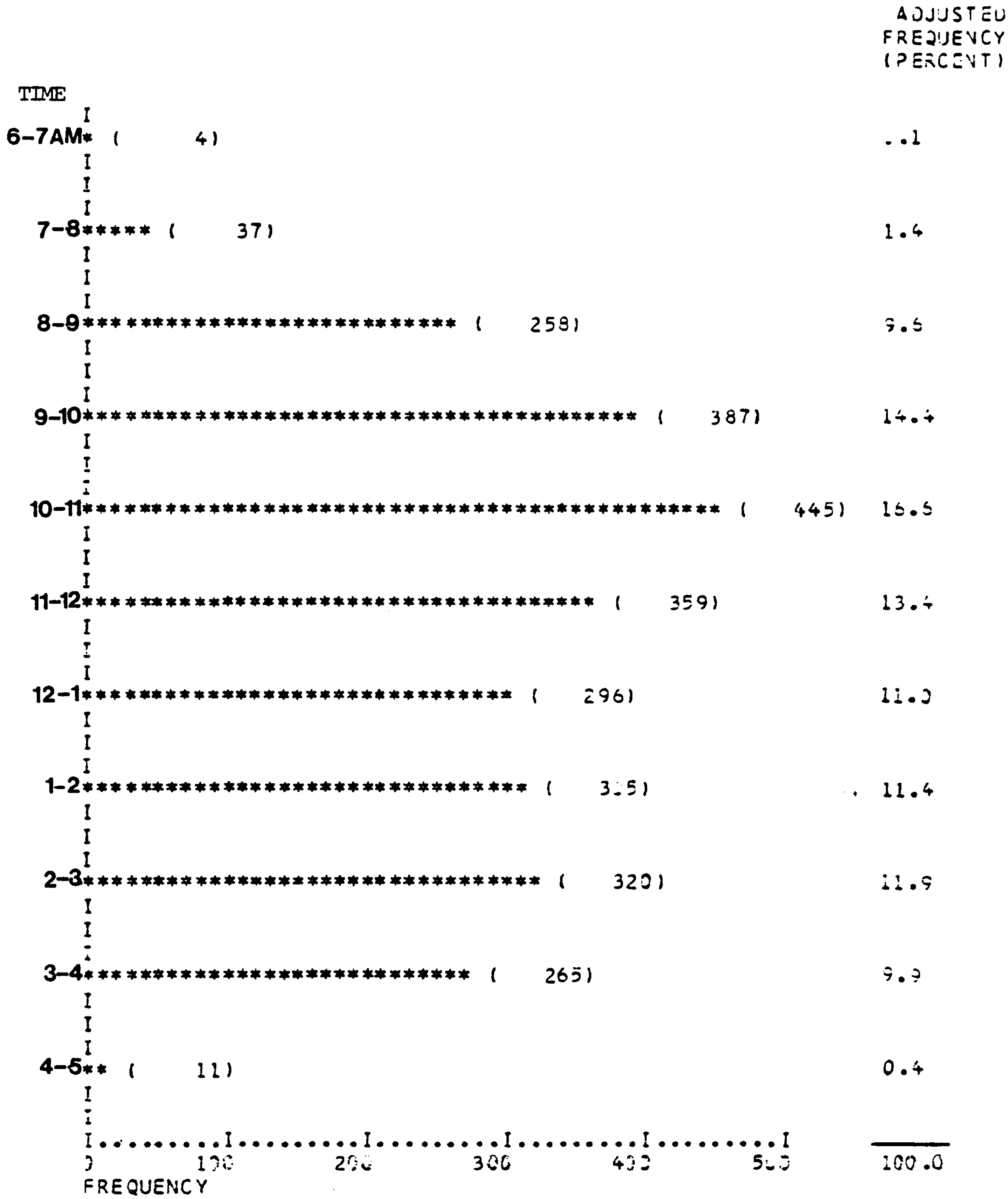


FIGURE I5. PLOT OF PUD ARRIVAL TIME FOR OFFICE LAND USE

ARRIVAL TIME FREQUENCIES

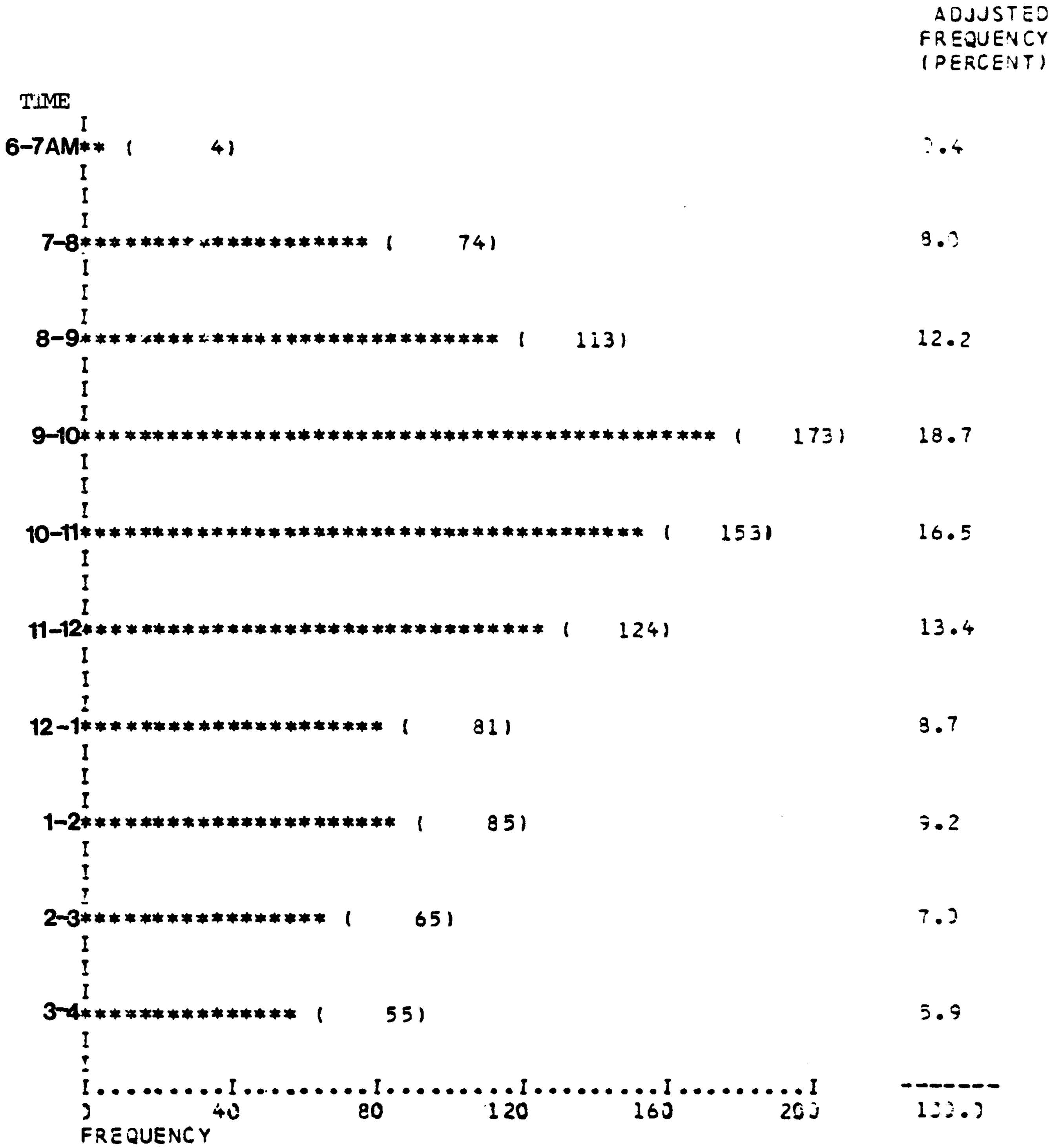


FIGURE I6. PLOT OF PUD ARRIVAL TIME FOR HOTEL AND RESIDENTIAL LAND USES

ARRIVAL TIME FREQUENCIES

```
                                                                   ADJUSTED
                                                                   FREQUENCY
                                                                   (PERCENT)
TIME I
6-7AM****  (      31)                                                2.9
    I
    I
    I
 7-8*********  (      77)                                            7.3
    I
    I
    I
 8-9**************  (     125)                                      11.6
    I
    I
    I
9-10**********************  (     205)                              19.4
    I
    I
    I
10-11**********************  (     208)                             19.7
    I
    I
    I
11-12*****************  (     162)                                  15.3
    I
    I
    I
12-1*********  (      80)                                            7.6
    I
    I
    I
 1-2*********  (      79)                                            7.5
    I
    I
    I
 2-3******  (      46)                                               4.3
    I
    I
    I
 3-4******  (      45)                                               4.3
    I
    I
    I.........I.........I.........I.........I.........I        -------
    0        100       200       300       400       500        100.0
    FREQUENCY
```

FIGURE I7. PLOT OF PUD ARRIVAL TIME FOR FOODS LAND USE

ARRIVAL TIME FREQUENCIES

```
                                                                    ADJUSTED
                                                                    FREQUENCY
                                                                    (PERCENT)
 TIME  I
6-7AM* (       3)                                                      0.2
       I
       I
       I
  7-8**** (      32)                                                   2.4
       I
       I
       I
  8-9******************* (     187)                                   14.0
       I
       I
       I
 9-10********************* (     205)                                 15.4
       I
       I
       I
10-11************************ (     241)                              18.1
       I
       I
       I
11-12***************** (     165)                                     12.4
       I
       I
       I
 12-1************ (     115)                                           8.6
       I
       I
       I
  1-2************** (     144)                                        10.8
       I
       I
       I
  2-3************* (     133)                                         10.0
       I
       I
       I
  3-4********** (      99)                                             7.4
       I
       I
       I
  4-5** (       9)                                                     0.7
       I
       I
       I.........I.........I.........I.........I.........I         -------
       0        100       200       300       400       500         100.0
       FREQUENCY
```

FIGURE I8. PLOT OF PUD ARRIVAL TIME FOR LIGHT INDUSTRY /WAREHOUSING LAND USE

ARRIVAL TIME FREQUENCIES

TIME	FREQUENCY	ADJUSTED FREQUENCY (PERCENT)
6-7AM	41	1.0
7-8	118	2.8
8-9	325	7.7
9-10	696	16.5
10-11	763	18.1
11-12	618	14.6
12-1	464	11.0
1-2	449	10.6
2-3	439	10.4
3-4	302	7.1
4-5	10	0.2
		100.0

FREQUENCY: 0 200 400 600 800 1000

FIGURE I9. PLOT OF PUD ARRIVAL TIME FOR RETAIL AND SERVICES LAND USE

CHAPTER 4

STOPPING CHARACTERISTICS OF PUD VEHICLES

The 'parked' PUD vehicle on a downtown arterial is the principal element influencing goods-movement related traffic delays. The needs of the generator to receive/ship goods, the need to use the curbside (and sometimes a traffic lane) for goods distribution and the need to use all available street space to efficiently move traffic all combine to produce 'the goods-movement problem.' During periods of the day when the individual needs are not all peaked simultaneously (or nearly so), the 'problem' is lessened or non existent. During the periods of the day when all demands for curb space are simultaneously heavy, severe congestion can and sometimes does result.

GENERAL PARKING PATTERNS

Some downtown areas have alleys. Alleys markedly affect PUD congestion in those cities, as they parallel the major arterial system and provide access to the rear of many establishments. Boston and Phoenix have several alleys that attract PUD vehicles from the arterial side of the establishment during peak traffic periods. However, most cities do not have alleys in the downtown area, and even fewer have them in the fringe areas. Table 11 summarizes how PUD vehicles surveyed parked.

TABLE 11 GENERAL CURBSIDE PARKING PATTERNS

	CBD	Non-CBD
Non Alley	90	99
Alley	10	1
	100%	100%

The results show that 90% of curbside PUD activity occurred on the non-alley system. For blocks studied which did have alley access, 38% parked on the alley and 62% parked on another blockface including main arterials. Table 12 shows how all non-alley PUD vehicles parked in the CBD.

TABLE 12 NON-ALLEY PARKING PATTERNS

Curbside-legal	52
Curbside-illegal	22
Double Parked in Moving Lane	17
Curbside in Moving Lane	9
	100%

'Curbside legal' represents space in which PUD vehicles park with no risk of a summons (no "pressure"), including meters, loading zones and unregulated curbspace. 'Curbside illegal' represents parking at bus stops, hydrants, in driveways, etc. About 9% of the vehicles parked in a curbside designated travel lane, and about one of six vehicles double parked on the non-alley system.

The vehicles that arrive and park in a traffic lane (double parked or in a curbside moving lane) will affect traffic speed depending primarily on the volume of traffic. Chapter 5 addresses these relationships. However, being able to predict the incidence and duration of traffic blockages becomes a key element in the transition from generation to lane blockage (see Figure 1) to traffic impact. The following section presents various analyses of double parking patterns.

CHARACTERISTICS OF DOUBLE-PARKED PUD VEHICLES

Several hypotheses that relate the incidence and duration of traffic blockages to PUD demand, available curbspace for PUD vehicles and enforcement of parking regulations have been put forward. The data collected for this study does allow the Research Team to evaluate these hypotheses and to develop new ones as necessary, to produce a predictive tool for lane blockage.

Dwell Characteristics

The dwell time of PUD vehicles is a key element affecting curb space demand as well as duration of blockages. Table 13 shows the frequency distribution of dwell times for the main parking modes for all data collected in six cities.

TABLE 13 DWELL TIME DISTRIBUTION BY PARKING MODE

Period	Double Parked in Moving Lane	Legally Parked at Curbside	Illegally Parked at Curbside
Under 1 minute	8.3	4.1	9.0
1-3	19.2	9.8	13.9
3-5	17.6	12.5	16.6
5-10	22.0	21.0	23.5
10-30	26.1	34.4	26.1
30-60	4.6	11.7	7.8
60-90	1.6	4.4	2.5
Over 90 minutes	0.6	2.1	0.5
	100%	100%	100%
Mean	11.5 min	19.5 min	13.8 min
Median	5.5	11.0	7.0

Double-parked PUD vehicles have the shortest dwell times. The vehicles parked at a hydrant, bus stop and in a no-parking zone had dwell characteristics substantially shorter than the PUD vehicles that are in a 'non-pressurized' parking mode at curbside. However, the mode of parking is not the only variable influencing dwell time. The land use where the PUD operation is being made has a significant effect on dwell time. Table 14 was prepared to show the dwell time distribution at each land use. It should be noted that all are curb side PUD and do not reflect longer dwell times of large office buildings which usually have off-street loading facilities.

TABLE 14 CURBSIDE PUD DWELL TIME DISTRIBUTIONS BY LAND USE

Dwell Time (Minutes)	Office	Residential	Hotel	Light Industry/ Warehousing	Foods	Retail/ Service
Under 1	3.2	15.0	4.3	4.1	3.9	4.3
1-3	11.4	22.2	15.4	10.0	11.2	11.4
3-5	16.9	14.7	16.9	10.2	17.3	13.0
5-10	24.5	14.0	22.3	19.6	23.6	21.3
10-30	29.0	24.0	31.8	31.8	33.3	31.5
30-60	9.2	4.7	5.9	11.7	6.7	10.9
60-120	4.6	3.6	3.0	8.4	2.6	5.5
Over 120	1.2	1.8	0.3	4.2	1.4	2.1
	100%	100%	100%	100%	100%	100%
Mean Dwell (minutes)	18	15	15	27	16	21

The longest dwell times are in light industry/warehousing. This land use generally is dominant near the edges of the CBD and not frequently found in the core. The mean values for the remaining land uses range between 15 and 21 minutes. However, as shown on Table 13, there is a significant disparity between parking modes.

One hypothesis as to which vehicles double park and which do not, relates to the driver's expectation of a short stop. This short stop could logically be caused by a small shipment. An analysis of shipment weight was done for the various parking modes. The results are presented in Table 15.

TABLE 15 SHIPMENT WEIGHT BY PARKING MODE

Shipment Weight(kg)	Double-Parked	Curbside Legally	Curbside Illegally	Curbside Moving-Lane
Under 10	48.5	49.7	50.2	57.5
10-25	13.5	13.7	15.0	12.0
25-45	13.2	12.9	14.0	10.8
45-90	9.7	9.9	8.3	8.0
90-180	7.5	6.4	7.3	4.9
Over 180 kg	7.6	7.4	5.2	6.8
	100%	100%	100%	100%
Mean Weight	43kg	42kg	38kg	37kg

Table 15 shows that there are no appreciable differences between double-parked and legally curbside parked PUD vehicles. All weight distributions are quite similar with the PUD vehicle parked in a curbside moving lane being most skewed towards the smaller weights. What then causes a driver to double park? Based on the results of this data base, the research could not identify any other characteristics of the goods-movement trip (driver, freight, vehicle, etc.) that could predict the randomness of when a lane blockage would occur.

Attention is now turned to the availability of curb space to load and unload freight as a means of identifying a predictive variable(s). This curb space would include bus stops, hydrant zones, driveways, loading zones, plus the various 'auto' spaces as they may become randomly available. Theoretically, for a given hourly demand, the double parking incidence should decrease as 'available' PUD space increases and as enforcement increases. In several cities, double parking is tolerated by enforcement agents as long as the PUD operation seems to be in progress. The initial analysis of double parking was conducted on all blockfaces studied. The preliminary results indicated that there were too many site specific situations (alleys, no non-PUD curbspace demand, other) to conduct the general analysis. Therefore, a sub-set of 13 'classical blockfaces was defined for analysis. This subset had auto parking, bus stops, hydrants, loading zones, and the other elements usually associated with the typical urban arterial blockface.

Table 16 shows the results of the regression analysis for predicting the minutes of double parking as a function of the available independent variables. These variables consisted of generation of PUD trips to the blockface, the allocation of curbspace to auto and non-auto uses, and the enforcement of parking regulations (except in San Francisco).

The regression analysis was conducted for each city separately in an effort to identify 'regional' differences in parking patterns should they exist. The length of available PUD parking space was determined by summing the lengths of bus stops, hydrant zones, truck loading zones and other loading zones on each blockface. This total available PUD space varied hourly. The enforcement of parking was also recorded hourly and was defined as the number of parking agents traversing the blockface (on foot, motorcycle, auto) in each hour. The hourly PUD demand was the number of arrivals in each hour. Using these variables, an hourly regression analysis was conducted for the candidate blockfaces.

The analysis indicates that availability of parking space does gradually reduce the incidence of double parking. The data from San Francisco and Boston are quite similar. Dallas and Oklahoma City

TABLE 16 GENERAL EQUATIONS FOR MINUTES OF DBL PARKING

City	Equation (a)	R^2	Samples (b)	
San Francisco	M = .45xHG- .13xL- .06xF+13	.50	93	(55)
Boston	M = .51xHG- .03xL+ 5xE + 3	.27	57	(44)
Oklahoma City	M = .28xHG+ .03xF+.1xE	.37	48	(35)
Dallas	M = .22xHG+ 1.0xE+ 1	.10	62	(15)
Phoenix	M = .05xHG+ .03xL- .03xF-2.4E+2	.11	85	(17)

(a) Includes all independent variables with coefficients of .01 and over.
(b) Number in brackets represents number of hours in which there was at least one minute of blockage by double parking PUD vehicle.

Where: HG is the hourly generation of PUD vehicles on the blockface
M is minutes of blockage in any hour
L is length (meters) of curbspace for PUD 'use' in that hour (loading zones, bus stops, hydrants, etc.)
F is all other blockface length (blockface length minus L) in meters.
E is number of enforcement agents in that hour crossing blockface. (Not recorded in pilot city, San Francisco).

are also similar to each other. It is also evident from Table 16 that in Phoenix and Dallas, the number of hours with double parking (17 and 15 respectively) is very small in the sample, thereby producing equations that are of a poorer quality. These equations should be dropped from consideration. Also evident from Table 16 are the positive coefficients of variable E (enforcement), which are counter-intuitive. This can be 'explained' by: (1) double parking is tolerated most of the time, (2) the worse the problem, the more agents are dispatched to an area and (3) E is really a 'non-variable,' as in no equation did it contribute more than .02 to R^2.

Therefore, in order to present 'usable' equations related to predicting minutes of double parking, Table 17 was developed.

TABLE 17 FINAL EQUATIONS FOR MINUTES OF DOUBLE PARKING LANE BLOCKAGE

City	Equation
San Francisco	M = 0.46xHG- .06xL+4
Boston	M = 0.54xHG+ 2
Oklahoma City	M = 0.28xHG+.03xF

Where:
- HG is the hourly generation of PUD vehicles on the blockface
- M is the minutes of blockage in any hour
- L is the length (in meters) of 'PUD curbspace'
- F is all other blockface length (blockface length minus L)

A review of Table 17 shows that the San Francisco and Boston equations yield similar results. For example, a typical 135 meter downtown blockface generating 15 PUD in an hour with nominal amount of 'PUD curb space' (30%) will have 8.5 minutes of blockage in San Francisco and 10.1 minutes of blockage in Boston. The corresponding amount for Oklahoma City would be 5.4 minutes. The three suggested equations do point out the regional differences in parking of PUD vehicles for typical field conditions. In Dallas and Phoenix, double-parking was seldom found during the survey, a further indication of the large regional differences in parking patterns, PUD trip densities and the provision of off-street (and alleys) facilities that exist in the various central areas nationwide.

Another method of viewing double parking is to determine the probability of its occurrence given various independent variables. Regression equations were developed for Boston and San Francisco as the data from these two cities consisted of an adequate number of cases for the regression analysis. Table 18 shows the results of this analysis.

TABLE 18 BOSTON, SAN FRANCISCO DOUBLE PARKING ANALYSIS

SAN FRANCISCO

Hourly number of double parkers=0.39xHG + .0002xL -2.32 (R^2 =0.75)

BOSTON

Hourly number of double parkers = 0.50xHG- 0.019xL +2.6 (R^2 = 0.50)

Where HG is total hourly generation of PUD vehicles and L is amount of available curbside PUD curbspace

Table 18 shows similar characteristics between Boston and San Francisco, with the regression equations predicting 37% to 48% of hourly PUD demand selecting the double parking mode under typical curbside conditions. In research conducted in Brooklyn (1) patterns were quite similar to those found in Boston and San Francisco. Table 19 summarizes the Brooklyn data.

TABLE 19 PUD PARKING MODE BY PARKING REGULATION IN FRONT OF DESTINATION ESTABLISHMENT

Parking Mode	When auto parking is: Allowed	Prohibited
Parking Meter	20	1
Loading Zone	6	18
Double Park	41	8
Curbside Illegal	33	73

Source (1)

The data from downtown Brooklyn indicates that when auto parking is allowed in front of the destination establishment only 20% of the PUD vehicles were able to park in these 'auto spaces' and therefore selected other modes of parking, primarily double parking (41%). When the curbspace was clear of auto parking (loading zone, bus stop, hydrant, no parking zones), only 8% of the arrivals found the need to double park. The 41% figure for double parking when auto parking dominates a blockface is similar to the values found in the Boston and San Francisco data (see Table 18).

The need to develop a single double parking forecasting tool is essential in the further development of the traffic impact tools for curbside PUD. The above data indicates that, given a blockface with little or no available PUD curbspace, approximately 37% to 48% of the arriving vehicles double park given no off-street facilities and no abnormal enforcement. On the other end of the scale, for a blockface where auto parking is completely prohibited, the theoretical percentage of double parking is zero. However, this zero value does not usually occur and the downtown Brooklyn findings of 8% double parking appears to be a realistic figure. From these basic inputs, and with the logical assumption that as PUD space 'availability' increases, double parking decreases, Figure 20 was developed to represent expected value of percentage double parking related to PUD curbspace availability.

Figure 20 clearly generalizes the condition as they appear in the field. As it is rare that the PUD demand on a blockface exceeds the capacity of the blockface to process these vehicles, the graph in Figure 20 provides an estimate of the probability that any single (independent event) PUD vehicle will double park. The ordinate of the graph, which has '% of blockface available for PUD use' provides the basis for combining two important 'supply' variables affecting PUD double parking: (1) general spaces availability and (2) space availability <u>in front (or very close to)</u> the destination establishment.

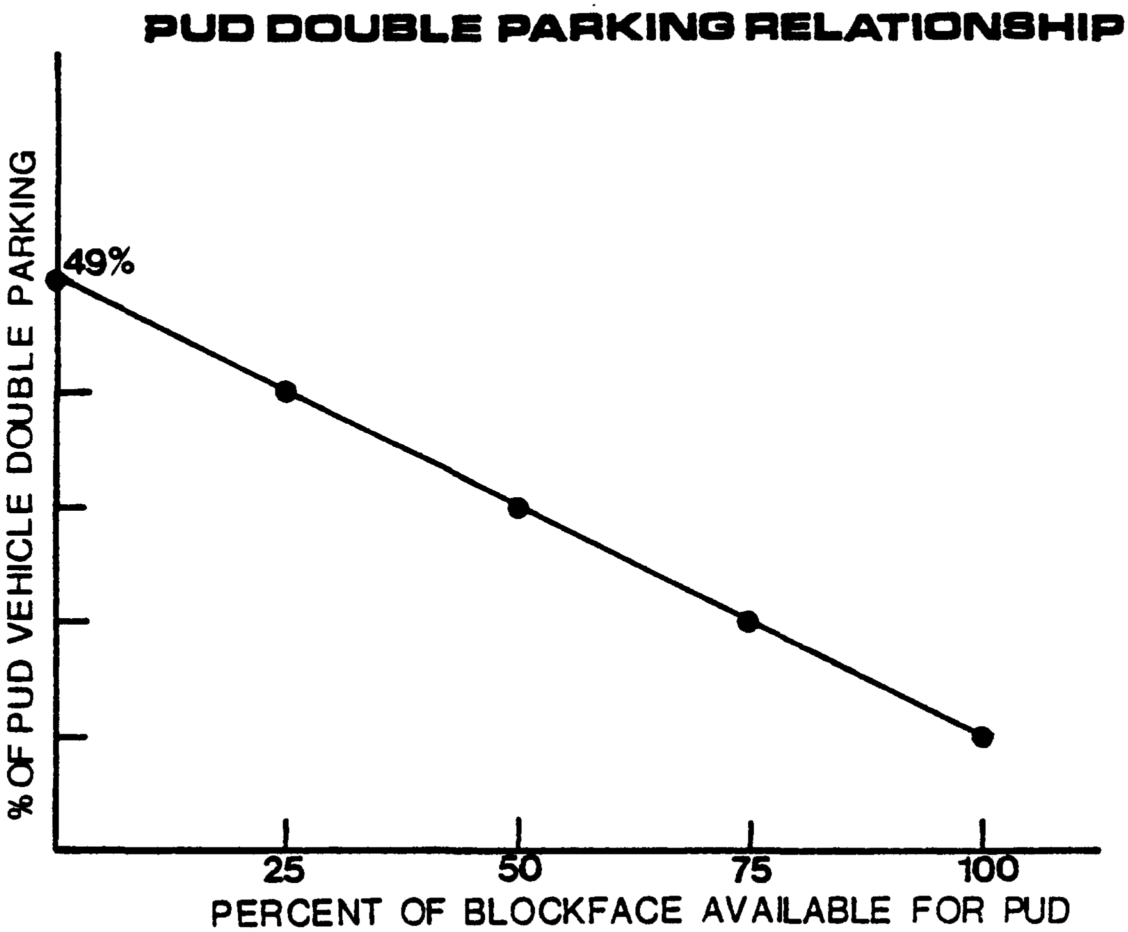


FIGURE 20. RELATIONSHIP BETWEEN PUD DOUBLE PARKERS AND AVAILABLE CURB SPACE

Parking in a Curbside Moving Lane

During certain periods of the day on selected arterials, the curb lane is designated no parking or no standing, primarily to facilitate traffic flow. When the standard arrival pattern shows generation during these no parking/no standing periods, a certain percentage of the normal PUD arrivals will still block the moving lane. The reasons are (1) it is legal (or unenforceable) for PUD vehicles to stand in these areas (2) the risk of a summons is worth taking and (3) there is no alternative (receiver must get merchandise by a certain hour). This section reviews the data collected on this matter. The analysis was done for peak periods (7 to 9 AM and 4 to 6 PM).

Table 20 presents the regression equations developed to predict curbside moving-lane blockages.

TABLE 20 GENERAL EQUATIONS FOR CURBSIDE MOVING LANE BLOCKAGE IN PEAK PERIODS

City	Equation	R^2	Samples
San Francisco	M = 0.33xHG + 1	.31	20
All other cities	M = 0.19xHG - .38xE + 10	.09	32

where M is minutes of blockage.

The equations developed are generally very poor predictors of blockage of a moving lane. This is primarily the result of a very limited amount of data for this type of PUD parking. As a blockface generates demand, parking in the moving lane increases. The San Francisco equation indicates that for an hourly generation of 15 PUD vehicles, a blockface would have about 6 minutes of moving lane blockage. This follows the 8.4 minutes calculated from the double parking lane blockage, equation of the previous section. Logically, there would be a difference due to: (1) the driver's awareness of the impact of the potential interruption and (2) the heavier enforcement during these periods. Subsequent analysis on this aspect of PUD parking can only proceed with additional data from subsequent studies. The San Francisco equation shown on Table 20 is somewhat reliable, whereas the 'All Other Cities' equation is quite unreliable for estimating blockage duration when the curbside is designated as a travel lane.

CHAPTER 5

EFFECTS OF TRAFFIC BLOCKAGES

As on-street pickup and delivery of freight is the dominant mode of accomplishing the transfer of materials in central areas, the PUD vehicle (primarily small and intermediate sized trucks) will park at curbside or double-park as close to the destination as possible. Several cities, such as Boston and Phoenix, have alleys from which goods can be transferred. However, in most cities, this transfer occurs either at curbside or off-street in a loading dock or parking lot. This chapter presents the analysis of the effect of curbside and double-parked PUD operations on traffic speed and level of service for arterial streets on which these operations are dominant.

The study design for traffic impact determination was to collect data on traffic blockages by PUD vehicles (see Chapter 2) and use this data to calibrate NETSIM, a widely accepted traffic simulator. NETSIM was then used to simulate the effect of PUD blockages under various traffic and street conditions.

The data was collected from films of actual on-street blockages. Travel time data on the subject blockface was sampled before and again during the blockage. Subsequent analysis of impact was done on average travel time delays, travel speeds and change in speeds due to lane blockages. It was not possible to distinguish a locked-wheel stop accurately from the films. As not all blocks were of equal length, speed data analysis proved preferable to travel time.

BLOCKAGE ANALYSIS

It is hypothesized that at a certain low volume level, a lane blockage does not impact flow speed. Also, at very high volume levels (near capacity), the intersection so controls the flow that a blockage (except right at the downstream intersection approach) does not affect speed. Figure 21 shows a hypothesized volume versus speed reduction for traffic impact due to a lane blockage. V_o would be a threshold volume below which there would be no apparent effect.

Figure 22 shows the results of the actual impact on speed caused by the lane blockage. It should be noted here that none of the cases shown is an approach-lane blockage at the downstream intersection. As such, in the cases shown, the intersection characteristics still control the capacity of the block, and it would be expected that speed reduction from the blockage would approach zero as volume approaches capacity (1400-1500 vphgpl).

NETSIM simulations were designed and run for each test case and the travel time and speed results of the simulation were compared with recorded field conditions. As NETSIM was not created to simulate lane blockages by trucks, the development of relationships between simulated and actual conditions was essential in interpreting the simulations to be made for the various volume levels, street sizes and

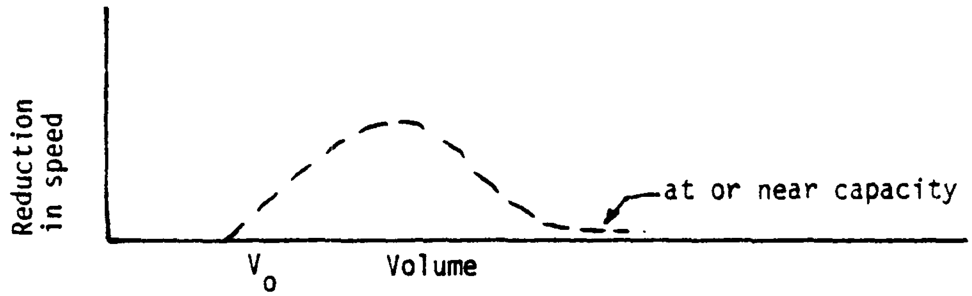


FIGURE 21. HYPOTHESIZED VOLUME/SPEED REDUCTION RELATIONSHIP FOR LANE BLOCKAGES

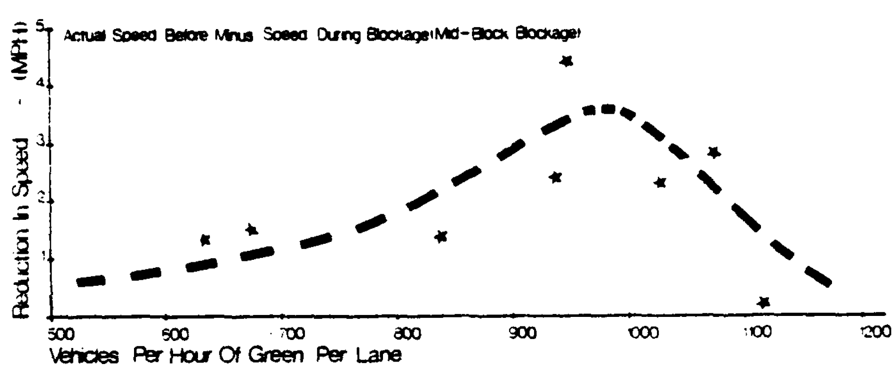


FIGURE 22. RECORDED VOLUME/SPEED REDUCTION RELATIONSHIP FOR LANE BLOCKAGES

types, and lane blockage configurations. The variable used to 'validate' NETSIM was reduction in average speed on the block due to lane blockage.

On a typical one-way or two-way arterial street there is a variety of blockage configurations. For instance, on a one-way facility there could be an upstream blockage, or a mid-block blockage, a downstream blockage, or a downstream blockage on one side and a mid-block blockage on the other side. There are, for all practical purposes, 64 blockage configurations on a one-way street and 6 on a two-way street (in one direction). Each blockage configuration will impact traffic differently. These configurations would define the state of the blockspace at time T. The state of the blockface would constantly change over time as PUD vehicles arrive and depart.

The analysis process defined six blockage configurations on a one-way street and three blockage configurations for a two-way street to which all configurations could be reduced for traffic impact purposes. It has been determined from previous research (and substantiated in this study) that a lane blockage at the downstream approach is the most severe conflict, and thereby controls the flow characteristics independent of other blockages upstream. Similar identification was done to define the 'hierarchy' of other lane blockages and their respective effects on traffic flow, and a set of different (and independent) blockage states were developed that contains all possible blockage states. Figure 23 shows the set of six independent (from the traffic impact viewpoint) blockage configurations for a one-way street. A two-way street would only have configurations 1, 2 and 3 in each direction.

These final configurations were simulated with NETSIM under varied volume levels and the results adjusted as per the field data test cases. These simulations were conducted to provide quantitative estimates of lane blockage impact for a variety of field conditions. The following is a listing of the ranges of the simulation parameters done for this study:

Number of Moving Lanes per Direction	2, 3, 4
Directions	one-way, two way
Volumes	v/c=.50,.70,.80,.85,.90,(5% trucks)
Blockage Durations	3,7,12,20 and 30 minutes
Intersection Characteristics	10% right and left turns, G/c=0.50, cycle length = 90 seconds
Block Length	122 meters
Other Considerations	NETSIM does not consider parking vs. no-parking nor does it consider lane widths.

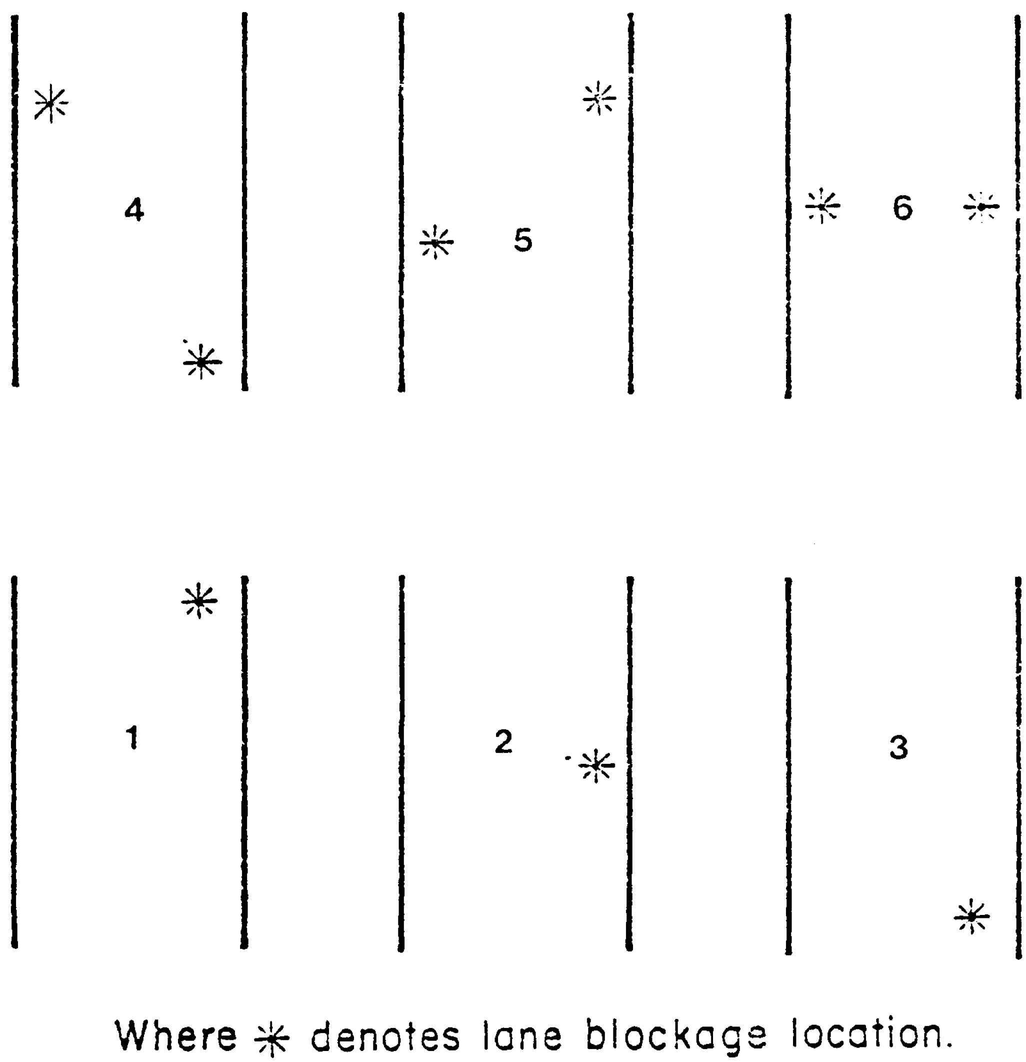
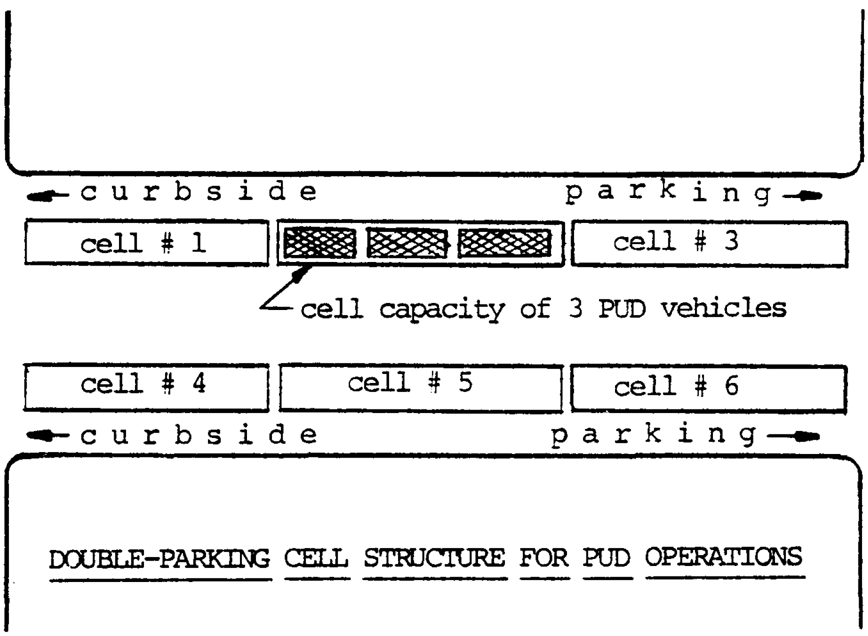


FIGURE 23. FAMILY OF BLOCKAGE CONFIGURATIONS
FOR ONE-WAY STREET

Figure 24 shows the developed speed reduction relationships for the blockage configurations simulated under the above defined conditions.

Given a PUD demand D for a block, and that 'd' is the estimated portion that will double park (from Figure 20), then dD is the hourly double parking demand for the block. These double parkers will be distributed along both blockfaces. The analysis process divides the urban block into six cells (three cells on each side of the street) in which the PUD vehicles could double park. Assuming that the distribution of double parkers is uniform over the entire block, then the demand for double parking in each cell is dD/6.



DOUBLE-PARKING CELL STRUCTURE FOR PUD OPERATIONS

The probability of any configuration state would be the product of the probabilities that double parkers only occupy the cells that define that configuration. On a typical urban blockface, each cell would be approximately 40 meters long and capable of processing up to 3 PUD vehicles at one time. Table 13 shows that the mean dwell time of a double parker is about 11.5 minutes excluding maneuvers, which can vary from one to three minutes. The analysis process conservatively assumes that each of the three serving positions in a cell can process PUD vehicles at a mean rate of four per hour. Therefore, the probability that any cell is empty (no double parkers in that cell) can be estimated by the general equation:

$$P_0 = \frac{1}{\sum_{n=0}^{c-1} \frac{1}{n!}\left(\frac{\lambda}{\mu}\right)^n + \frac{1}{C!}\left(\frac{\lambda}{\mu}\right)^C \left(\frac{\mu C}{\mu C-\lambda}\right)}$$

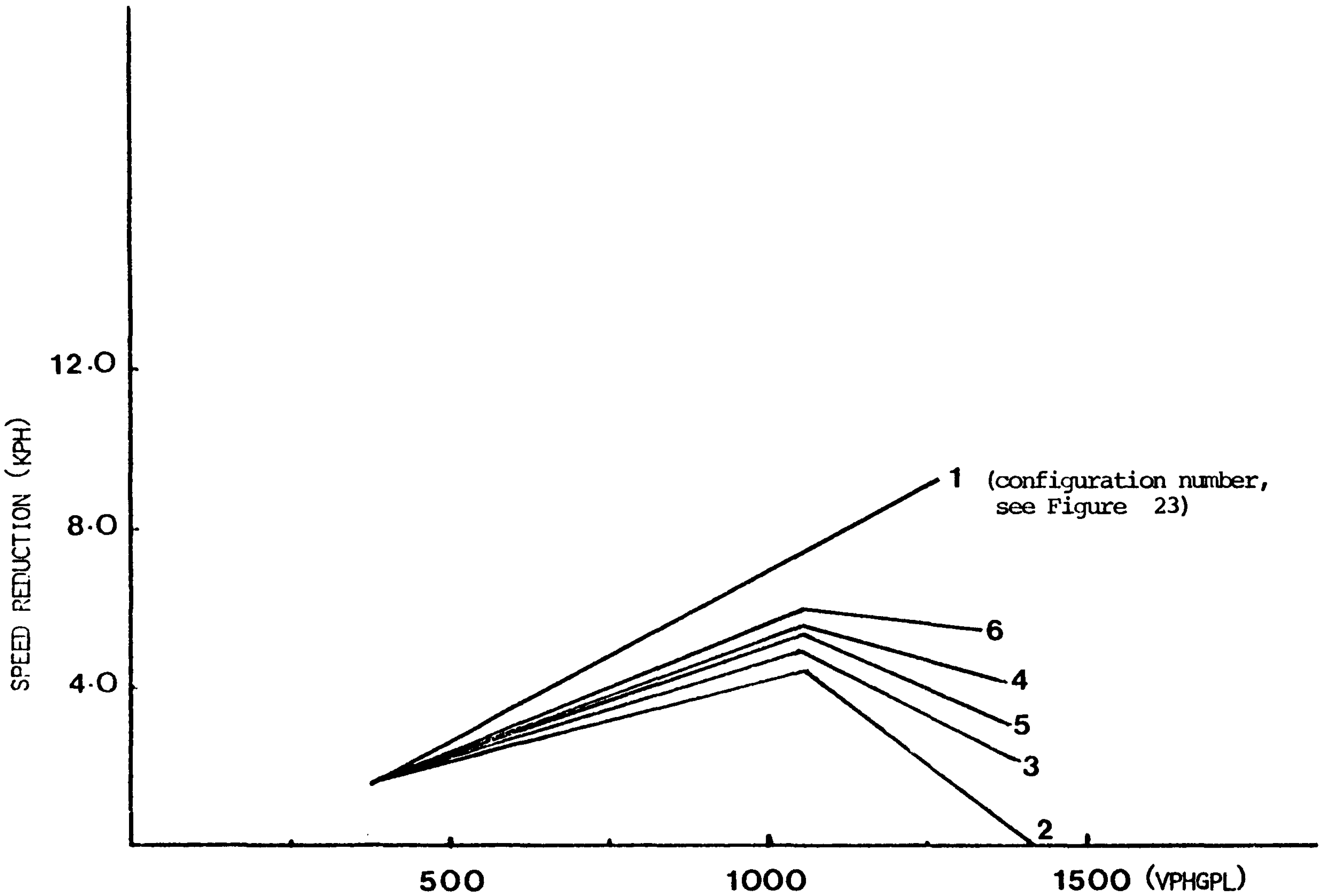


FIGURE 24. TRAFFIC FLOW SPEED REDUCTION
FOR VARIOUS BLOCKAGE CONFIGURATIONS

where P_o is the probability of no PUD vehicles in any cell,
λ is the hourly arrival rate for double parkers to any cell,
μ is the service rate per position in any cell,
C is the number of positions in any cell.

For the analysis process developed herein,

$$\lambda = \frac{dD}{6}\ \text{PUD/HR}$$

$$\mu = 4\ \text{PUD/HR}$$

$$C = 3\ \text{positions per cell}$$

and

$$P_o = \frac{1}{\sum_{n=0}^{2} \frac{1}{n!}\left(\frac{dD}{24}\right)^n + \frac{.00087(dD)^3}{72-dD}}$$

where dD is the total number of double parkers arriving to the block per hour.

The probability of any blockage configuration would then be calculated as follows:

$$\text{Prob. of Configuration} = (1 - P_o)^b \times P_o^{6-b}$$

where: b is number of cells in which there must be at least one PUD vehicle and P_o is the probability that there is no PUD vehicle in the cell.

As an example, the probability of configuration 2 on a one-way street (noting that this configuration can occur on either side of the street with the same impact) would be:

$$\text{Prob. of Configuration 2} = 2 \times (1 - P_o)P_o^5$$

The above technical presentation shows that the probability of an arterial block being in any of the various configuration states is a function of demand of PUD vehicles on that block. Therefore, probability matrices were developed for each configuration under different PUD demand levels. As demand rises, the probability of the most severe configurations also rises.

RESULTANT LEVELS OF SERVICE

Tables 21 and 22 show the expected reduction in speed (KPH) for a variety of traffic volume and PUD double parking demand, for one-way and two-way operation on arterial streets. Tables 23 and 24 show the expected resultant level of service on the arterial street under various traffic volumes and PUD double parking demand. The reductions in speeds due to each PUD double parker demand were

TABLE 21

SPEED REDUCTION(KPH) FOR ONE-WAY ARTERIALS FOR VARIOUS DOUBLE-PARKING PUD VEHICLE DEMAND ON BLOCK-BOTH SIDES

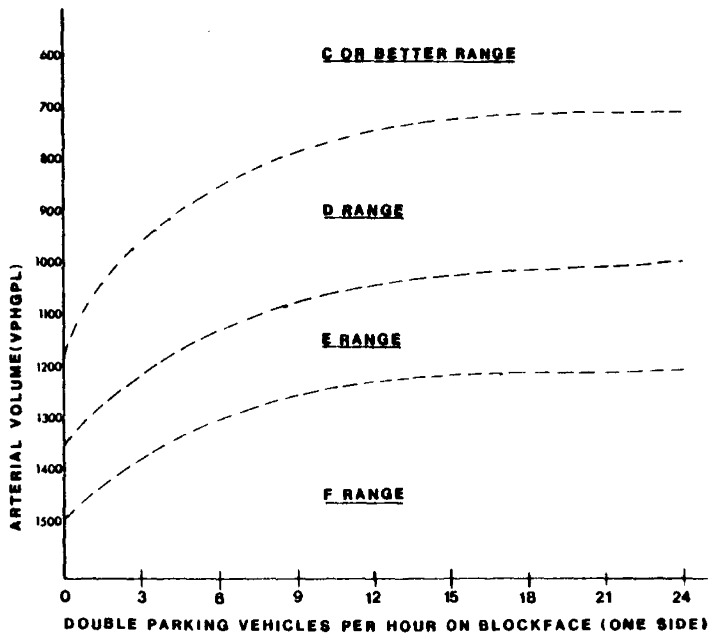
VOLUME VPHGPL)		6 PUDS PER HR	12 PUDS PER HR	24 PUDS PER HR	36 PUDS PER HR	48 PUDS PER HR
500	*	2.1	2.7	2.9	3.0	2.9
550	*	2.4	3.0	3.2	3.4	3.3
600	*	2.6	3.3	3.6	3.7	3.7
650	*	2.9	3.6	3.9	4.1	4.1
700	*	3.1	3.9	4.2	4.5	4.5
750	*	3.4	4.2	4.6	4.9	4.9
800	*	3.6	4.5	4.9	5.3	5.3
850	*	3.9	4.8	5.2	5.6	5.8
900	*	4.1	5.1	5.5	6.0	6.2
950	*	4.4	5.4	5.9	6.4	6.6
1000	*	4.7	5.5	5.9	6.5	6.8
1050	*	4.7	5.5	6.0	6.7	7.1
1100	*	4.6	5.5	6.1	6.9	7.4
1150	*	4.5	5.5	6.2	7.2	7.7
1200	*	4.5	5.5	6.2	7.4	8.1
1250	*	4.4	5.5	6.3	7.6	8.4
1300	*	4.3	5.5	6.4	7.8	8.7
1350	*	4.3	5.5	6.5	8.1	9.0
1400	*	4.2	5.5	6.6	8.3	9.3

TABLE 22

SPEED REDUCTION(KPH) FOR TWO-WAY ARTERIALS FOR VARIOUS

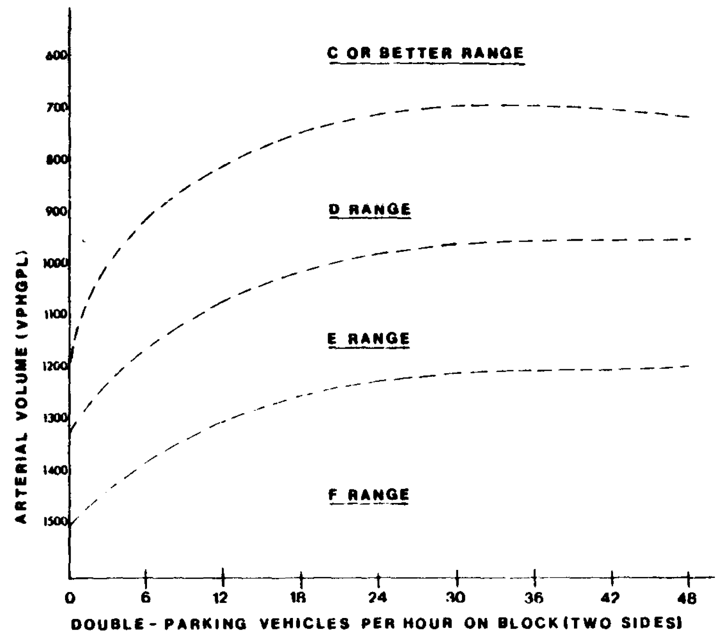
DOUBLE-PARKING PUD VEHICLE DEMAND ON BLOCK - ONE SIDE

VOLUME (VPHGPL)		3 PUDS PER HR	6 PUDS PER HR	12 PUDS PER HR	18 PUDS PER HR	24 PUDS PER HR
500	*	1.4	2.2	2.7	2.8	2.8
550	*	1.6	2.4	3.0	3.2	3.2
600	*	1.8	2.7	3.4	3.6	3.6
650	*	1.9	2.9	3.7	3.9	4.0
700	*	2.1	3.2	4.0	4.3	4.4
750	*	2.3	3.4	4.3	4.7	4.8
800	*	2.4	3.6	4.6	5.0	5.2
850	*	2.6	3.9	5.0	5.4	5.6
900	*	2.8	4.1	5.3	5.8	6.0
950	*	2.9	4.4	5.6	6.1	6.4
1000	*	3.3	4.8	6.0	6.4	6.7
1050	*	3.2	4.7	6.0	6.6	7.0
1100	*	3.1	4.6	6.0	6.7	7.3
1150	*	3.0	4.5	6.0	6.9	7.5
1200	*	2.9	4.4	6.0	7.0	7.8
1250	*	2.8	4.3	6.0	7.2	8.0
1300	*	2.7	4.2	6.0	7.3	8.3
1350	*	2.6	4.1	6.1	7.4	8.6
1400	*	2.5	4.0	6.1	7.6	8.8



LEVEL OF SERVICE FOR LANE BLOCKAGES ON TWO-WAY ARTERIALS

TABLE 24



LEVEL OF SERVICE FOR LANE BLOCKAGES ON ONE WAY ARTERIALS

TABLE 23

calculated by multiplying the probability of each configuration (under that demand) by the speed impact for each configuration (Figure 24) and then summing the products.

The levels of service shown in Tables 23 and 24 were determined by combining the no-blockage volume-speed curve from the NETSIM simulations with a general volume/level-of-service relationship (see Figure 25). This relationship is drawn from Transportation Research Circular #212, Interim Materials on Highway Capacity, January 1980. To find the resultant level of service caused by PUD blockages, the hypothetical volume was used to find the no-blockage speed, which in turn was reduced by appropriate values (from Tables 21 or 22) to determine the resultant level of service.

These levels of service would be more appropriate descriptors of a segment (several blocks) of arterial than for an individual block as a random PUD arrival pattern based on a uniform distribution along the block was assumed in the analysis process. That is, if a block has a very large downstream generator and little or no generation elsewhere, the tables shown would underestimate the impact. On the other hand, should that major generator be at mid-block, an over-estimate would be expected.

ASSESSMENT OF RESULTS

Tables 23 and 24 show that PUD activities can have a significant effect on level of service on the arterial street. It should be noted that a single 122 meter (400 foot) blockface can process about 40 PUD operations per hour in a blocked lane. As such, the PUD demand levels shown in Tables 23 and 24 are not worst case conditions. In addition, previous work (1) in this area showed no relationship between block length and traffic impact from PUD operations. Therefore, the PUD double-parking demand rates shown in this report are PUD demand per 122 meters per hour. This implies that the results would be transferable to other block lengths without much loss in accuracy.

Under a very small amount of PUD activity, the maximum throughput of an arterial street will be reduced from about 1500 VPHGPL to 1325 VPHGPL. This reduction must be viewed as the minimum effect of PUD operations. The range of effects grows larger as PUD demand increases.

As PUD activity is regular and not a random occurance, auto drivers know of the expected delays and avoid specific streets as not being on the minimum impedance path for their trip. Therefore, the hypothetical impact may never occur as the traffic volume would generally not reach the hypothesized level. However, traffic engineers that calculate downtown street capacity without a great deal of assessment of on-street PUD operations are overlooking a key determinant in street-segment capacity and quality of flow.

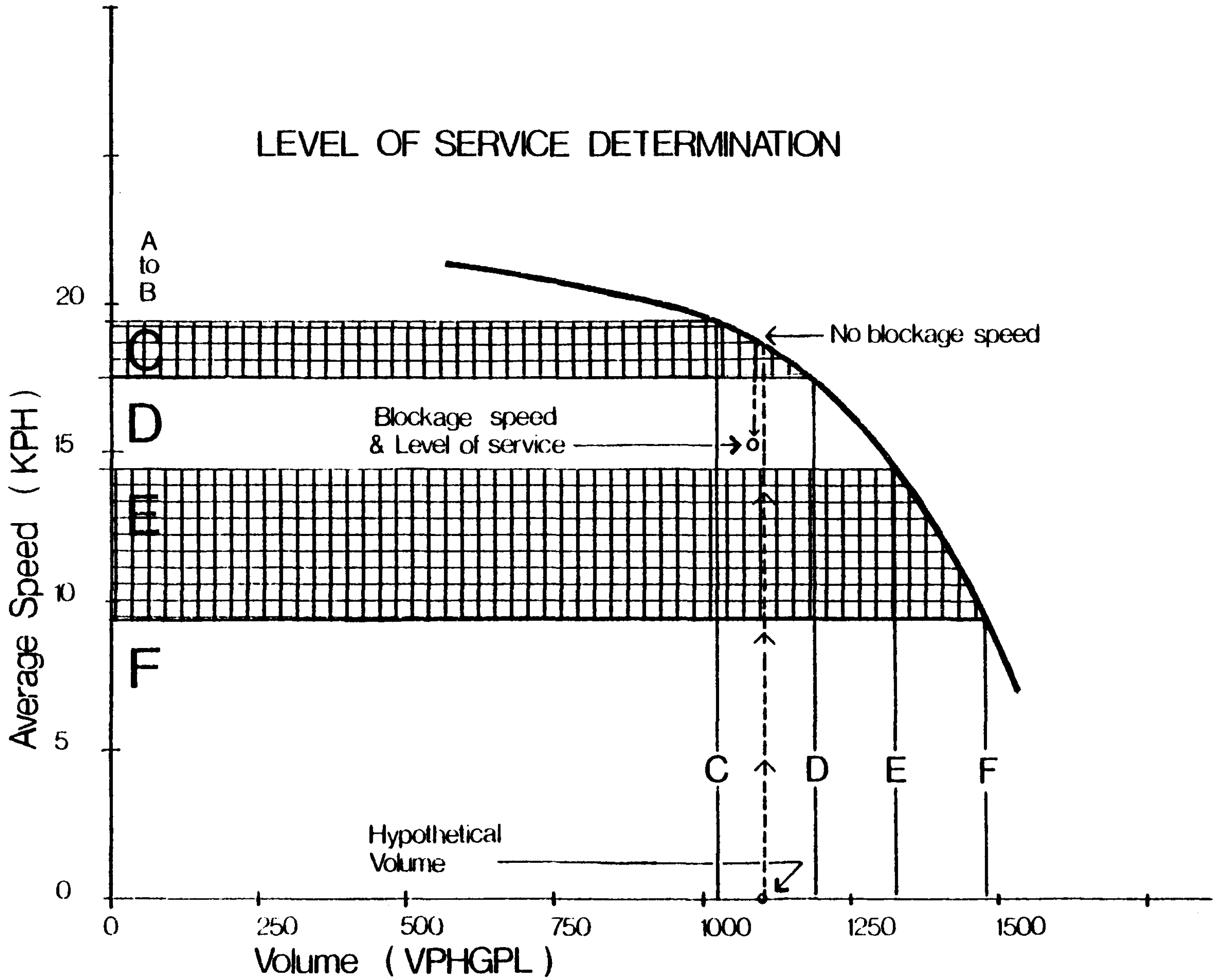


FIGURE 25. LEVEL OF SERVICE DETERMINATION

CHAPTER 6

STRATEGIES FOR IMPROVING ARTERIAL FLOW

Thus far in this report the tools have been developed to:

- o Estimate PUD demand
- o Estimate percentage double-parking
- o Estimate the effect of double parking on arterial traffic

This chapter presents an analysis of the various options available to the traffic engineer/planner in order to reduce the impact of PUD operations on traffic flow.

Initially, it becomes necessary to define the analysis objectives. For this type of analysis it appears that a specified level of service would be that objective. The recognition of curbside goods movement as a 'problem' related to traffic flow occurs when the traffic state is approaching or at capacity. An arterial with freely flowing traffic does not appear (to the traffic engineer) to represent a problem even though there is some speed reduction due to double-parked vehicles. Therefore, for each strategy developed and evaluated in this Chapter, the evaluation is based on the effectiveness of the strategy to improve the traffic flow on the arterial street to either:

o upper limit level of service C (C/D boundary)
or o upper limit level of service D (D/E boundary).

It is evident that different cities have different objectives in traffic control management, with many cities viewing the D/E border as unsatisfactory while others consider it a realistic level of congestion. Therefore, both the C/D and D/E boundaries will be used as strategy objectives where appropriate with the option available to the traffic engineer/planner to use one or the other as determined by local policy.

Each strategy developed includes: description of the strategy, analysis and variability, and implementation plan. Below is a listing of strategies that are addressed herein:

(1) Curb Space Management
(2) Signing of Curb Usage and Enforcement
(3) Signal Timing Adjustments
(4) Temporal Control of PUD Operations
(5) Demand Reduction Methods
(6) Other Traffic Engineering Techniques

The above strategies will be applied to specific blocks where goods-movement problems <u>have been determined to exist</u>. The presentation format is structured as a users guide and, where appropriate, examples are given. It should be stated here that goods-movement problems, though in some cases severe, are isolated and solutions presented to address these problems must recognize this characteristic.

CURB SPACE MANAGEMENT

The basic question to be addressed in this section is-- for a given traffic volume level, how much curbspace should be allocated as 'available' for PUD use, or rather, not available for normal auto parking. It should be noted that PUD vehicles will seek out and use bus stops, hydrants, driveways or any other 'available' space to load/unload freight and therefore, the existence of such space does generally act as loading zone space. The analysis is done to provide upper limits of level of service C and D operation as the alternate objectives.

The purpose of curbspace management is to reduce the number of double parkers in order to produce a desired level of service. For a given PUD demand and a given traffic volume level, curb space is needed in amounts necessary to reduce conflicts and produce the desired level of services. The data used in this analysis are from Figure 20, and Tables 23 and 24. These relate to the estimated percentage of double parkers for various amounts of allocated PUD curbspace and the effects of these double parkers on level of service of one-way and two-way arterial streets.

The procedure followed in the development of curb space requirements for PUD vehicles is to: (1) find the maximum number of double parked PUD vehicles that can be tolerated for a specific traffic volume and level of service (Tables 23, 24), (2) find the estimated number of vehicles that will double park for various demands and curbspace allocations (Table 20) and (3) select the curbspace needed that reduces the number of double-parkers below the tolerable level. Table 25 was prepared for one-way arterials and Table 26 applies to two-way arterials. These tables show the required percentage of curbspace on a block that should be available for PUD vehicles under various traffic volume levels.

Tables 25 and 26 show that there are traffic volume levels below which there need not be any designated PUD curbspace to obtain a desired level of service. These are 650 VPHGPL for level C and 950 VPHGPL for level D. The tables also show that one-way streets generally require slightly more total curbspace than two-way streets, due primarily to the different blockage patterns and their respective probabilities. The tables further show the NS, or no-solution condition, where all space is allocated and the desired level of service is still not obtained. Under such a no-solution scenario, additional strategies must be considered, including reducing PUD demand in that period, reducing traffic volume, changing signal timing, stepped-up enforcement or other methods. Most of these are discussed throughout this chapter.

TABLE 25 PERCENTAGE OF CURBSPACE NEEDED ON BOTH SIDES OF A ONE-WAY ARTERIAL

BLOCK (BOTH SIDES OF STREET) PUD DEMAND PER HOUR								
Volume VPHGPL	Level of Service	10	20	30	40	50	60	70
700	C*	0	0	0	0	0	10	20
	D*	0	0	0	0	0	0	0
800	C	0	0	40	60	70	80	90
	D	0	0	0	0	0	0	0
900	C	0	60	80	90	100	100	NS
	D	0	0	0	0	0	0	0
1000	C	70	100	NS	NS	NS	NS	NS
	D	0	0	0	20	40	60	70
1100	C	100	NS	NS	NS	NS	NS	NS
	D	0	30	60	80	90	100	100
1200	C	NS	NS	NS	NS	NS	NS	NS
	D	50	80	100	NS	NS	NS	NS
1300	C	NS	NS	NS	NS	NS	NS	NS
	D	NS	NS	NS	NS	NS	NS	NS

NS represents 'no-solution' for conditions.
*Represents the upper limit of each level of service.

TABLE 26 PERCENTAGE OF CURBSIDE NEEDED ON ONE SIDE OF A TWO-WAY ARTERIAL

Volume	Level of	BLOCKFACE (ONE-SIDE) PUD DEMAND PER HOUR						
VPHGPL	Service	5	10	15	20	25	30	35
700	C*	0	0	0	0	0	10	30
	D*	0	0	0	0	0	0	0
800	C	0	0	20	40	60	70	80
	D	0	0	0	0	0	0	0
900	C	0	30	60	80	90	100	100
	D	0	0	0	0	0	0	0
1000	C	0	60	80	90	100	100	NS
	D	0	0	0	0	0	10	20
1100	C	70	100	NS	NS	NS	NS	NS
	D	0	0	10	30	50	60	70
1200	C	NS	NS	NS	NS	NS	NS	NS
	D	0	30	60	80	90	100	100
1300	C	NS	NS	NS	NS	NS	NS	NS
	D	70	100	NS	NS	NS	NS	NS

NS Represents - no-solution for conditions.
* Represents the upper limit of each level of service.

Example

Field Conditions - Estimated PUD generation to block from 9-10 AM is 30 vehicles

One-way arterial, 3 through lanes plus parking

Volume 1850 VPH, arterial G/C = .55

10% available PUD space on one side of street

30% (due to far side bus stop) available PUD space on other side of street

135 meter block length.

Determine present level of service and find the curbspace PUD needs necessary to achieve level of service D operation on the arterial during that period.

Step 1. Calculate traffic volume in vehicles per hour of green per lane: (1850/3) x 1/.55 = 1121 VPHGPL

Step 2. Assuming uniform distribution of PUD demand to both sides of the street, the estimated PUD double parkers is 12 per hour. Using Table 23, it is seen that for 12 double parkers per hour and 1121 VPHGPL, the one-way arterial operates at level of service E.

Step 3. The review of Table 23 indicates that only a modest improvement is needed from 12 to 8 double parkers to reach the level of service D border. Table 25 shows that, for 30 PUD vehicles per hour and 1121 VPHGPL, the objective can be reached by providing 60% of curbspace on both sides of the street to PUD use. Therefore, to achieve this modest reduction in double-parkers, a sizeable amount of curbspace is required.

Step 4. The allocation of this space should be done on the basis of demand, with the downstream end of the block taking the highest priority, the upstream end taking second priority and the midblock section being the lowest priority for allocating space. This general priority allocation of space at curbside is based on the effects of blockages at different locations on the blockface as depicted in Figure 24. Figure 26 shows the recommended allocation for the sample problem.

The example shown assumes that there is equal PUD demand on both blockfaces. Should the PUD demand on one side be significantly higher (more than 70%, 30%) than the other, then the blockage pattern becomes similar to that of a two-way street and Table 26 would be more appropriate for analysis. In addition, the minimum size allocation should be 14.5 meters, except at corners where the minimum acceptable would be 10 meters.

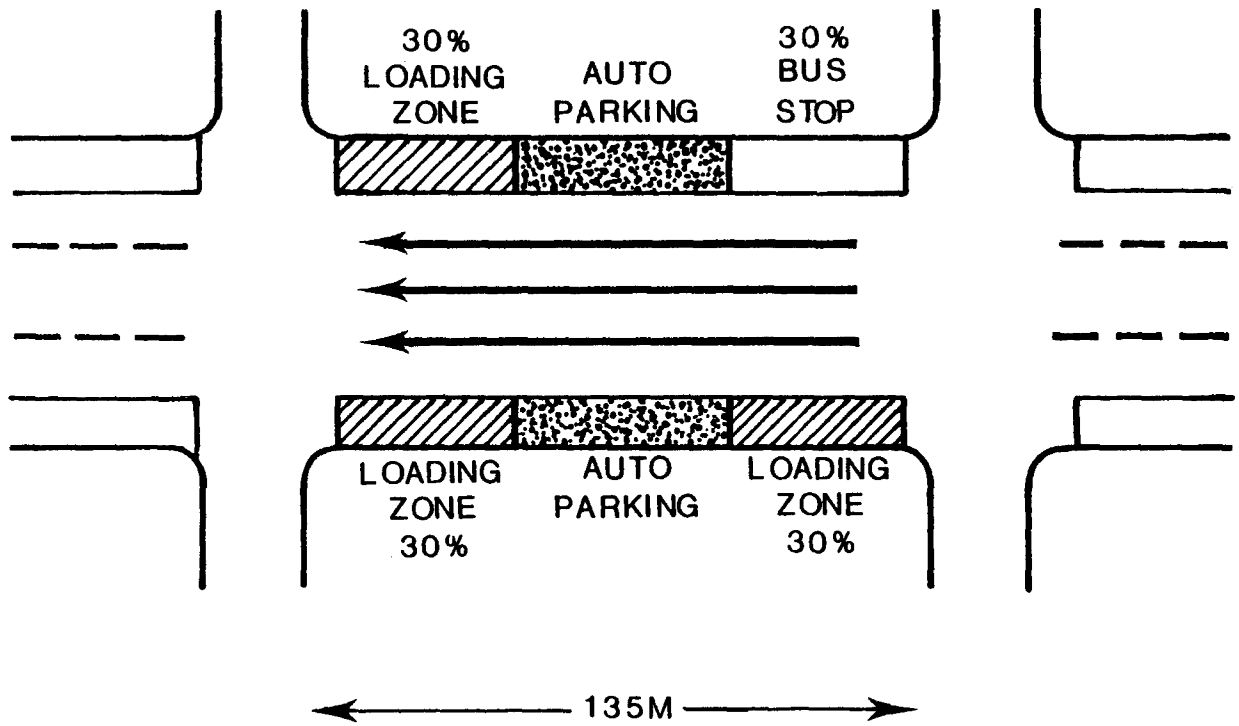


FIGURE 26 SAMPLE RECOMMENDED CURBSPACE ALLOCATION PLAN

The implementation of this curb management strategy requries the acquisition of hourly PUD demand data either by using field observers or by using the generation equations and hourly arrival patterns developed in this report. In addition, traffic volumes and signal splits should be known, as well as, the utilization of existing curbspace (available, or not available for PUD use). The subsequent analysis would be as shown in the above example.

SIGNING AND ENFORCEMENT OF CURB USAGE

The conventional method of 'rationing' curbspace for PUD usage is to designate that space as a truck loading zone, with the appropriate signing. In New York, the sign reads 'no-standing except trucks loading and unloading'. Most cities would have similar signing, while some other cities allocate the curbspace just as a loading zone (passengers not differentiated from freight). The objective of such signing is to provide curbspace for the exclusive use of loading/ unloading, with no parking allowed for <u>all vehicles</u> and no standing allowed for all non-loading/unloading vehicles. The Research Team can identify two major problems with this type of signing that contribute to arterial conflicts, especially in off-peak periods. First, the percentage of trucks in the total vehicle population is rising and is expected to continue to rise into the short-term future (at least). The identification of a truck (except large ones) as a PUD vehicle is not obvious for a parking-enforcement agent and therefore non-PUD truck parking in designated space will continue to rise. Second, when a PUD vehicle stops in a truck loading zone, or any other 'non-pressurized' (parking meter, etc.) parking space, the total dwell time of the stop increases greatly, as shown in Chapter 4, Table 13. This increase is attributable only to the type of parking. Therefore, the loading zone is less effective, due to the increased longer occupancy time for each PUD vehicle.

An objective of curb space management and control is to minimize the occupancy time of the designated users and eliminate (if possible) the non-designated users. Elimination of all designated (and signed) truck loading zones appears to be a strategy capable of achieving this objective. Those parking areas 'intended' for PUD use should be signed and controlled (enforced) as <u>'no parking'</u> zones. PUD vehicles that are loading/unloading freight would be considered as standing (and therefore legally stopped), while all other vehicles would obviously be illegallyparked and subject to a summons.

This strategy deviates from the primary conventional regulatory role of signing and adds the secondary role of correcting the inadequacy of the primary role. However, the regulatory role of a 'no parking' sign is just as specific as that of a no standing except trucks loading and unloading' sign and field enforcement would not be affected.

The table below summarizes the research findings with respect to PUD dwell time. The introduction of 'pressurized' parking could reduce the mean dwell time of PUD vehicles in 'intended' loading zones by about 30%. In addition, the anticipated reduction of non-PUD parking would increase the capacity of that space for PUD vehicles.

Parking Mode	Mean Dwell Time (Min.)	Samples
Double Parked in Moving Lane	11.5	1398
Curb-parked legally(*)	19.5	5046
Curb-parked illegally	13.8	1697

(*) Includes Truck Loading Zones.

The proposed strategy would only be implemented in the highest density areas, with conventional loading zone signing remaining in other areas. This dual system of 'intended' (no-parking) and 'designated' (no standing except trucks) signing has two advantages. First, drivers of PUD vehicles would recognize the existence of the designated space and therefore be less likely to recognize the intended signing objective (using the no parking sign). The second advantage is that, where time is needed by the driver for personal purposes (coffee break, lunch, telephoning the terminal, other), the likelihood of drivers taking this time while at a 'no parking' zone is less than while in a truck loading zone.

The major disadvantage of the 'no parking' zone concept is the fact that PUD vehicles could be ticketed if the driver is not at or close to the vehicle. However, it is just the existence of such an enforcement option (although it may rarely be exercised) that produces the expected operational benefits. The reduction in non-PUD use of the 'no parking' zone would also be a positive benefit of the enforcement ambiguity.

In order to quantitatively assess the impact on level of service of the increased 'loading zone' capacity due to signing changes, the Research Team recommends use of an equivalent loading zone, 30% smallerthan the conventionally signed loading zone as means to assess impact. For the example used in the curb management section, the block needed 60% 'PUD available' space to meet the level of service objective, a large increase over the existing 20% total. If the new 40% loading zone space were to be signed through intended signing (with no parking signs), only an additional 30% (40% ÷ 1.3) would be necessary in achieving the desired level of service objective.

The implementation of such a strategy should have the highest priority on main streets in the CBD and on blockfaces where existing loading zone space is fully utilized. The second priority would be in the CBD on cross streets where loading zones exist at the corners with the major street. The third priority, would be on cross streets in the CBD where the curbspace is designated for use by queued vehicles at loading docks. In all cases, the existence of conventionally signed designated loading zones must be maintained in non-critical areas.

SIGNAL TIMING ADJUSTMENTS

The friction caused by the goods/people conflict on a block reduces the intersection service volumes. For many arterials, a constant G/C is maintained throughout peak and(or) off-peak periods, and for several intersections neither cross street volume or pedestrian needs can support this uniformity. The opportunity may exist there_ fore, to increase arterial G/C in order to increase the service volume of a congested block(s) to the level of upstream and downstream blocks.

The goal of this strategy is to determine the required arterial green split (G/C) in order to achieve a desired level of service on a problem segment. This level of service would logically be the same as the upstream blocks. The material developed in this research has consistently defined volume in vehicles per hour of green per lane. Therefore, given that actual traffic volume is known, the identification of a 'service volume' at various levels of service can readily be translated into a required G/C.

Tables 27 and 28 were prepared to show the service volume at upper levels of service C and D for various total PUD curbside generation and the percentage amount of available curbspace for PUD vehicles. The traffic engineer/planner can therefore use these tables to find the amount of arterial green phase necessary to accomodate the actual volume on the street at the desired level of service.

Example:

For the exact base conditions previously presented in the curb management example, the traffic engineer wishes to provide level of service D operation through signalization. The previous analysis concluded that 1121 VPHGPL operated at level of service E. The average amount of the block available for PUD use is 20% (average of 10% and 30%).

Table 27 shows that, for a demand of 30 PUD vehicles per hour and 25% available PUD space, the service volume at level of service D is 1025 VPHGPL. Therefore, for an actual volume of 1850 VPH on 3 through lanes (i.e. 617 VPHPL), the major street green split should be raised from 0.55 to .60 (617 VPHPL/1025 VPHGPL). In terms of solution scale, this G/C increase would be more attractive than any elaborate curb space management plan to achieve level of service D on the arterial.

There are various combinations of curb management, signing and signal adjustments that can produce the desired operating level of service. In order to implement such a signal strategy it is necessary to inventory (or calculate) PUD hourly demand, count main street traffic and determine what curbspace is already available for PUD use. These basic inputs will allow the determination of a target service volume, from which the required split can be calculated. For computer traffic controlled signal systems, adjusting signal splits for specific periods of the day is facilitated.

TABLE 27 - SERVICE VOLUME (VPHGPL) AT VARIOUS LEVELS OF SERVICE ON ONE-WAY ARTERIALS

BLOCK GENERATION (PUD/HR)	LEVEL OF SERVICE	PERCENTAGE OF AVAILABLE PUD SPACE (AVERAGE FOR BOTH SIDES) 0	25	50	75	100
10	C*	900	925	1000	1050	1125
	D*	1125	1150	1175	1225	1275
20	C	850	875	900	950	1075
	D	1075	1075	1100	1150	1225
30	C	775	800	850	900	1025
	D	1000	1025	1050	1100	1200
40	C	750	775	800	850	975
	D	975	1000	1025	1075	1175
50	C	725	750	775	825	950
	D	975	1000	1000	1050	1150
60	C	700	750	775	800	925
	D	950	975	1000	1025	1125
70	C	700	725	750	775	900
	D	925	950	975	1025	1100

* Represents upper limit of each level of service.

TABLE 28 SERVICE VOLUME (VPHGPL) AT VARIOUS LEVELS OF SERVICE ON TWO-WAY ARTERIALS

BLOCKFACE GENERATION (PUD/HR)	LEVEL OF SERVICE	PERCENTAGE OF AVAILABLE PUD SPACE (ONE SIDE ONLY) 0	25	50	75	100
5	C*	975	1025	1075	1125	1175
	D*	1250	1275	1300	1325	1350
10	C	850	925	950	1025	1125
	D	1150	1200	1225	1275	1325
15	C	800	825	875	975	1075
	D	1100	1125	1175	1225	1300
20	C	750	775	825	925	1025
	D	1050	1075	1125	1200	1275
30	C	700	725	775	850	975
	D	1000	1050	1075	1125	1250

* Represents upper limit of each level of service.

TEMPORAL CONTROL OF PUD DEMAND

The use of a temporal control strategy by the traffic engineer/ planner usually applies under one or more of the following conditions: (1) to provide the needed curb lane(s) for through traffic, (2) to control PUD operations on downtown malls and (3) to reduce people/ goods conflicts even in the off-peak periods in selected downtown areas.

Curb Lane Control

The need to provide additional lanes to ease peak period traffic flow is apparent in most downtown areas. The need to provide curb-side express bus lanes (or contra flow lanes) is also present in many larger cities (generally those that also have goods movement problems). In the cities where alleys parallel the main arterials, provision of the curb lane for non-PUD operations is greatly facilitated. In cities where no alternate PUD stopping space exists, the effectiveness of such a curb lane strategy would be reduced as all that is needed to disrupt heavy traffic flow is a single blockage per three block segment. The research on this study also showed a marked variation among cities in terms of compliance with a no-stopping curb lane control.

The Research Team has developed general guidelines for implementing a temporal displacement curb lane strategy based on providing the carrier with the option of compliance without rendering the PUD process inefficient. These guidelines apply to cases where no alley access is available.

- As traffic does not peak in both directions at the same time, PUD operations in the non-peak direction should be encouraged through the provision of loading zones. This applies to alternate parallel arterials or to alternate directions of two-way arterials.

- In addition, for blockfaces that normally generate 5 to 10 PUD operations per hour, provide 15 meters of available curb loading space on the corners of each cross-street. Normal enforcement of parking would suffice.

- For blockfaces that normally generate over 10 PUD operations per hour during the strategy period all above space requirements should be implemented, plus heavy enforcement (5 minute coverage) to control the no stopping prohibition.

- For an arterial segment which has over 20 PUD operations per hour on one or more blockfaces, the effectiveness of the strategy would be such that it should generally not be implemented.

Pedestrian Malls

As an increasing number of urban pedestrian malls are being implemented in small as well as large cities, the need to distribute freight in a limited time period usually exists. This need does not exist where there is access to individual generators from locations other than the mall itself. Where existing streets (without rear alleys) are turned into pedestrian malls, PUD operations on the mall itself are usually limited to before 10 AM and in the evenings (given that receivers are there to accept the freight). Freight delivered after 10 AM is 'walked' onto the mall by the driver.

The problem that arises with respect to PUD operations occurs when the demand is high and the blocks are over 75 meters in length. This implies difficulty in transferring all freight in the prescribed time and the inconvenience of transferring freight by handtruck from the closest cross-street due to the long block lengths.

Each specific mall requires special considerations; however the earlier receivers are available to accept freight (8:30 AM is the latest) the better the process and the lower number of PUD vehicles delivering elsewhere in the CBD during the AM peak traffic period. If truck space (lane) on the mall is less than 8 meters wide, then PUD vehicles can only park on one side of the travelway. This one-sided operation would be adequate for generation of up to 11 PUD operations per 35 meters of mall per hour. For larger demands at least a 9 meter PUD 'travelway' should be provided on the mall and loading operations allowed on both sides of the travelway. The elimination of curbing on pedestrian mall facilitates the freight flow process on the mall and reduces PUD vehicle dwell time.

Areawide Temporal Control

In selected portions of downtown areas where PUD demand is heavy enough to 'stifle' normal urban communication/transportation processes, it may be desirable to consider a radical temporal separation plan, including night deliveries. Research to date (8,9) shows that off-hour delivery is not a practical solution from the carrier/receiver viewpoint due to the expense burdens imposed on this cost-sensitive group. The benefits of such a strategy can readily be evaluated in terms of the relief in traffic congestion and the resultant availability of curbspace to auto parkers. Tables 21 and 22 would be used to estimate increased operating speeds without PUD vehicles, and Tables 23 and 24 provide estimates of the improvements in level of service under varied field conditions.

PUD DEMAND REDUCTION METHODS

Conflicts between goods and people can also be minimized by reducing the total number of possible conflicts. This implies either reducing the amount of curbside PUD operations in a 'problem' period or by reducing the traffic volume in that period (see next section). The two methods generally available for PUD demand reduction are land use planning and consolidation terminals. In both cases the effect of such a strategy on arterial level of service can be determined by using Tables 25 through 28 as needed.

The control of development through land use planning is a long term solution. On problem blocks, land uses that generate lower amounts of PUD trips and/or provide off-street loading for these trips should be promoted in future development. For instance, the zoning of a warehousing section to permit loft residential dwellings would drastically reduce PUD demand to that block over time. Conversely, the zoning of that warehousing block to retail/ commercial uses would increase PUD demand. An office building reconstructed to provide off-street loading facilities will also reduce curbside PUD demand.

Short-term land use planning for PUD should be concentrated on removing 'food' (retail and prepared) from principal arterials that have PUD related congestion. The PUD arrival patterns and demand rates associated with this land use puts it in direct conflict with the AM peak traffic period. It should be a land use planning objective to not allow retail foods (supermarkets and drugstores) on principal arterials unless rear access is available. It should also be a land use objective to restrict prepared foods establishments from opening on congested blocks unless side street access is available. The traffic planner should be reviewing zoning changes on principal arterials to evaluate their effect on PUD generation and curbside operations over the short term (2-5 years) as well as in the longer term.

The consolidation terminal concept can reduce some PUD demand, although various studies dispute the realistic market percentage. However, the effectiveness of this terminal concept is greater if it is desired to consolidate a percentage (any) of PUD trips destined to be curbside parkers on problem blocks. The effect of reducing 10,15 or 20 percent of PUD curbside demand (the realistic range for a consolidation terminal) can be evaluated. However, the traffic impact analysis conducted in this study (Chapter 5) clearly showed that marginal reduction (even up to 20%) of PUD demand on blocks with 30 or more hourly generation does not measurably improve arterial flow. Therefore, if the terminal concept is designed to address such <u>high</u> PUD demand problem condition, its resultant effect would be minimal.

OTHER TRAFFIC ENGINEERING STRATEGIES

There are three traffic engineering strategies presented in this section: (1) reduce arterial traffic, (2) provide wider parking lanes and (3) relocate bus stops. Each is presented with a short description and a brief effectiveness evaluation.

Reduce Arterial Traffic

One option to reduce goods/people conflicts on arterials is to reduce the number of people (vehicles) without changing the goods flow process. This can be done through the diversion of vehicles to parallel arterials using turn controls in critical periods. That is, allow vehicles to turn off but not onto the arterial in a problem segment. This technique, the Research Team estimates, could reduce volume by 10 to 15% through a problem area. Figures 23 and 24 show that such a reduction in volume can translate into real changes in level of service on the arterial. This traffic reduction measure can be implemented independently of all other strategies and therefore produce compounding of benefits. In the example being used throughout this chapter, in order to achieve level of service D operation, turn controls to reduce traffic from 1850VPH to 1780VPH (4% reduction) would be required. The traffic engineer would determine the method of best achieving this reduction.

Wider Parking Lanes

The striping of lane markings on arterials can be used to 'diffuse' goods/people conflicts by increasing the size of one or both curb lanes to accomodate the parked auto plus the double parked PUD vehicle. Due to the fact that fewer than 1 in 20 PUD vehicles are tractor trailers in the CBD, a 5 meter curb lane can usually accommodate a parker and a compactly parked double parked PUD vehicle. The increase in curb lane-width is 2 meters. It would be very rare to find an arterial wide enough such that 4 meters (additional for two double-parking curb lanes) could be subtracted from the through lanes without reducing the number of these lanes. However, it does appear feasible to provide the wider curb lane on one side of the arterial, the side generating most of the PUD demand. The following example shows the effectiveness of such a one sided double-parking curb lane.

Example

Given: 18 meter wide one-way arterial with three through lanes and two parking lanes. Each lane is 3.60 meters. PUD demand in one hour is 30 to both blockfaces, split 60%-40% (18 one side, 12 other side), 20% of both blockfaces available for PUD operations, volume is 1121 VPHGPL.

Find: Existing level of service and resultant level of service of a double-parking lane.

As this example is the same as that being used throughout this chapter, the existing arterial operates at level of service E. The proposed re-striping plan would call for a 5 meter double parking curb lane, three 3.35 meter travel lanes and a 3.25 meter parking lane. The 5 meter lane should logically be placed on the side of the street with the 18 PUD per hour demand. Therefore, the problem is now reduced to having 12 PUD operation on one side of an arterial with no blockages the other side (blockage pattern of a two-way arterial). Figure 24 shows that for a volume of 1121 VPHGPL and 5 double parkers per hour (12 PUD x .41, see Figure 20), the arterial would operate at level of service D. Further, Table 26 shows that, for a two way arterial generating 12 PUD per hour, no curbspace is needed to achieve level of service D. Therefore, if that level of service is the strategy objective and if the 20% available PUD space is really a dedicated truck loading zone, then as a part of implementing this strategy, that dedicated space could be turned over to curbside auto parking.

The implementation of such a double-parking lane strategy would produce more effective results if the PUD demand is consistently biased towards one side of the arterial and would be rendered less effective with radical shifting of PUD demand from one side to the other over the problem arterial segment. Therefore, a careful inventory of PUD demand should be a prerequisite to considering this strategy.

Bus Stop Relocation

Bus stops are generally placed on one of three to one of four blocks on an arterial. The placement of these bus stops is usually on the far side of an intersection as this requires less curb space. The use of bus stops for PUD operations is an ongoing process in downtown areas today. Therefore, the question becomes: can bus stop location be coordinated with PUD curb space needs? Clearly, Figure 24 shows that elimination of the downstream double parker (blockage configuration 1) would provide markedly higher benefits than reducing double parking elsewhere on the blockface. Therefore the ideal placement for a bus stop (from the PUD perspective) would be at the near side of the intersection.

It can be argued that planning bus stop space for PUD use is not good practice. However, because this bus stop space is now used in the field and because the value of such bus stop space is lessened in off-peak periods (when PUD operations peak), then in order to make better transporation use of existing facilities, near side bus stops must be considered on arterials where PUD problems arise. In order to lessen the interference with right-turning traffic, near sided bus-stops should be coordinated with the one-way pattern (if it exists) of the cross streets.

The quantitative effect of near-side versus far side bus stops cannot be determined here because of the many non PUD interdependent variables including: enforcement of bus stop parking regulations, different bus driver habits in stopping at 'curbside' may cause traffic interference, frequency of bus service, as well as the PUD variables such as demand and other available curb space. It is evident, however, that nearside bus stops will lower the probability of the PUD blockage configurations that most adversely affect traffic operations and therefore, implementing of such a strategy would be beneficial to improving travel speed and level of service.

RANKING OF STRATEGIES

It is clear to the reader that the specific problem situation in the field will dictate the most effective strategy or combination of strategies. The basic information provided in this report allows the traffic engineer/planner to evaluate alternative options for improvement. The strategies presented in this chapter are all very low capital intensive, and the selection of a strategy should not generally be influenced by cost.

The research and analysis has pointed out that strategies that tolerate normal PUD characteristics are more effective than those that try to alter these characteristics. In the curb-management example, it showed the large spatial requirement to achieve the level of service objective, while subsequent strategies achieved the objective in a more concise manner. Recognizing that field conditions will dictate the best course of action, the following is a priority ranking of these strategies under typical conditions in the CBD. It is highly recommended that combinations of these strategies always be considered for each problem.

Moderate PUD Problems	Severe PUD Problems
1. Change Signal Timing	1. Double-Parking Lane
2. No-Parking Signing	2. Turn Controls
3. Double-Parking Lane	3. Curbspace Management
4. Turn Controls	4. No-Parking Signing
5. Relocate Bus Stop	5. Relocate Bus Stop
6. Curbspace Management	6. Change Signal Timing

The data from which the findings were developed showed that goods movement problems are not the same in different parts of the country. The development density of the specific downtown as well as the characteristics of the arterial grid system are the principal differences. Other differences include traffic enforcement, PUD driver habits and adherence to enforcement. The material presented in this chapter is an initial step towards understanding and improving the PUD problem, as to do so can markedly improve the surface transportation system in the downtown.

CHAPTER 7

DEMONSTRATION STRATEGIES

The various strategies presented and evaluated in Chapter 6 are all low cost, operations oriented options. As such each (except PUD demand reduction techniques) is an ideal candidate for demonstration. The value of such demonstrations in urban goods movement is very high as no operations work has yet been done to try to improve the quality of arterial flow by altering the PUD process.

The strategies recommended for possible demonstration are:

1. Curbspace management. This is the allocation of curbspace on the arterial (in amount and location) during various periods of the day.

2. Pressurized (intended) signing. The replacement of truck loading zone signing with no-parking signing on principal arterials that have PUD problems.

3. Signal timing. The increase in main-street green time in order to increase service volume on a segment of arterial with PUD problems.

4. Double-parking curblane. The provision of a widened curb-lane (about 5 meters) to accommodate a curbside parker plus a compactly parked PUD vehicle. This wider curb lane cannot be implemented where a reduction in the number of through lanes would result.

5. Bus stop relocation. Where bus stops exist on an arterial that experiences PUD problems, these bus stops would be placed at near-side instead of far-side.

This and previous studies have pointed out that problems related to curbside PUD are almost exclusively concentrated in the downtown area. In addition, the Research Team considers that a city which has a population of 500,000 or less usually does not have sufficient PUD problems to warrant strategies related to easing these problems. In addition, the nation's more spread out cities (Houston, Phoenix, Los Angeles) also do not appear to possess the concentration of curbside PUD operation to warrant inprovement strategies. Table 29 shows a listing of cities that are considered candidate sites for the above mentioned strategies. It should be noted that the population figures are for 1970.

The sixteen cities shown on Table 29 can generally be described as 'older' (mature) cities. They are all the densest of large American cities. In a survey of traffic engineers conducted in 1974 for Habib's Ph.D. dissertation (10), New York, Pittsburgh, St. Louis and San Francisco were perceived to have severe goods-movement problems. Boston, Cleveland, New Orleans and Detroit were perceived to have moderate goods movement problems. Baltimore and Washington, D.C. were perceived to have low goods movement problems and Chicago,

TABLE 29 - CANDIDATE SITES FOR DEMONSTRATION

City Name	Population (1970)	Population Density ($Person/Km^2$)
New York	7,894,798	10,273
Chicago	3,362,947	5,898
Philadelphia	1,948,608	5,938
Detroit	1,511,322	4,297
Baltimore	905,757	4,531
Washington, D.C.	756,492	4,805
Cleveland	750,932	3,867
Milwaukee	717,110	2,930
San Francisco	715,673	6,172
Boston	641,056	5,469
St. Louis	622,234	3,984
New Orleans	593,467	2,656
Seattle	530,860	2,500
Pittsburgh	520,146	3,672
Minneapolis	434,408	3,164
Buffalo	462,781	4,375

Philadelphia, Milwaukee, Seattle, Buffalo and Minneapolis did not respond to the survey. Based on the above, it would appear that New York, Pittsburgh, St. Louis and San Francisco would be principal candidates for demonstration, with Boston, New Orleans, Cleveland and Detroit being classified as possibilities. Although no specific information is available on goods movement problems there, it is anticipated that Chicago and Philadelphia would also classify as possibilities.

The evaluation of the implemented strategy is best done with a before and after study of traffic characteristics. The recommended measures of effectiveness to be used are travel speed and stops. The study should also collect before and after data on traffic volumes PUD demand and vehicle parking patterns. In constructing the demonstrations, the seasonal patterns in PUD activity must be recognized (Table 10). The ideal condition to implement the strategy is in late September with the 'before' data taken in early September and the 'after' data taken in late October. Depending on weather conditions in the demonstration cities, this schedule could be advanced by one month.

Although additional research needs can be easily identified in urban goods movement, the Research Team considers demonstration programs to be the most meaningful focus of expanding knowledge in this area of transportation. This research project identifies a prime set of options for such demonstration.

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APPENDIX I

CODING FOR PUD OPERATIONS DATA

Format of information storage for all files.
Urban Curbside Pickup and Delivery Operations.

File A- Final Field Form
File B- Final Curb Inventory and Enforcement Form
File C- Final Establishment Inventory Form

File A - FINAL FIELD FORM

Column #	Description
1	Form Type 1 = Pud Field Operations Form 2 = Curb Inventory and Enforcement Form
2-5	Sequential Form Number (begin with 0001 in every City)
7	City 1 = San Francisco 2 = Boston 3 = St. Paul 4 = Oklahoma City 5 = Dallas 6 = Phoenix
8-9	Block # (see Attachment 1)
10	Blockface # 1 = North 3 = East 2 = South 4 = West 5 = Alley 6-8 = Complementary Side (When both FACES on a given street are either ODD or EVEN, it signifies that establishments on only one side of the street were on the sample.)

Column #	Description
12	Day of the Week 1 = Monday 4 = Thursday 2 = Tuesday 5 = Friday 3 = Wednesday
14-15	Month 1 = January 2 = February 3 = March 4 = April 5 = May 6 = June 7 = July 8 = August 9 = September 10 = October 11 = November 12 = December
16-17	Day of the Month
18-19	Last Two Digits of Year
21-24	Time of Arrival (First two digits-hour in military time - last two digits minutes).
25-28	Time of Departure (same as above)
30	Vehicle's Parking Mode 1 = Moving Lane (double parked) 2 = Non Moving Lane Legally 3 = Non Moving Lane Illegally 4 = Other: Alley, Walking, Sidewalk, etc. 5 = Moving Lane (Parked by curb) 6 = Another Block 7 = Loading Dock 8 = Driveway
32-45	These information refers to the first establishment visited only.

Column #	Description
32-33	Establishment Number (begin with 01 in every block) (see Attachment 2)
34	Operation Type 1 = Pickup 2 = Delivery 3 = Service 4 = Pickup and Delivery 5 = Unknown 6 = Delivery & Service
36-37	Type of Goods (see Attachment 3)
38-40	Number of Parcels (999-unknown)
42-45	Total Shipment Weight for this establishment (9999-Unknown)
47-60	This information refers to the second establishment visited only
47-48	Establishment number
49	Operation Type
51-52	Type of Goods
53-55	Number of parcels
57-60	Total Shipment weight for this establishment
62-75	This information refers to the third establishment visited only
62-63	Establishment number
64	Operation Type
66-67	Type of Goods
68-70	Number of Parcels
72-75	Total Shipment weight for this establishment
77-90	These information refers to the fourth establishment visited only

Column #	Description
77-78	Establishment number
79	Operation Type
81-82	Type of Goods
83-85	Number of Parcels
87-90	Total Shipment weight for this establishment
91-92	Total number of establishments visited while parked at this location

FILE B - Final Curb Inventory and Enforcement Form

Column #	Description
1	Form Type 2 = curb inventory and enforcement form
2	City: 1= San Francisco 4= Oklahoma City 2= Boston 5= Dallas 3= St. Paul 6= Phoenix
3-4	Block Number (see Attachment 1)
5	Blockface Number: 1= North 4= West 2= South 5= Alley 3= East 6-8= Complementary sides
7	Day of the Week: 1= Monday 4= Thursday 2= Tuesday 5= Friday 3= Wednesday
9-10	Month: 1= January 2= February 3= March 4= April 5= May 6= June 7= July 8= August 9= September 10= October 11= November 12= December

Column #	Description
11-12	Day of the Month
13-14	Last Two digits of year
16-19	Block length in feet
21-23	Loading zone width (in feet and tenths)
25-27	Time limit on loading zone (in minutes)
29-46	This information refers to a one hour period
29-30	Hour in military time representing the beginning of a one hour period
31-32	Number of parking enforcement agents that passed through the block on foot during this time period
33-34	Number of parking enforcement agents that passed through the block on a vehicle during this time period.
35	Existence of a Loading Zone 1 = No 2 = Yes, full hour 3 = Yes, fcr the first one half hour 4 = Yes, for the second one half hour
36	Is the Curb Lane a Moving Lane? 1 = No 2 = Yes, full hour 3 = Yes, for the first one half hour 4 = Yes, for the second one half hour
38-40	Length of curb designated as a loading zone (in feet)
42-44	Length of curb designated as other legal (meters, unrestricted,etc.) (in feet)
46-48	Length of curb designated as illegal (Hydrant Bus Stop, Driveway,etc.) (in feet)

FILE C - Final Establishment Inventory Form

Column #	Description
1	City: 1 = San Francisco 4 = Oklahoma City 2 = Boston 5 = Dallas 3 = St. Paul 6 = Phoenix
2-3	Block Number (see Attachment 1)
4	Blockface Number: 1 = North 4 = West 2 = South 5 = Alley 3 = East 6-8 = Complementary sides
5-6	Establishment Number (see Attachment 2)
7-8	Land Use of establishment (see Attachment 4)
9-12	Size of Establishment : If residential or hotel in number of units all others in thousands of square feet.
13-16	Number of employees (only if retail, commercial or service establishment)
17	Area Classification: 1 = CBD 2 = Fringe
18-21	City Population in thousands of Sq. ft.
22-24	Blank

FILE C - Final Establishment Inventory Form

Column #	Description
25	City 1 = San Francisco 4 = Oklahoma City 2 = Boston 5 = Dallas 3 = St. Paul 6 = Phoenix
26-27	Block Number (see Attachment 1)
28	Blockface Number 1 = North 4 = West 2 = South 5 = Alley 3 = East 6-8 = Complementary sides
29-30	Establishment Number (see Attachment 3)
31-32	Land Use of establishment (see Attachment 4)
33-36	Size of Establishment If residential or hotel in number of units all others in thousands of square feet.
37-40	Number of employees (only if retail, commercial or service establishment)
41	Area Classification 1 = CBD 2 = Fringe
42-45	City Population in thousands of Sq. ft.
46-49	Blank

FILE C - Final Establishment Inventory Form

Column #	Description
50	City 1 = San Francisco 4 = Oklahoma City 2 = Boston 5 = Dallas 3 = St. Paul 6 = Phoenix
51-52	Block Number (see Attachment 1)
53	Blockface Number: 1 = North 4 = West 2 = South 5 = Alley 3 = East 6-8 = Complementary sides
54-55	Establishment Number (see Attachment 3)
56-57	Land Use of establishment (see Attachment 4)
58-61	Size of Establishment If residential or hotel in number of units all others in thousands of square feet.
62-65	Number of employees (only if retail, commercial or service establishment)
66	Area Classification 1 = CBD 2 = Fringe
67-70	City Population in thousands of Sq. ft.
71-80	Blank

ATTACHMENT 1

BLOCK DESIGNATION CODES

Block Number	Description: Name	(Between) Boundaries
San Francisco		
01	Geary St.	Mason & Taylor
02	Geary St.	Stockton & Grant
03	Ellis St.	Stockton & Powell
04	O'Farrell St.	Stockton & Powell
05	Minna	3rd St. & New Montgomery
06	Sutter	Jones & Leavenworth
07 (S.G.)[1]	California	Davis
Boston		
08 (S.B.)[2]	Boylston	Berkeley & Arlington
09 (S.B.)	Friend	Causeway & Traverse
10 (S.B.)	Federal	Franklin & Milk
11 (S.G.)	Franklin	Federal & Devonshire
St. Paul		
12 (S.B.)	St.Paul Ave.	Davern & Edgecombe Rd.
13	St.Paul Ave.	Edgecombe Rd. & Dorothea Ave.
14 (S.B.)	University Ave.	Franklin & Cromwell
15 (S.G.)	4th St.	Wabasha & Cedar
16(S.G.)	Cedar	6th Ave. & Seventh Ave.
17 (S.B.)	Robert	Fourth St.& Kellog Blvd.
Oklahoma City		
18 (S.B.)	Park Ave.(So.Side)	N. Robinson & N.Broadway
19 (S.B.)	Park Ave.(No.Side)	N. Robinson & N.Broadway
20	S.W. 49th St.	S. Ross & S. May

(1) Special Generator
(2) Square Block

ATTACHMENT 1 (continued)

Dallas

Block Number	Description	
21 (S.B.)	Commerce	Ervay & Ackard
22 (S.B.)	Main	St.Paul & Harwood
23	Elm St.	Walton & Oakland Ave.
24 (S.B.)	Lovers Lane	Inwood
25 (S.G.)	Northwest Hwy.	Pickwick Lane
26 (S.G.)	Northwest Hwy.	Baltimore Dr. & W.Drive

Phoenix

27 (S.B.)	N. Central	Monroe & Adams
28 (S.G.)	E. Adams	N. Central & 1st Street
29	W. Adams	1st Ave. & 2nd Ave.
30 (S.G.)	Second Street	E. Monroe & E. Adams
31 (S.B.)	Fourth Ave.	Jackson & Madison

ATTACHMENT 3

COMMODITY CODES

Code	Description of Goods
000	No goods
017	Mail envelopes, etc.
018	Laundry - linen
020	Food & kindred products
021	Tobacco products
022	Basic textiles
023	Apparel (including kit & finished textile products)
024	Lumber & wood products except furniture
025	Furniture & fixtures
026	Pulp paper & allied products (i.e. money)
027	Unidentifiable parcel post and parcel service shipments
028	Chemical & allied products
029	Petroleum & coal products
030	Rubber & miscellaneous plastic products
031	Leather & leather products
032	Stone, clay & glass products (i.e. building materials)
033	Primary metal products
034	Fabricated metal products (i.e. tools)
035	Machinery except electrical
036	Electrical machinery and electronic equipment
037	Transportation equipment
038	Instruments (musical & measurement), photographic goods, optical goods, watches & clocks
039	Miscellaneous products of manufacturing
040	Waste & scrap material
041	Mixed freight & consolidated warehouse shipments
050	Bill (not money)
051	Plants & flowers
052	Gauze & health & beauty supplies
053	Reuseable, returnable containers
999	Unknown

ATTACHMENT 4

LAND USE CODES USED

Retail/Commercial Codes

Appliances	= 01	(Prepared)Food	= 10
Banks	= 02	(Retail) Foods	= 11
Books & Cards	= 03	Furniture	= 12
Clothes	= 04	Jewelry	= 13
Department Stores	= 05	Liquor Store	= 14
Drug Store	= 06	Novelties	= 15
Electronic &Camera	= 07	Miscellaneous(Retail)	= 16
Fabrics	= 08	Shoes	= 17
Flowers	= 09		

Other Codes

Bar, Tavern	= 18
Entertainment	= 19
Garage or Service Station	= 20
Hospital	= 21
Hotel	= 22
Hotel Prep.foods	= 23
Light Industry	= 24
Office	= 25
Residential	= 26
Service (Barber, Tailor, T.V. Repairman, Check Cashing, Physical Therapy, etc.)	= 27
Sidewalk Use	= 28
Vacant or Construction	= 29
Warehousing	= 30

APPENDIX II

HOURLY ARRIVAL TIMES

Legend: ARRHR is hour of arrival

CODE	7	-	7 to 8 AM
	8	-	8 to 9
	9	-	9 to 10
	10	-	10 to 11
	11	-	11 to 12
	12	-	12 to 1 PM
	1	-	1 to 2
	2	-	2 to 3
	3	-	3 to 4
	4	-	4 to 5
	5	-	5 to 6 PM

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
          I
       7  *** (       2)
          I
          I
          I
       8  ************ (       11)
          I
          I
          I
       9  ***************************************** (       40)
          I
          I
          I
      10  ************************************** (       37)
          I
          I
          I
      11  *********************************** (       34)
          I
          I
          I
      12  ************************ (       23)
          I
          I
          I
      13  **************** (       15)
          I
          I
          I
      14  ******************* (       18)
          I
          I
          I
      15  *************************** (       26)
          I
          I
          I.........I.........I.........I.........I.........I
          0        10        20        30        40        50
          FREQUENCY
```

VALID CASES   206   MISSING CASES   0

BANK

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
          I
      6   **** (       1)
          I
          I
          I
      8   ****** (       2)
          I
          I
          I
      9   ******************* (       7)
          I
          I
          I
     10   ******************* (       7)
          I
          I
          I
     11   ******************* (       7)
          I
          I
          I
     12   ***************************** (      11)
          I
          I
          I
     13   ************************************ (      14)
          I
          I
          I
     14   ************** (       5)
          I
          I
          I
     15   ******************************* (      12)
          I
          I
          I
     16   **** (       1)
          I
          I
          I.........I.........I.........I.........I.........I
          0         4         8        12        16        20
          FREQUENCY
```

VALID CASES   67   MISSING CASES   0

BAR/TAVERN

ARRIVAL TIME FREQUENCIES

```
06/15/79            FILE - NONAME   - CREATED 06/15/79

ARRHR


    CODE
          I
      6   ** (       1)
          I
          I
          I
      8   ****** (      10)
          I
          I
          I
      9   ************************** (      50)
          I
          I
          I
     10   *********************** (      44)
          I
          I
          I
     11   *************************** (      51)
          I
          I
          I
     12   ******************* (      36)
          I
          I
          I
     13   ******************** (      37)
          I
          I
          I
     14   ************************* (      47)
          I
          I
          I
     15   ********** (      17)
          I
          I
          I
     16   ** (       1)
          I
          I
          I.........I.........I.........I.........I.........I
          0        20        40        60        80       100
          FREQUENCY

VALID CASES      294       MISSING CASES      0
```

CLOTHING

ARRIVAL TIME FREQUENCIES

06/15/79 FILE - NONAME - CREATED 06/15/79

ARRHR

```
    CODE
         I
      6  ****** (       20)
         I
         I
         I
      7  *********** (       41)
         I
         I
         I
      8  *********************** (       87)
         I
         I
         I
      9  ****************************************** (      165)
         I
         I
         I
     10  ****************************************** (      164)
         I
         I
         I
     11  *********************************** (      135)
         I
         I
         I
     12  ******************* (       71)
         I
         I
         I
     13  *********************** (       88)
         I
         I
         I
     14  *********************** (       86)
         I
         I
         I
     15  *************** (       54)
         I
         I
         I.........I.........I.........I.........I.........I
         0        40        80       120       160       200
         FREQUENCY
```

VALID CASES 911 MISSING CASES 0

ARRIVAL TIME FREQUENCIES

```
06/15/79          FILE - NONAME    - CREATED 06/15/79

ARRHR


    CODE
         I
       8 *********** (       2)
         I
         I
         I
       9 ************************** (       5)
         I
         I
         I
      10 ********************* (       4)
         I
         I
         I
      11 ****** (       1)
         I
         I
         I
      12 *********** (       2)
         I
         I
         I
      13 ****** (       1)
         I
         I
         I
      14 ********************* (       4)
         I
         I
         I
      15 *********** (       2)
         I
         I
         I
      16 ****** (       1)
         I
         I
         I.........I.........I.........I.........I.........I
         0         2         4         6         8         10
         FREQUENCY

VALID CASES      22      MISSING CASES     0
```

ARRIVAL TIME FREQUENCIES

```
06/15/79            FILE - NONAME    - CREATED 06/15/79

ARRHR

    CODE
          I
       8  ******** (       7)
          I
          I
          I
       9  ******************* (      18)
          I
          I
          I
      10  ************************************* (      36)
          I
          I
          I
      11  **************************** (      27)
          I
          I
          I
      12  ********************** (      21)
          I
          I
          I
      13  ********************** (      21)
          I
          I
          I
      14  ******************** (      19)
          I
          I
          I
      15  ************** (      13)
          I
          I
          I.........I.........I.........I.........I.........I
          0        10        20        30        40        50
          FREQUENCY

VALID CASES      162       MISSING CASES      0
```

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
         I
       9 **************** (      3)
         I
         I
         I
      10 **************** (      3)
         I
         I
         I
      11 **************** (      3)
         I
         I
         I
      12 *********** (      2)
         I
         I
         I
      13 ********************* (      4)
         I
         I
         I
      14 *********** (      2)
         I
         I
         I.........I.........I.........I.........I.........I
         0         2         4         6         8        10
         FREQUENCY
```

VALID CASES   17   MISSING CASES   0

ARRIVAL TIME FREQUENCIES

```
06/15/79          FILE - NONAME    - CREATED 06/15/79

ARRHR


     CODE
             I
        8    **************** (        3)
             I
             I
             I
        9    ************************** (        5)
             I
             I
             I
       10    *********** (        2)
             I
             I
             I
       11    ************************** (        5)
             I
             I
             I
       12    ************************** (        5)
             I
             I
             I
       13    ****** (        1)
             I
             I
             I
       14    ****** (        1)
             I
             I
             I.........I.........I.........I.........I.........I
             0         2         4         6         8        10
             FREQUENCY

VALID CASES      22       MISSING CASES     0
```

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
         I
      7  ********* (        3)
         I
         I
         I
      8  ********************************** (      13)
         I
         I
         I
      9  ***************************** (      11)
         I
         I
         I
     10  ***************************** (      11)
         I
         I
         I
     11  ************************ (       9)
         I
         I
         I
     12  ************************** (      10)
         I
         I
         I
     13  ************************ (       9)
         I
         I
         I
     14  ******************* (       7)
         I
         I
         I
     15  ************************ (       9)
         I
         I
         I
     16  ****** (       2)
         I
         I
         I
     17  **** (       1)
         I
         I
         I.........I.........I.........I.........I.........I
         0         4         8        12        16        20
         FREQUENCY
```

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
         I
      6  ******* (     23)
         I
         I
         I
      7  *************** (     56)
         I
         I
         I
      8  ************************* (     94)
         I
         I
         I
      9  ********************************************* (    170)
         I
         I
         I
     10  ****************************************** (    158)
         I
         I
         I
     11  ****************************** (    116)
         I
         I
         I
     12  ************** (     50)
         I
         I
         I
     13  ************** (     50)
         I
         I
         I
     14  ********** (     36)
         I
         I
         I
     15  ********* (     32)
         I
         I
         I.........I.........I.........I.........I.........I
         0        40        80       120       160       200
         FREQUENCY
```

VALID CASES   785   MISSING CASES   0

FOOD (PREPARED)

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
     CODE
           I
      6    *********  '        8)
           I
           I
           I
      7    *********************  (      21)
           I
           I
           I
      8    *******************************  (      31)
           I
           I
           I
      9    ***********************************  (      35)
           I
           I
           I
     10    **************************************************  (      50)
           I
           I
           I
     11    **********************************************  (      46)
           I
           I
           I
     12    ******************************  (      30)
           I
           I
           I
     13    *****************************  (      29)
           I
           I
           I
     14    **********  (      10)
           I
           I
           I
     15    *************  (      13)
           I
           I
           I.........I.........I.........I.........I.........I
           0        10        20        30        40        50
           FREQUENCY
```

VALID CASES   273   MISSING CASES   0

```
ARRIVAL TIME FREQUENCIES

06/15/79          FILE - NONAME    - CREATED 06/15/79

ARRHR


    CODE
           I
       8   ** (       1)
           I
           I
           I
       9   ************* (     12)
           I
           I
           I
      10   ****************** (     17)
           I
           I
           I
      11   *********************** (     22)
           I
           I
           I
      12   ******** (       7)
           I
           I
           I
      13   *************** (     14)
           I
           I
           I
      14   ********** (       9)
           I
           I
           I
      15   ******** (       7)
           I
           I
           I.........I.........I.........I.........I.........I
           0        10        20        30        40        50
           FREQUENCY

VALID CASES      89      MISSING CASES     0
```

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
         I
      6  *********** (        2)
         I
         I
         I
      7  *********** (        2)
         I
         I
         I
      8  *********** (        2)
         I
         I
         I
      9  **************** (        3)
         I
         I
         I
     10  ************************************ (        7)
         I
         I
         I
     11  ******************************* (        6)
         I
         I
         I
     12  ****** (        1)
         I
         I
         I
     14  ************************** (        5)
         I
         I
         I
     15  *********** (        2)
         I
         I
         I.........I.........I.........I.........I.........I
         0         2         4         6         8        10
         FREQUENCY
```

VALID CASES   30   MISSING CASES   0

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
          I
      6   *** (      4)
          I
          I
          I
      7   ********************* (     39)
          I
          I
          I
      8   ********************************** (     66)
          I
          I
          I
      9   ********************************************* (     87)
          I
          I
          I
     10   ************************************ (     69)
          I
          I
          I
     11   **************************** (     54)
          I
          I
          I
     12   ****************** (     34)
          I
          I
          I
     13   ********************* (     40)
          I
          I
          I
     14   ********************* (     40)
          I
          I
          I
     15   ********* (     15)
          I
          I
          I.........I.........I.........I.........I.........I
          0        20        40        60        80       100
          FREQUENCY
```

VALID CASES   448   MISSING CASES   0

HOTEL

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
          I
       8  ******** (       7)
          I
          I
          I
       9  ********************* (      20)
          I
          I
          I
      10  ************************** (      25)
          I
          I
          I
      11  ************* (      12)
          I
          I
          I
      12  *************** (      14)
          I
          I
          I
      13  ************** (      13)
          I
          I
          I
      14  ******************** (      19)
          I
          I
          I
      15  **** (       3)
          I
          I
          I
      16  ** (       1)
          I
          I
          I.........I.........I.........I.........I.........I
          0        10        20        30        40        50
          FREQUENCY
```

VALID CASES   114   MISSING CASES   0

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
          I
      6   ** (      2)
          I
          I
          I
      7   ****** (      18)
          I
          I
          I
      8   ************************* (      96)
          I
          I
          I
      9   ****************************** (     115)
          I
          I
          I
     10   ********************************** (     132)
          I
          I
          I
     11   ******************** (      77)
          I
          I
          I
     12   ***************** (      62)
          I
          I
          I
     13   ****************** (      66)
          I
          I
          I
     14   **************** (      60)
          I
          I
          I
     15   ************* (      48)
          I
          I
          I
     16   * (       1)
          I
          I
          I.........I.........I.........I.........I.........I
          0        40        80       120       160       200
          FREQUENCY
```

LIGHT INDUSTRIAL

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
     CODE
           I
        7  *** (        2)
           I
           I
           I
        8  ****************** (      17)
           I
           I
           I
        9  ******************* (      18)
           I
           I
           I
       10  ********************************* (      32)
           I
           I
           I
       11  ****************** (      17)
           I
           I
           I
       12  ********* (        8)
           I
           I
           I
       13  ******************** (      19)
           I
           I
           I
       14  **************** (      15)
           I
           I
           I
       15  ************ (      11)
           I
           I
           I.........I.........I.........I.........I.........I
           0         10        20        30        40        50
           FREQUENCY
```

VALID CASES   139   MISSING CASES   0

LIQUOR STORE

ARRIVAL TIME FREQUENCIES

```
06/15/79            FILE - NONAME    - CREATED 06/15/79

ARRHR

     CODE
           I
       6   *** (      2)
           I
           I
           I
       7   ******* (      6)
           I
           I
           I
       8   ********** (      9)
           I
           I
           I
       9   *************************************************** (     50)
           I
           I
           I
      10   ************************************************ (     47)
           I
           I
           I
      11   ************************************ (     35)
           I
           I
           I
      12   **************************************** (     39)
           I
           I
           I
      13   *********************************** (     34)
           I
           I
           I
      14   ********************************** (     33)
           I
           I
           I
      15   ******************** (     19)
           I
           I
           I.........I.........I.........I.........I.........I
           0        10        20        30        40        50
           FREQUENCY

VALID CASES      274       MISSING CASES      0
```

ARRIVAL TIME FREQUENCIES

```
06/15/79            FILE - NONAME    - CREATED 06/15/79

ARRHR


    CODE
         I
       8 ****** (       1)
         I
         I
         I
       9 *********** (       2)
         I
         I
         I
      10 **************** (       3)
         I
         I
         I
      11 ********************* (       4)
         I
         I
         I
      12 ****** (       1)
         I
         I
         I
      13 **************** (       3)
         I
         I
         I
      14 ****** (       1)
         I
         I
         I.........I.........I.........I.........I.........I
         0         2         4         6         8        10
         FREQUENCY

VALID CASES      15      MISSING CASES     0
```

ARRIVAL TIME FREQUENCIES

```
06/15/79          FILE - NONAME   - CREATED 06/15/79

ARRHR

    CODE
          I
      7   ***************** (     33)
          I
          I
          I
      8   *********************** (     46)
          I
          I
          I
      9   ****************************************** (     83)
          I
          I
          I
     10   ************************************** (     76)
          I
          I
          I
     11   ******************************** (     64)
          I
          I
          I
     12   ********************* (     41)
          I
          I
          I
     13   *********************** (     45)
          I
          I
          I
     14   ********** (     19)
          I
          I
          I
     15   ******************* (     38)
          I
          I
          I.........I.........I.........I.........I.........I
          0        20        40        60        80       100
          FREQUENCY

VALID CASES     445      MISSING CASES     0
```

RESIDENTIAL

```
ARRIVAL TIME FREQUENCIES

06/15/79            FILE - NONAME    - CREATED 06/15/79

ARRHR

    CODE
         I
      6  ** (       1)
         I
         I
         I
      7  ******* (       6)
         I
         I
         I
      8  ************************** (      25)
         I
         I
         I
      9  ************************************************* (      48)
         I
         I
         I
     10  *********************************************** (      46)
         I
         I
         I
     11  ********************************** (      33)
         I
         I
         I
     12  *********************************************** (      46)
         I
         I
         I
     13  ******************************* (      30)
         I
         I
         I
     14  ******************************* (      30)
         I
         I
         I
     15  ******************** (      19)
         I
         I
         I
     16  ** (       1)
         I
         I
         I.........I.........I.........I.........I.........I
         0        10        20        30        40        50
         FREQUENCY
```

ARRIVAL TIME FREQUENCIES

```
06/15/79            FILE - NONAME    - CREATED 06/15/79

ARRHR

     CODE
          I
       7  **** (       1)
          I
          I
          I
       8  ****** (       2)
          I
          I
          I
       9  ********************* (       8)
          I
          I
          I
      10  *********** (       4)
          I
          I
          I
      11  ************************** (     10)
          I
          I
          I
      12  ***************************************** (     16)
          I
          I
          I
      13  ******************* (       7)
          I
          I
          I
      14  ************** (       5)
          I
          I
          I
      16  **** (       1)
          I
          I
          I.........I.........I.........I.........I.........I
          0         4         8         12        16        20
          FREQUENCY

VALID CASES      54      MISSING CASES      0
```

ARRIVAL TIME FREQUENCIES

```
06/15/79            FILE - NONAME    - CREATED 06/15/79

ARRHR


    CODE
          I
      6   ***** (       8)
          I
          I
          I
      7   **** (       6)
          I
          I
          I
      8   ********** (      18)
          I
          I
          I
      9   *************************** (      52)
          I
          I
          I
     10   **************************** (      53)
          I
          I
          I
     11   **************** (      30)
          I
          I
          I
     12   *********** (      20)
          I
          I
          I
     13   ************** (      25)
          I
          I
          I
     14   **************** (      30)
          I
          I
          I
     15   ************* (      23)
          I
          I
          I
     16   **** (       5)
          I
          I
```

ARRIVAL TIME FREQUENCIES

```
06/15/79            FILE - NONAME    - CREATED 06/15/79

ARRHR

   CODE
          I
     7    *** (        2)
          I
          I
          I
     8    ******** (        7)
          I
          I
          I
     9    ********************************* (       32)
          I
          I
          I
    10    ********************************** (       33)
          I
          I
          I
    11    ********************* (       20)
          I
          I
          I
    12    ************** (       13)
          I
          I
          I
    13    **************** (       15)
          I
          I
          I
    14    ********* (        8)
          I
          I
          I
    15    *********** (       10)
          I
          I
          I.........I.........I.........I.........I.........I
          0        10        20        30        40        50
          FREQUENCY

VALID CASES      140       MISSING CASES      0
```

ARRIVAL TIME FREQUENCIES

06/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

```
    CODE
          I
      7   **** (      1)
          I
          I
          I
      8   ****** (      2)
          I
          I
          I
      9   ******************* (      7)
          I
          I
          I
     10   **************** (      6)
          I
          I
          I
     11   ******************* (      7)
          I
          I
          I
     12   ********************************** (     13)
          I
          I
          I
     13   **************** (      6)
          I
          I
          I
     14   ************************ (      9)
          I
          I
          I
     15   ********* (      3)
          I
          I
          I.........I.........I.........I.........I.........I
          0         4         8        12        16        20
          FREQUENCY
```

VALID CASES   54   MISSING CASES   0

VACANT (CONSTRUCTION)

ARRIVAL TIME FREQUENCIES

```
06/15/79            FILE - NONAME    - CREATED 06/15/79

ARRHR

  CODE
         I
     6   * (       1)
         I
         I
         I
     7   ***** (      14)
         I
         I
         I
     8   ************************ (      91)
         I
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*U.S. GOVERNMENT PRINTING OFFICE: 1981-0-341-428/1082

FEDERALLY COORDINATED PROGRAM (FCP) OF HIGHWAY RESEARCH AND DEVELOPMENT

The Offices of Research and Development (R&D) of the Federal Highway Administration (FHWA) are responsible for a broad program of staff and contract research and development and a Federal-aid program, conducted by or through the State highway transportation agencies, that includes the Highway Planning and Research (HP&R) program and the National Cooperative Highway Research Program (NCHRP) managed by the Transportation Research Board. The FCP is a carefully selected group of projects that uses research and development resources to obtain timely solutions to urgent national highway engineering problems.*

The diagonal double stripe on the cover of this report represents a highway and is color-coded to identify the FCP category that the report falls under. A red stripe is used for category 1, dark blue for category 2, light blue for category 3, brown for category 4, gray for category 5, green for categories 6 and 7, and an orange stripe identifies category 0.

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems associated with the responsibilities of the FHWA under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion, and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by balancing the demand-capacity relationship through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements that affect the quality of the human environment. The goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge and technology of materials properties, using available natural materials, improving structural foundation materials, recycling highway materials, converting industrial wastes into useful highway products, developing extender or substitute materials for those in short supply, and developing more rapid and reliable testing procedures. The goals are lower highway construction costs and extended maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural and hydraulic designs, fabrication processes, and construction techniques to provide safe, efficient highways at reasonable costs.

6. Improved Technology for Highway Construction

This category is concerned with the research, development, and implementation of highway construction technology to increase productivity, reduce energy consumption, conserve dwindling resources, and reduce costs while improving the quality and methods of construction.

7. Improved Technology for Highway Maintenance

This category addresses problems in preserving the Nation's highways and includes activities in physical maintenance, traffic services, management, and equipment. The goal is to maximize operational efficiency and safety to the traveling public while conserving resources.

0. Other New Studies

This category, not included in the seven-volume official statement of the FCP, is concerned with HP&R and NCHRP studies not specifically related to FCP projects. These studies involve R&D support of other FHWA program office research.

* The complete seven-volume official statement of the FCP is available from the National Technical Information Service, Springfield, Va. 22161. Single copies of the introductory volume are available without charge from Program Analysis (HRD-3), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.