Generation of Curbside Pickup-and-Delivery Trips

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Data collected in a study of the generation of curbside pickup-and-delivery trips in six U.S. cities are presented and analyzed. The generation rates and analysis presented were developed from field data collected in six cities of more than 250 000 population. The study includes data on some 11 000 curbside pickup-and-delivery operations collected at more than 500 generators in the downtown, fringe, and residential sections of the sampled cities. The generation equations presented show that no single independent variable can be consistently used to accurately forecast pickup-and-delivery trips to all land use types. Employment was found to be the most reliable variable for the typical retail or service generator, whereas floor area was found to be best for office buildings. For hotels and residential generators, number of dwelling units was found to be the most reliable variable and, for industrial land uses, a combination of employment and floor area was the best descriptor. Shipment characteristics for the various land uses and conclusions that relate these characteristics to the size of the city in which the generator is located, as well as to other generator attributes, are presented.

The trip-generation rates presented in this paper are developed from field data collected in six U.S. cities of more than 250 000 population. Included are data on some 11 000 curbside pickup-and-delivery (PUD) operations collected at more than 500 establishments in the downtown, fringe, and residential sections of the sampled cities. This paper presents the data-collection methods and the developed demand equations that resulted from the analysis.

SELECTION OF CITIES

The 1970 Census of Population lists 56 cities that have a population of 250 000 or more, among which are six cities that have more than 1 000 000 people: New York, Los Angeles, Chicago, Philadelphia, Detroit, and Houston. The primary concern in selecting the cities to be surveyed in this study was how many other cities could be "represented" by the sampled cities. For this reason, none of the six largest cities were 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, whether the city is part of a "megalopolis", and geographic location.

The population used was that of the city, and the density measurement used was population per square mile (U.S. customary units of measurement were used in the study). Industrialization relates to the percentage of total city employment engaged in manufacturing. Three classes of industrialization were referred to: producing, balanced, and 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. After a more detailed review of parking, goods movement, traffic engineering concerns, survey logistics, and weather considerations, six cities were selected for the survey (see Table 1): Boston, Dallas, Oklahoma City, Phoenix, San Francisco, and St. Paul. San Francisco was selected as the city in which to conduct the pilot study, primarily because of its weather (the study was conducted in early March) and its size.

The survey was predominantly conducted in the downtown areas 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 pickup or delivery on the study blocks, as well as characteristics of the establishments (land use, size, and employment) and parking regulations and enforcement on each block face, were recorded.

The number and types of generators surveyed in each land use are given below:

Land Use (activity or product)	Number Surveyed	Land Use (activity or product)	Number Surveyed
Bank	10	Liquor	3
Stationery	7	Novelties	5
Clothing	46	Miscellaneous (retail)	22
Department store	5	Shoes	9
Drugstore, health, beauty aids	6	Bar or tavern	9
Electronic	5	Entertainment	3
Fabrics	1	Garage or service station	10
Flowers	2	Hotel	8
Food		Light industry	24
Prepared	47	Office	52
Retail	10	Residential	100
Furniture	3	Service	53
Jewelry	13	Warehousing	11
		Vacant or construction	46

Data on employment and floor area (or number of dwelling units) were collected for each generator.

SURVEY PROCEDURES

The data collection was carried out by locally hired field crews that consisted of college students and/or temporary personnel obtained through employment agencies. A classroom-type training session was followed, where practical, by a dry run on the street under the supervision of study staff personnel.

With the exception of some special generators, each site was observed for a period of five days from Monday through Friday. Daily coverage by the full crew extended from before 8:00 a.m. to after 4:00 p.m. and was dictated by goods-movement activity. Various data-collection forms relating to different needs for the overall project were used. The trip-generation data collected were

1. Generator characteristics—(a) size (gross floor area or units if residential or hotel), (b) employment (except for office buildings and residential), and (c) location [central business district (CBD), fringe, and outlying]; and
2. Trip characteristics—(a) time and date of arrival and departure, (b) type of operation performed (pickup, delivery, or pickup and delivery), (c) parking characteristics, and (d) shipment characteristics.

The data collected on PUD operations in each city are summarized below. These data include about 2000

Table 1. Description of survey cities.

City	Population (000s)	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

service calls (repairs or installations) that are not included in the PUD trip-generation data base:

City	Number of Edited 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

TRIP GENERATION

Previous studies have developed equations for truck trips in urban areas. Since PUD is not entirely a truck-related operation, especially for CBD distribution, many of these studies are not applicable. Variables determined in four related studies on PUD trip generation (1-4) are given below (S = floor area in thousands of square feet, and E = employment):

Study	Type of Activity Area	Daily-Trip-Generation Variable
Marconi (1)	Light industry or warehousing	0.04S
	Retail	0.12S
	Financial (office)	0.12S
Traffic Research Corporation (2)	Manufacturing	0.082E
	Office	0.110E
	Retail	0.278E
Bates (3)	Manufacturing	2.2 + 0.61S
	Warehousing	2.3 + 0.48S
	Office	3.6 + 0.18S
Chatterjee and others (4)	Downtown retail	0.63S, 0.40E
	Wholesale operations	0.55S, 0.50E
	Truck terminal	3.61S, 1.40E

Our study, which obtained data on both employment and floor area, builds on these previous studies to advance the state of the art in PUD trip generation.

It should be noted that the seasonal nature of PUD activity (5) could have resulted in the discrepancies evident in the table above. In this study, data were collected in March in San Francisco, in September in Boston and St. Paul, in October in St. Paul and Oklahoma City, in November in Oklahoma City and Dallas, and in December in Phoenix. The fall period, during which all of the cities except San Francisco were surveyed, is the peak PUD season in downtown areas because of back-to-school activity, fall shopping, Thanksgiving sales, and the imminent Christmas period. Freight movements of consumer products (and studies thereof) are primarily a fall phenomenon in the CBD. Therefore, in order to make the San Francisco data consistent with those for the other five cities, a correction factor of 1.15 (5) was applied to all demand data for that city.

It was felt that the use of a very disaggregated land use structure for the research project would be too cumbersome when it came to possible application of the results in the field. Selected land uses, such as office space, generally stand alone. Other land uses are grouped if they had similar generation and arrival patterns. A PUD trip is defined as a pickup, a delivery, or a pickup-and-delivery trip. Although they are not directly related to demand analysis, the resultant hourly arrival distributions by land use are given below for use in estimating hourly PUD activity:

Time	Arrival Distribution (%) Office	Residential and Hotel	Food	Industry and Warehousing	Retail and Service
6:00-7:00 a.m.	0.1	0.4	2.9	0.2	1.0
7:00-8:00 a.m.	1.4	8.0	7.3	2.4	2.8
8:00-9:00 a.m.	9.6	12.2	11.8	14.0	7.7
9:00-10:00 a.m.	14.4	18.7	19.4	15.4	16.5
10:00-11:00 a.m.	16.6	16.5	19.7	18.1	18.1
11:00-12:00 a.m.	13.4	13.4	15.3	12.4	14.6
12:00-1:00 p.m.	11.0	8.7	7.6	8.6	11.0
1:00-2:00 p.m.	11.4	9.2	7.5	10.8	10.6
2:00-3:00 p.m.	11.9	7.0	4.3	10.0	10.4
3:00-4:00 p.m.	9.9	5.9	4.2	7.4	7.1
4:00-5:00 p.m.	0.3	–	–	0.5	0.2

Office

Office land use is clearly definable as office use in office buildings and does not include other ground-floor uses, such as restaurants and banks. Employment information for office buildings was not obtained because of the decentralized nature of the tenants and because previous studies have shown that PUD demand at office buildings is a function of building size.

Figure 1 shows a plot of weekly generation of PUD trips versus floor area for various land uses. The weekly generation equation for office use is

$$WG = 0.80 \times FA + 2.0 \quad (N = 48, R^2 = 0.93) \tag{1}$$

where WG is average peak weekly generation of PUD trips and FA is floor area (hundreds of square meters).

The distributions of shipment weight and size (number of pieces) at office uses are given in Tables 2 and 3. Mean shipment size was 5.2 packages, and mean shipment weight was 44 kg.

Residential

Single-family dwelling units were predominant among the residential land uses surveyed, but several small and large residential buildings are also represented. Figure 2 shows a plot of weekly PUD trip generation versus number of dwelling units. The resultant weekly generation equation is

$$WG = 0.15 * DU + 2.27 \quad (N = 87, R^2 = 0.94) \tag{2}$$

where DU is the number of dwelling units in the generator.

The distributions of shipment weight and size are given in Tables 2 and 3. The mean shipment weight was 39 kg, and the mean shipment size was 3.8 packages.

Hotels

The downtown areas of the various cities surveyed have both old and new hotels. As hotels grow old, the tenants generally tend to be of the longer-term type and PUD characteristics become similar to those of residential apartment buildings. However, most functioning downtown hotels are an aggregate of rooming and support (restaurants, shops, etc.) functions and are therefore quite dissimilar to residential development. Therefore, the hotel samples shown in this section are functioning hotels, and the "rooming houses" have been grouped with the residential samples.

Figure 2 shows a plot of the weekly generation of PUD operations versus the number of rental units. The resultant demand equation is

$$WG = 0.30 * RU - 12.0 \quad (N = 11, R^2 = 0.96) \quad (3)$$

where RU is the number of rental units in the generator. The negative constant indicates that the equation should only be applied to generators that have more than 100 rooms.

The distributions of shipment weight and size are given in Tables 2 and 3. The average shipment weight was 120 kg, and the average shipment size was 9.1 packages.

The analysis of demand variables presented for land uses in the remainder of this paper uses both floor area and employment. These variables themselves are correlated to varying degrees for specific land uses. Where necessary, single-variable regression equations will be presented.

Figure 1. PUD trips generated per week versus floor area.

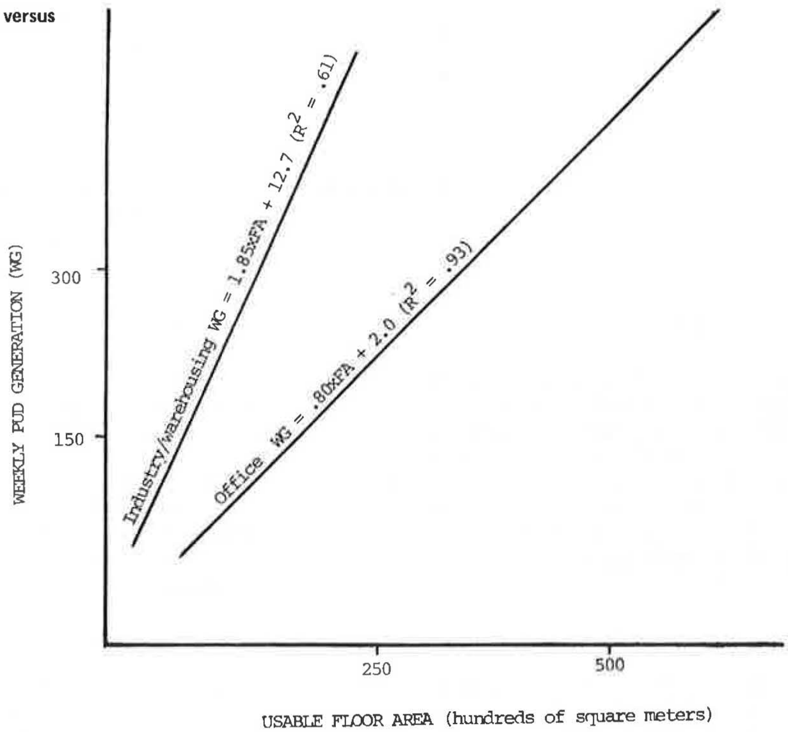


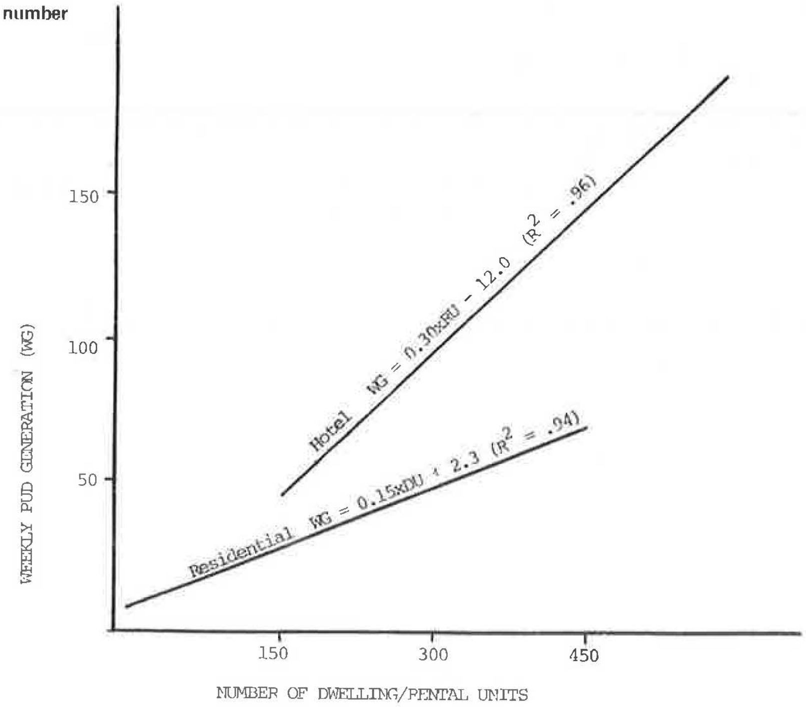
Table 2. Distribution of PUD shipment weights by land use.

Land Use	Distribution by Weight per Shipment (%) <2 kg	2-5 kg	5-25 kg	25-50 kg	50-250 kg	250-500 kg	>500 kg	Avg Weight per Shipment (kg)
Office	29	16	27	11	14	2	1	44
Residential	34	13	34	9	5	2	3	39
Hotel	8	10	24	12	32	7	7	120
Food	6	16	34	16	22	4	2	61
Light industry and warehousing	16	12	21	12	22	7	10	265
Retail and service	22	14	26	13	18	3	4	95

Table 3. Distribution of PUD shipment sizes by land use.

Land Use	Distribution of Shipment Size by Pieces per Shipment (%) <4	4-5	6-10	11-50	>50	Avg No. of Pieces per Shipment	No. of Sample Trips	Avg Weight per Piece (kg)
Office	70	11	10	8	1	5.2	2873	8.5
Residential	79	10	7	4	0	3.8	472	10.3
Hotel	45	13	19	20	3	9.1	535	13.2
Food	51	14	17	16	2	8.0	1098	7.6
Light industry and warehousing	53	12	13	15	7	22.6	1333	11.7
Retail and service	60	12	13	12	3	11.8	3970	8.1

Figure 2. PUD trips generated per week versus number of dwelling (or rental) units.



Retail and Prepared Foods

The foods category of land use is usually omnipresent in downtown areas. It is treated separately because, as mentioned earlier, its demand characteristics by time of day are unique in that a higher percentage of arrivals occur before 9:00 a.m., the time when most other establishments are still closed. The results of the demand analyses indicate that both floor area and employment contribute significantly to R^2. The resultant demand equation is

$$WG = 1.65 \times FA + 1.21 \times E + 5.20 \quad (N = 44, R^2 = 0.25) \tag{4}$$

The employment variable contributes 0.22 to R^2. Figure 3 shows the weekly demand equation, in which employment is used as the only variable.

The demand analysis for food has the lowest R^2 value of all demand equations done for this study, although the equation itself produces results that are reasonable. Loebl's work (6) essentially concluded that a constant value of generation for prepared foods was usable (Loebl's work did not include employment data). For a prepared-food establishment with 10 employees and 1000-m^2 floor area, this research would predict a daily generation of 6.7 PUD trips. Loebl's demand equation would predict a range of 4-6 trips/day.

The shipment characteristics are given in Tables 2 and 3. The weight transferred per trip was 61 kg, and the mean size was 8 packages.

Light Industry and Warehousing

The combination of manufacturing and warehousing was precipitated because (a) only 13 warehousing samples were surveyed in the central areas, (b) several of the manufacturing samples also did some warehousing, and (c) the arrival patterns were quite similar. The weekly generation equation is

$$WG = 1.28 \times FA + 0.31 \times E + 11.96 \quad (N = 31, R^2 = 0.64) \tag{5}$$

The resultant regression equation, if employment only was used as the variable, is shown in Figure 3. Figure 1 shows the demand equation data if floor area was the only variable used. Since floor area and employment are highly correlated for this land use, either of these variables could be used independently with similar accuracy.

The distributions of shipment weight and size are given in Tables 2 and 3. The mean shipment weight was 265 kg, and the mean shipment size was 22.6 packages.

Retail and Service

The retail and service aggregated land use category comprises the following establishment types: bank; stationery; clothing; department store; drugstore, health, and beauty aids; electronic; camera; flowers; furniture; jewelry; liquor; novelties; shoes; bar or tavern; entertainment; garage or service station; service (locksmith, shoe repair); and miscellaneous. They were combined because (a) there were several establishment types for which there were too few samples, (b) the establishment types for which there were large samples all showed similar generation characteristics, and (c) all establishments had similar arrival patterns (primarily because the same carriers service all uses). The weekly generation equation found for the samples is

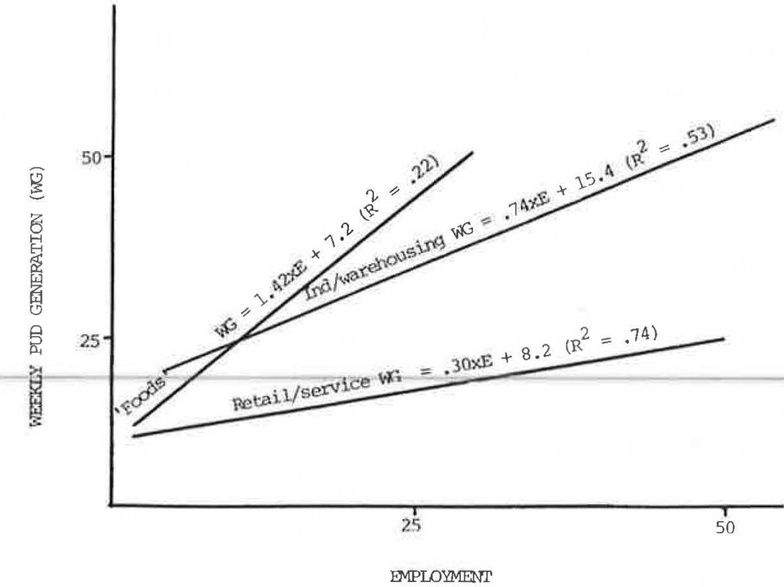
$$WG = 0.024 \times FA + 0.30 \times E + 8.25 \quad (N = 219, R^2 = 0.75) \tag{6}$$

The contribution of R^2 is 99 percent from E and 1 percent from FA. Because of this, it is recommended that the following weekly equation be adopted for use by sacrificing a small amount of accuracy for simplicity. Figure 3 shows a plot of the resultant equation:

$$WG = 0.30 \times E + 8.2 \quad (N = 219, R^2 = 0.74) \tag{7}$$

The distributions of shipment weight and size are given in Tables 2 and 3. The mean shipment weight was 95 kg, and the mean shipment size was 11.8 pieces.

Figure 3. PUD trips generated per week versus employment.



SUMMARY

The data base from which this research was developed is a comprehensive one that encompasses statistics from six cities stratified by size, location, and industrialization. The research could not validate some hypotheses. For example, the research could not substantiate whether demand characteristics vary by city size and location. Another hypothesis was that shipment characteristics within each land use vary by the size of the generator. This was not substantiated within the ranges studied. Therefore, the generation of shipment size and weight for a particular site can be found by using the trip-generation rate and the average shipment characteristics for that land use (Tables 2 and 3).

ACKNOWLEDGMENT

The research reported in this paper is part of the Federal Highway Administration's project on metropolitan multimodal traffic management and was performed with the support and under the supervision of the Office of University Research, Federal Highway Administration. The conclusions reported are ours and do not necessarily reflect the opinions of the Federal Highway Administration.

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Publication of this paper sponsored by Committee on Urban Goods Movement.

Factors That Influence Freight-Facility Location Preference

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An analysis of factors that affect freight-facility location is presented. A multinomial logit formulation is used. Correlation between attributes in the model is minimized by means of a factor analysis. The modeling approach is then shown to be a suitable and potentially valuable approach to analyzing facility location. By using data collected in Melbourne, Australia, the model calibration shows that the decision on facil-