needed to determine what factors may account for this finding.

There were very few medium- and heavy-truck trips to residential land areas; thus no regression equations could be estimated. Nearly 50 percent of the truck trips to residential land were made by light vehicles. Several equations for light trucks to residential activity were estimated (Equations 15-17). Again, the multiple regression with residential land area and dwelling units proved to be the best model and slightly improved the results obtained for total truck trips to residences.

The subdivision of truck trips by vehicle type did not improve the results in any case for trips to commercial land areas. Commercial employment provided the best-fitting models, although the relation for heavy vehicles was poor. This may indicate that further subdivision of the commercial category is needed in dealing with heavy trucks, since it is obvious that the retail, wholesale, and service activities now included in this aggregate category display substantial differences in the movement of goods that require heavy trucks. For the medium-truck class the best results were obtained when commercial employment was used as the explanatory variable (Equation 28). Finally, the sparse sample of medium and heavy trips to public buildings and public open space land prevented estimation of relations for these categories. Light-truck trips to these land uses, however, were significantly explained by public building and public open space land area, respectively (Equations 21 and 22).

SUMMARY AND CONCLUSIONS

The results obtained even at this rather aggregate level of analysis exhibit sufficient significance to warrant continued effort at a finer level of detail, both spatially and in land use categories. For most models, the statistical tests yielded positive results and support the adoption of this methodological framework for commercial vehicle trip generation analysis. The significant and regular variation in the truck trips per developed land acre and trips per employee ratios as distance from the CBD varies may indicate that adding an access measure to the models would improve their performance. The addition of zonal industrial composition may also improve the results. Such a measure would account for external economies that arise from similar activities being located next to each other and thereby affect their freight-transportation characteristics.

The overriding determinant of truck-trip-generation characteristics, however, remains the type of activity in the zone. We have observed substantial improvement over the unstratified results when trips were subdivided by type of activity. This was particularly evident in the total truck models but also appeared to a lesser degree in the models for individual truck types. In general, the weight-classification scheme for vehicle type did not seem to yield improved results. Except for the heavy-truck trips to manufacturing activities, better results were obtained with the total truck models. This preliminary finding, however, does not justify elimination of this truck-type factor from further consideration in the generation analysis. Because heavy and medium trucks tend to concentrate service to freight-oriented industries, future work will be devoted to analyze these heavy-freight generators. Finally, this analysis has proved encouraging and should be continued with effort devoted to resolving some of the problems that remain.

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Service and Supply Trips at Federal Institutions in Washington, D.C., Area

FRANK SPIELBERG AND STEVEN A. SMITH

Knowledge of the number and time distribution of goods and service trips is essential for the proper planning of dock and parking facilities at large employment sites. Federal office buildings in Washington, D.C., are typical of many large office complexes, particularly those of state governments. Federal warehouse operations have characteristics similar to those of large distribution centers. The results of a survey of goods and service vehicle trips to federal facilities in the Washington metropolitan area are presented and suggest specific guidelines for the planning and operation of similar facilities. Data were collected on vehicle trips that involved a service or supply function at 10 federal facilities in the Washington area. By using a combination of on-site observation and driver interviews, data on arrival and departure times, vehicle characteristics, trip purpose, origin of trip, and nature and size of load were obtained, analyzed, and used to develop planning guidelines.

Although the charge to analyze goods movements has been with urban transportation planning agencies since 1962, it was only in the 1970s that substantial attention was devoted to the issue. This period saw not only the undertaking of significant studies by several local planning groups but also

Table 1. Sites selected for service and supply trip surveys.

Site	Location	Type of Operation
Cameron Station	Northern Virginia	Military warehousing and supplies
Department of Commerce	Washington CBD	Government offices
GPO	Washington CBD	Printing
GPO, Eisenhower warehouse	Northern Virginia	Bulk document distribution
GPO, Franconia warehouse	Northern Virginia	Paper supply
NBS	Maryland	Offices, research
National Park Service	Washington	Maintenance depot
NRL	Washington, outskirts	Offices, research
Pentagon	Northern Virginia	Military offices
VA hospital	Washington, outskirts	Hospital

new research at the federal level. These federal studies included Urban Mass Transportation Administration (UMTA) research on problems and opportunities in urban goods movement and the preparation for the Federal Highway Administration (FHWA) of a handbook on planning for urban goods movement.

As a result of these efforts a body of knowledge has begun to develop on the size of the urban goods problem. Data on delivery and service-trip-generation rates have been assembled and a start has been made toward the development of planning standards.

In the Washington, D.C., metropolitan area, planning for the largest employer--the federal government--is overseen by the National Capital Planning Commission (NCPC). To improve the planning for federal installations NCPC commissioned a study of service and supply trips. The data from this study, presented here, provide guidance on goods movement requirements at similar sites.

STUDY METHODOLOGY

NCPC has, over the last several years, been conducting the federal transportation study. Phase 4 of the study consists of an assessment of trips to federal government installations by tourists, visitors, and service and supply vehicles. The purpose of the study is to determine current and future requirements at government facilities for serving such trips.

The study reported on here concerns the service and supply trip element of the NCPC study. For purposes of this study, service and supply trips were defined as trips in which a service was performed (e.g., repairing office equipment, work utilities, etc.) or in which some type of commodity was either picked up or delivered. Thus, the study considered trips that may have been made in vehicles other than trucks.

Site Selection

Sites were selected by using general site selection criteria, which include the following:

1. Geographic location,
2. Type of operation,
3. Size of operation, and
4. Feasibility of conducting the surveys.

The application of the above criteria resulted in the 10 selected sites shown in Table 1.

Data Collection

Data were collected on service and supply trips during the summer 1979. Interviewers were stationed at each location at a particular building where service and supply trips were expected. The observers were responsible for identifying those vehicles that arrived at a building that were performing a service or supply function. There were very few instances where this could not be easily done. However, the vehicle had to be marked with a company name or other identifier to be included. The observers recorded information on vehicle type, whether it was government owned, arrival and departure time, and parking location, and questioned the driver in regard to origin of trip, trip purpose, and specific commodities carried or service to be performed. In many cases, some of the driver interview questions could be observed directly.

Obtaining sufficient origin information proved to be a fairly difficult task. First, drivers were often reluctant to give any information whatsoever, and when information was given, it was very general. Most often, it was given in the form of a large geographic area (e.g., Largo, Maryland).

OVERVIEW OF FINDINGS

As would be expected in a small sample of this type, there was significant variation among the sites in the nature of goods movement activity, the types of vehicles used, number of goods-related trips, and the duration of stay. For each site surveyed an individual data sheet was prepared. These showed the percentage distribution of

1. Vehicle type,
2. Government owned versus private,
3. Time of arrival,
4. Duration of stay,
5. Purpose of visit,
6. Type of commodity, and
7. Weight of commodity.

At warehouse-distribution facilities, semitrailers tend to predominate. At all other facilities the majority of deliveries are by van or single-unit truck. However, all facilities surveyed received at least a portion of deliveries by semitrailer, which indicates a need to provide for such vehicles in site design. Privately owned vehicles accounted for most of the goods movement activity at all sites, and much of the government-owned vehicle activity was related to mail.

All sites, whether city, suburban, office, or warehousing, show peak arrival activity between 8:30 and 9:30 a.m. Arrivals are high throughout the morning hours but decline sharply about noon. At all sites a secondary peak occurs just after lunch. Arrivals after 4:00 p.m. are rare.

The duration of stay is a function of the type of activity performed and the facilities visited. For warehouse-distribution sites, trucks tended to remain for extended periods that averaged almost 1.5 h. The duration of stay at office sites showed considerable variation, which ranged from 18 to 51 min. For the typical office site the mean duration was 30-35 min.

Except for the Government Printing Office (GPO) on North Capitol Street, which is a distribution site, more than one-half the trips at all locations

Table 2. Summary of service and supply trip generation rates.

Site	Daily Trips	Employees No.	Employees Trip Rate[a]	Occupiable Space Square Feet (000s)	Occupiable Space Trip Rate[b]	Loading Docks No.	Loading Docks Trip Rate[c]
Cameron Station	128	3 330	0.038	835	0.153	–	–
Department of Commerce	91	4 790	0.019	1019	0.089	8[d]	11
GPO, North Capitol	265	5 350	0.050	952	0.278	18[d]	15
GPO, Franconia	21	17	1.235	148	0.142	3	7
GPO, Eisenhower	19	178	0.107	102	0.186	4	5
Hoffman Building	34	4 800	0.007	776	0.044	4	9
NBS	65	3 160	0.021	1319	0.049	10[d]	7
National Park Service	104	117	0.889	–	–	–	–
NRL	63	4 350	0.014	1550	0.041	–[e]	–[e]
Pentagon	219	23 200	0.009	3784	0.058	≥15	15
VA hospital	26	1 650	0.015	387	0.067	4	7

[a]Trips per employee. [b]Trips per 1000 ft2. [c]Trips per loading dock. [d]Approximate. [e]Unknown.

Table 3. Summary of truck trip generation rates.

Site	No. of Trips	No. of Trucks	No. of Employees	Square Feet (000s)	Trip Generation Rate: Truck Trips per Employee	Trip Generation Rate: Truck Trips per 1000 ft	Trip Generation Rate: Total Trips per 1000 ft
Cameron Station	128	125	3 330	835	0.037	0.149	0.153
Department of Commerce	91	66	4 790	1019	0.014	0.065	0.089
GPO, North Capitol	265	175	5 350	952	0.033	0.184	0.278
GPO, Franconia	21	17	17	148	1.0	0.115	0.142
GPO, Eisenhower	19	14	178	102	0.078	0.137	0.186
Hoffman Building	34	32	4 800	776	0.007	0.041	0.044
NBS	65	54	3 160	–	0.017	–	–
NRL	63	56	4 350	1550	0.013	0.036	0.041
Pentagon	219	175	23 200	3784	0.008	0.046	0.058
VA hospital	26	11	1 650	387	0.007	0.028	0.067

Table 4. Representative time distributions of arrivals.

Time	Percentage of Arrivals: GPO, North Capitol	NBS	NRL	Pentagon	Cameron Station
7:00-8:00 a.m.	3	4	6	10	9
8:00-9:00 a.m.	10	4	8	12	14
9:00-10:00 a.m.	20	15	20	18	17
10:00-11:00 a.m.	23	22	18	18	12
11:00 a.m.-noon	15	9	17	12	13
Noon-1:00 p.m.	5	0	7	4	8
1:00-2:00 p.m.	9	12	9	6	10
2:00-3:00 p.m.	8	16	10	10	8
3:00-4:00 p.m.	7	15	5	5	9
4:00-5:00 p.m.	0	3	0	2	0

involved deliveries. On average, about 10 percent of the truck trips to office activities involved service calls.

SPECIFIC RESULTS OF SERVICE AND SUPPLY SURVEY

Classification of Sites

Sites surveyed are of three basic types. The following sites have characteristics that are primarily office: Department of Commerce, Hoffman Building, National Bureau of Standards (NBS), Naval Research Laboratory (NRL), Pentagon, and Veterans Administration (VA) hospital.

Characteristics of terminal-warehouse facilities are found at Cameron Station (also includes substantial office functions); GPO warehouse, Franconia; and GPO warehouse (Eisenhower, although slightly different due to the high proportion of deliveries).

GPO on North Capital Street has characteristics of both office and warehouse facilities. The VA hospital also has unique characteristics but is included in the office category.

The National Park Service Maintenance Depot is a garage facility. It is unlike any of the other sites as its primary function is the storage of vehicles.

For planning purposes, the items of interest in the analysis of plans for federal installations are

1. Number of truck trips,
2. Time-of-day distribution of trips,
3. Size of loads,
4. Vehicle type, and
5. Duration of stay.

Items 1 through 4 are required for site impact analysis. Items 1 through 5 are required for design of loading facilities. In the following discussion we present summaries of the data together with some suggested planning guidelines.

Trip Generation Rates

As would be expected in a small sample of this type, there was considerable variation among the sites in the nature of the goods movement activity. Table 2 summarizes service and supply trip generation rates for the sites surveyed. The survey data indicate substantial variation in the rate of service and supply trips per employee or gross (occupiable) square feet. However, as shown in Table 3, when surveyed trips by vehicles other than trucks are deducted, a pattern does emerge.

For office-type facilities the number of truck

trips seems best related to the number of employees, as shown in the table below:

Location	Truck Trips per Employee
Commerce Department	0.014
NBS	0.017
NRL	0.013
Pentagon	0.008
Hoffman Building	0.007
VA hospital	0.007

The range is from 0.007 to 0.017 truck trips/day per employee, with a suggested tendency for the rate to drop with a larger facility (e.g., Pentagon). The Hoffman Building may have special characteristics that lead to the observed low rate.

The range is considerably lower than the rate for office space of 0.05/employee (based on 2.0/10 000 ft²), which is suggested in the report on urban goods movement prepared by FHWA. This may be a result of the special nature of government work. Government installations, because of their size, tend to make the consolidation of service and supply functions much easier than in the private sector. This was observed in the course of the surveys as a single Government Services Administration (GSA) truck would often deliver days or weeks worth of certain types of supplies for a large number of employees. A value of 0.013/employee would seem appropriate for planning purposes.

For warehouse-type facilities the truck trip rate seems best related to square footage, as shown in the table below:

Location	Truck Trips per 1000 ft²
Cameron Station	0.149
GPO, North Capital	0.184
GPO, Franconia	0.115
GPO, Eisenhower	0.137

The range is from 0.115 to 0.184. A value of 0.15 truck trips/day per 1000 ft² would be appropriate for planning.

Time of Day

The time-of-day distribution of truck arrivals shows a consistent pattern for the sites surveyed. There is little activity prior to 8:00 a.m. Most loading facilities maintain regular 8-h/day working hours. During the morning, arrivals per hour are roughly constant. A distinct drop is observed from 11:30 a.m. to 1:30 p.m. Afternoon arrivals are at a lower rate than morning arrivals, falling rapidly after 4:00 p.m.

The time distributions of arrivals shown in Table 4 are those observed at several sites of varied character and location. The distributions are representative, rather than typical, of the surveyed installations.

The single peak hour occurs in the morning--roughly between 9:30 and 10:30 a.m. Approximately 20 percent of all arrivals occur in this interval. A planning parameter of 25 percent will ensure that adequate loading space is provided.

Size of Load

The typical load size varies with the character of the installation. The table below presents the proportion of commodities greater than and less than 100 lb:

Site	Percentage of Commodities <100 lb	Percentage of Commodities >100 lb
Department of Commerce	60	40
Hoffman Building	43	57
NBS	61	39
NRL	37	63
Pentagon	44	56
VA hospital	65	35
GPO, North Capital	74	26
Cameron Station	32	68
GPO, Franconia	19	81
GPO, Eisenhower	27	73

This weight is used as a breakpoint because it represents the division between hand carried and other types of loads.

No clear pattern can be discerned in these data as to the load size to be expected. What can be said is that at all sites the proportion of loads exceeding 100 lb is sufficiently great that provision must be made to accommodate such loads.

Type of Vehicle

The type of vehicle used to make deliveries affects not only the design of loading space but also the impact of truck trips on surrounding streets. Table 5 presents the observed distribution by vehicle type. Perhaps the only inference that can be drawn from these data is that shippers do not use semitrailers for deliveries to downtown locations. The lowest proportion of semitrailer trips was observed at the downtown facilities (Department of Commerce and GPO, North Capitol). The low proportion observed at the Pentagon may be a function of either the type of delivery or the loading-dock facilities. As it is generally more efficient for shippers to use larger vehicles, this suggests the need for NCPC to assure that loading areas and approaches to loading areas provide adequate space for semitrailers.

Duration of Stay

The duration of stay of vehicles is a critical measure in the design of loading facilities. Sufficient space must be provided to accommodate the maximum accumulation of vehicles. Observed duration at the survey is a function of the number of trips, existing loading facilities, type of commodity, initial operation of the installation, and management practices. A central-receiving function that obviates the need for drivers to deliver to individual locations within buildings will substantially reduce time at the loading dock and promote more-efficient use of dock space.

For the facilities surveyed the mean duration of stay ranged from a low of 18 min at NBS to a high of 86 min at the GPO, Franconia, as shown in the table below:

Location	Mean Duration of Stay (min)	Percentage of Load More than 100 lb
NBS	18	39
Hoffman Building	26	57
GPO, North Capitol	27	26
Department of Commerce	29	40
NRL	39	63
VA hospital	39	35
Pentagon	51	66
GPO, Eisenhower	28	73
Cameron Station	79	68
GPO, Franconia	86	81

For office-type facilities, the range is from 18 to 51 min with some slight indication that the variation is related, in part, to the preparation of deliveries that exceed 100 lb. An average of about 30 min should be useful for planning purposes. The larger value at certain locations suggests that the goods receiving and dispatching functions may not be organized or that loads have special characteristics.

For warehouse facilities that have both pick-up and delivery functions a duration of about 80 min was observed. The relatively short duration (28 min) at GPO, Eisenhower, appears to be a result of the fact that 84 percent of the truck arrivals were for delivery only. It is not clear if this pattern represents a typical day. The table above also lists the percentage of trips for which size of loads were more than 100 lb. The duration of stay could be logically related to size of load, but the data suggest only a moderate degree of correlation.

Table 5. Distribution of trips by vehicle type.

Location	Percentage of Service-Supply Trips by		
	Automobile, Pickup, and Van	Single-Unit Truck	Semi-trailer
Department of Commerce	74	22	4
Hoffman Building	28	35	37
NBS	41	45	14
NRL	33	46	21
Pentagon	59	36	5
VA hospital	58	42	0
GPO, North Capitol	63	28	9
Cameron Station	21	56	23
GPO, Franconia	18	15	67
GPO, Eisenhower	27	26	47

Table 6. Percentage of service and supply trips by purpose.

Location	Pick-Up	Delivery	Pick-Up and Delivery	Service Call	Service Call and Pick-Up and Delivery
Cameron Station	9	72	9	7	3
Department of Commerce	25	62	8	6	0
GPO, Eisenhower	5	84	11	0	0
GPO, Franconia	37	57	5	0	0
GPO, North Capitol	48	44	6	2	0
Hoffman Building	15	64	6	12	3
NBS	18	63	15	3	0
NRL	3	70	4	14	9
Pentagon	10	60	16	13	1
VA hospital	13	46	33	4	4

Vehicle Ownership

The table below lists the percentage of arriving vehicles that are government owned.

Location	Percentage of Government-Owned Vehicles
Cameron Station	8
Department of Commerce	44
GPO, Eisenhower	16
GPO, Franconia	14
GPO, North Capitol	42
Hoffman Building	32
NBS	34
NRL	6
Pentagon	35
VA hospital	8

The largest percentage of government vehicles was 44 percent at the Department of Commerce. The warehousing-type facilities tend to have the smaller percentage of government vehicles. From the data and from discussions with dock superintendents, it appears that much of the heavier goods movement operations are contracted out.

Purpose of Visit

Table 6 summarizes the purposes of service and supply trips to government facilities. In most cases, the data can be related to the type of operation. For example, the functions of the GPO, North Capitol, with the highest percentage of pick-up trips, is to print and deliver government documents. The incoming materials tend to come in bulk loads while the outgoing products are picked up in smaller quantities to be disseminated to diverse locations. Most of the other installations tend to be users rather than producers of goods and services and thus have high delivery percentages.

Types of Commodities and Services

Table 7 indicates the type of commodities and services that are primarily being dealt with at government installations. These percentages can also be related to type of operation involved. For example, GPO operations deal largely with paper products, which is reflected in the percentages. The types of commodities and services are reflected in the types of vehicles used, as discussed in a previous section.

Planning Guidelines

The observations of the service and supply survey suggest the following planning guidelines for federal office facilities:

1. 0.013 truck trips/day per employee,
2. 25 percent peak-hour factor (mid-morning), and

Table 7. Types of commodities and services.

Location	Commodities					Services			
	Mail and Trash	Food and Beverage	Hard Goods	Paper	Other	Utilities	Office Equipment	Vending Machine	Other
Cameron Station	5	30	38	2	12	5	1	4	3
Department of Commerce	16	7	38	30	4	1	0	0	2
GPO, Eisenhower	10	0	10	80	0	0	0	0	0
GPO, Franconia	14	5	0	81	0	0	0	0	0
GPO, North Capitol	14	4	6	59	12	1	2	0	2
Hoffman Building	20	33	0	9	6	0	20	0	12
NBS	11	15	63	2	5	2	0	0	0
NRL	11	7	43	6	3	7	16	3	3
Pentagon	11	9	36	26	2	5	1	1	9
VA hospital	12	20	56	4	0	4	0	4	0

3. 30-min mean duration.

Minimum space requirements may be estimated based on the above data. However, it is important to recognize that each site may have significantly different requirements due to particular functions contained, size of facility, and other factors.

For planning purposes it should be assumed that at least one-third of the vehicles will be semitrailers. A minimum of one dock space should be provided for such vehicles, with 1 of 3 dock spaces designed for semitrailers in larger facilities.

The survey also suggests the following planning guidelines for federal warehouse facilities:

1. 0.15 truck trips/day per 1000 ft^2,
2. 25 percent peak-hour factor, and
3. 80-min duration.

The same qualifications in regard to the application of these data to facility planning as were mentioned for office facilities should be recognized. At least one-half of the dock spaces should be designed for semitrailers.

The guidelines above relate to design of the facility. Impact of truck traffic on adjacent streets is a function of the number of trips that occur during the peak hour of on-street traffic. As noted, truck activity prior to 8:00 a.m. is quite low. However, for certain locations pick-up and delivery activity between 8:00 and 9:00 a.m. may conflict with adjacent street traffic. The guidelines for these analyses are 12.5 percent for 8:00-9:00 a.m. deliveries and 0.8 vehicles/1000 employees for office and 0.025 vehicles/1000 ft^2 for warehouse-type facilities.

CONCLUSIONS

The data obtained in the survey and presented in this paper relate to a specific type of facility--federal employment sites in the Washington, D.C., area. The findings, therefore, are most applicable to these operations. However, federal government facilities in Washington have characteristics similar to those found in many large office centers, particularly those of state government. To this extent the findings will provide assistance to those involved in planning similar facilities.

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Direct and Indirect Energy Consumption by Chicago's Urban Trucking Industry

FRANK SOUTHWORTH, BRUCE JANSON, EVANGELOS PAPATHANASSOPOULOS, AND DAVID ZAVATTERO

A procedure for establishing a set of urban truck movement energy accounts is described. Direct energy consumption, in the form of truck fuel consumption, and indirect energy consumption on terminal, vehicle, roadway and fuel operation, maintenance, and construction are discussed. Another form of indirect energy consumption is the passenger vehicle fuel consumed due to truck-induced traffic congestion. The procedures are applied to an empirical study of the urban trucking industry in Chicago. Estimates are provided for the total direct and indirect energy consumed on an annual basis. By using a marginal approach to indirect energy accounting, both direct and indirect energy can be specified on a vehicle-kilometer or ton-freight kilometer of travel basis. Direct fuel energy consumption rates are compared across truck sizes, fuel, carrier and commodity types, time of day, and by base terminal district. Emphasis is given to the effects of truck route circuity on fuel consumption.

To date, very little work has been done to quantify the energy consumed by urban goods movement systems, despite the findings of the few studies available that indicate the potential for considerable energy savings in the urban trucking industry. In this paper we present an accounting framework for estimating such energy consumption and present the results from an application of the accounting procedure to the urban trucking industry in Chicago. The results are taken from a study by Southworth and others (1) for the Illinois Institute of Natural Resources, in cooperation with the Chicago Area Transportation Study (CATS). Since trucks move some 90 percent of all urban freight within our cities, we concentrated our analysis on this single mode.

Figure 1 shows the major data inputs required by our energy accounting procedures. The accounts pay particular attention to the distinction between "direct" fuel consumption energy and the "indirect" energy requested for system construction, operation, and maintenance. The indirect energy analysis is itself divided into three sections:

1. Infrastructure energy consumption (the energy required to operate, maintain, and renew vehicles, terminal facilities, and roads),
2. Fuel production energy consumption (the energy used in producing gasoline and diesel fuel for urban trucking), and
3. Congestion energy consumption (the additional fuel energy used by personal travel vehicles due to interaction with trucks in the same traffic stream).

On the transportation supply side we are concerned with the available terminal, roadway, vehicle, and fuel resources. On the demand side we are dealing with the interindustry demand for urban freight pickups, deliveries, and services. The manner in which carriers respond to this demand through investment in, and use of, their resources will determine the resulting pattern of truck movements at any given time. This pattern of pickups, deliveries,