PLANNING CRITERIA FOR OFF-STREET SERVICE AREAS

E. M. Whitlock and J. G. Schoon, Wilbur Smith and Associates

This paper describes essential characteristics of certain existing truck freight service areas and operational aspects of the facilities based on field study. Sampled study projects include office and retail-oriented developments in New York, Connecticut, Pennsylvania, and Texas. Evaluations were made of the relations of design and operational aspects, number and frequency of truck arrivals, durations of stay, vehicle types, and generation rates based on number of service vehicles and floor area of major land uses. Additional research using a mathematical estimate of arrival rates from the known data (Poisson distribution) supports the application of this technique for predicting potential use of an off-street truck service area.

• THE optimum design of truck freight receiving facilities in congested city areas is of utmost concern in minimizing costs to carriers, the public, and freight recipients. In addition to cost, inconvenience, noise, air pollution, and aesthetics must be considered in truck freight service area planning and design.

This paper describes typical characteristics of existing service facilities physically separated from, but related to, city streets via service tunnels and off-street areas where unloading and loading operations are carried out. Characteristics of land use areas, operating techniques, numbers and types of trucks, and space requirements and a comparison of theoretical design methods are presented.

PHYSICAL CONFIGURATIONS

Functional design of truck terminal facilities is generally dictated by location and size of the development to be served, by access available from adjoining streets, and frequently by underground obstructions and soil conditions. The concern of this paper is essentially with off-street surface and underground truck service facilities served by a tunnel or ramp access.

Four basic service area types are shown in Figure 1. The 4 selected configurations are as follows:

1. A single access, 2-way service area with truck bays at right angles to the roadway with a mechanical assist (turntable) to facilitate reversing direction of vehicles (this arrangement would only normally be used in instances where horizontal dimensions are below those necessary for vehicles to maneuver unassisted);

2. A configuration similar to the first arrangement but without a turntable and with an extended area where turn-around maneuvers may be conducted without mechanical assistance;

3. A 2-way roadway with loading-unloading bays at right angles to facilitate entering and exiting from either end of the facility; and

4. A 1-way system with truck bays arranged in a sawtooth pattern (this configuration provides service vehicles loading-unloading capacity with a minimum width of service tunnel).

Sponsored by Committee on Passenger and Freight Transportation Characteristics.

Loading areas may be included along sides of roadways in addition to designated truck bays, depending on the types of goods and vehicles being handled and the available turning radii. Also, combinations of the configurations given above may be provided for specialized conditions. Internally, goods are generally transferred to smaller carts, elevators, vehicles, or microsystems for transshipment to final destinations within the buildings served.

OPERATIONAL CONSIDERATIONS

Depending on size and composition of the off-street vehicle service areas, methods of operation vary considerably. The following factors affect operations: location of service area, land uses served, functional design of service area, number of loadingunloading berths, frequency of truck arrivals and departures, ownership of access street, times of service vehicle loading-unloading, labor policies, and management controls dictated by building owners.

It is desirable to maintain published hours of operation, which, in theory, should be during evening hours when local streets have capacity to serve access needs. This is difficult, however, in view of service vehicle (delivery) requirements of the building during the day and desire to minimize evening work.

Of utmost importance is maintenance of surveillance in the service area during all hours of operation. Some service tunnel operations require truck drivers to sign a log when entering and leaving, and others perform this function with a full-time dispatcher. Closed-circuit television is also utilized in some service areas to ensure security. Where sight distances are restricted, traffic control devices (signs, signals, pavement markings, and channelization) are used to establish rights-of-way, control ingressegress, set speed limits, and facilitate safe operations.

Frequently, after the construction of extensive redevelopment over existing streets, truck service tunnels may remain as dedicated city streets, in which case all necessary traffic signing and law enforcement must be carried out in accordance with city ordinances. Access in these cases implies use of a public street, and individual owners are, therefore, sometimes required to fence and control access to loading-unloading bays.

LAND USES ASSOCIATED WITH EXTENSIVE TRUCK-FREIGHT SERVICE FACILITIES

The most extensive specialized freight-handling facilities, apart from manufacturing and freight transfer terminals, are those required for retail, commercial, and office use.

Types of goods delivered depend on the land use served and vary from large equipment deliveries by large trucks to frequent small-package deliveries during the day. Also, regular truck movements for garbage disposal and other daily service functions affect design and operation. In some cases, particularly where the garbage is characterized by early decomposition, refrigeration or other special storage facilities may be required.

CHARACTERISTICS OF SURVEYED LOCATIONS

Features of the several locations investigated for this paper are given in Table 1. Each of these developments comprises office or retail establishments or both. Gross floor areas of the buildings studied range from approximately 250,000 sq ft for Roosevelt Field Shopping Center to approximately 5 million sq ft for Rockefeller Center.

Configurations of the loading-unloading areas investigated consist of most features previously described. An interesting exception is the access system to the Time-Life Building service area; it consists of 2 elevators onto which trucks are driven before they are either lowered or raised between the service and street levels. At Rockefeller Center, a single access leads to a large rectangular area around which the truck bays are located. The service area to Chapel Square includes both a sawtooth configuration and bays at 90 deg to the access road. The number of bays associated with these service



Figure 1. Schematic arrangement of typical truck freight-handling configurations.

Table 1. Freight service characteristics at selected locations.

Location	Loca- tion Num- ber	Type of Land Use	Net Floor Area of Building (sq ft)	Unloading Area Configuration	Loading- Unloading Bays
Center city locations		_			
Time-Life Building, New York	1	Office, retail	1,500,000	Elevator entry and exit and turn- table	7
Rockefeller Center, New York	2	Office, retail	5,000,000	Single access, 2-way with central maneuvering area and peripheral bay locations	30
Chapel Square, New Haven	3	Retail, office	900,000	Single, 2-way access with 1-way internal circulation sawtooth and 90-deg bays	12
Penn Center Plaza, Philadelphia	4	Office, retail	1,750,000	Dead-end roadway with adjoining 90-deg unloading bays	7
Midtown Plaza, Rochester	5	Office, retail	1,200,000	Single 2-way access with truck bays at 90-deg to underground bays	20
Republic Bank Building, Dallas	6	Office, retail	1,300,000	Street level operations	7
Suburban locations					
Westchester County Shopping Center, New York	7	Retail	260,000	Surface level loading-unloading bays	3
Valley Stream Shopping Center, Long Island	8	Retail	270,000	Surface level loading-unloading bays	4
Roosevelt Field Shopping Center, Long Island	9	Retail	250,000	Surface level loading-unloading bays	5

areas varies from 3 at the Westchester County Shopping Center to 30 in Rockefeller Center.

Deliveries are frequently made to the buildings by vehicles parking, legally and illegally, at the curbs on surface streets. Unless very stringent regulations and enforcement are implemented, this is an unavoidable, undesirable feature of building service. Adequate design capacity, signing, and arranging off-street service areas in good proximity to local streets can improve this situation and enhance nearby traffic operations.

TRUCK SERVICE PROVISION AND UTILIZATION DATA

The daily number of trucks arriving at the facilities observed varied from 34 at Westchester County Shopping Center to 440 at Rockefeller Center (Table 2). These data apply to typical weekdays, and considerable fluctuations to higher levels can be expected during other times of the year, such as at Christmas. Friday tends to be a busy day for truck deliveries to retail establishments because of anticipated weekend demands.

Daily truck arrival rates per 1,000 sq ft of floor area were observed to vary from 0.088 to 0.195. The former occurred at Rockefeller Center and the latter at Chapel Square, New Haven. Reasons for the wide difference appear to be that Rockefeller Center is predominantly an office type of complex and Chapel Square is oriented to retail activities requiring considerably greater truck movements because of mer-chandising requirements. It is further noted that because of the ease of access-egress to the service area at Chapel Square more trucks utilized this area. At Rockefeller Center, many deliveries were made from vehicles that were parked or double parked at the curb and not recorded in the subject survey.

Generally, urban store customers demand more home delivery of purchased merchandise than do suburban customers. Historically, an average of 11 percent of urban purchases and 3 percent of suburban purchases are delivered to the residence of the purchaser. Because of this, less stock is normally kept in the urban store and deliveries of purchased goods are made directly from a central warehouse.

Furthermore, a significant characteristic for comparing store operations at urban versus suburban locations is duration of loading dock operations. In the urban store, the receiving bay pattern is more dispersed during receiving hours and, therefore, fewer trucks per hour are likely for a given floor area. For these reasons, the planned hours of dock operation from 7:00 a.m. to 7:00 p.m. compare with 8:00 a.m. to 4:00 p.m. at suburban locations. Vehicular loading-unloading activities by type of vehicle are given in Table 3 for a suburban shopping center store. Influence of local supplier trucks on this store is most significant.

Definitions of truck service are as follows:

1. Shuttle. Vehicle serving goods movements from store to store or from warehouse to store.

2. Local supplier. Vehicle serving goods movements to the store by outside supplier.

3. Long-haul. Vehicle serving goods movements oriented to the store from outside the city.

4. Customer service. Vehicle serving goods movements such as parcel pickup or delivery by U.S. mail, United Parcel Service, or Railway Express Agency.

The approximate floor areas served by a single truck bay vary from approximately 50,000 sq ft at Chapel Square to 250,000 sq ft at Penn Center Plaza. Differences reflect variations in goods requirements between retail and office activities and the ease of access and capacity of the service areas.

Of critical importance in the design of facilities is the average utilization likely to be experienced by each truck bay to enable a direct relation to be extrapolated between arriving vehicles and the number of bays to be provided. The daily truck turnover per bay is approximately 25 vehicles at Penn Center Plaza and approximately 7 vehicles at Roosevelt Field Shopping Center. Other observed turnovers ranged between these values. Of the trucks visiting the Time-Life Building, approximately 80 percent were pickup trucks or station wagons, 19 percent were medium-sized vans, and only 0.5 percent were semi-trailers (Table 4). Of the daily loading-unloading truck activity at this location, 64 percent took place at curbside and 36 percent took place in the off-street truck service area.

DEMANDS FOR BERTHS

Needs for individual loading-unloading dock spaces are affected by the character of tenant activities in buildings being served, methods of service area operation, size of building complex, and arrival-departure patterns of the service vehicles. For small retail-commercial establishments, the unit loading dock requirements are generally greater than for larger complexes because of the frequency of vehicle arrivals and departures. These needs range from about 1 space for each 10,000 gross sq ft of floor area to 1 space for each 25,000 sq ft for office buildings and mixed retail uses.

For the large office-commercial complexes, field studies support a theoretical demand for about 1.4 dock spaces for each 100,000 gross sq ft of floor area. Most building codes are responsive to this situation.

Many large department store chains have greater control over deliveries than do office buildings because of central warehousing operations. In large metropolitan areas, for instance, a major retail chain may serve as many as 10 stores from 1 central distribution point. With this approach, management can exercise control of times of truck arrivals and departures and thereby gain more efficient use of fewer dock spaces.

Typical dwell times or load-unload durations for trucks utilizing off-street loading areas by vehicle type at suburban shopping centers around New York are as follows:

Vahiala	Duration of Stay (min)					
Туре	Minimum	Maximum	Average			
Panel or pickup	5	20	12.5			
2-axle, 6-tire and over	5	35	15.5			
Semi-trailer	5	15	10.5			

At the Time-Life Building, 47 percent of truck durations at the service area were less than 20 min and only 13 percent remained for more than 1 hour. Overall, the average service time was 26 min; for semi-trailers, the average duration was about 1 hour (Table 5).

TRUCK ARRIVAL PATTERNS

Truck arrivals observed throughout the day indicate that at Rockefeller Center the maximum arrival rate occurs between approximately 10:00 a.m. and 2:00 p.m. (Fig. 2). In some cases truck deliveries and collections were permitted during evening hours; however, this is generally infrequent and was only noted in isolated cases. Also apparent was the fact that truck arrival patterns appear to be essentially similar on surveyed weekdays—Monday, Tuesday, and Thursday. Prior experience at retail-oriented service areas indicates that more activity occurs on Friday than on other days, however.

Truck arrivals may indicate less pronounced peaking characteristics than those shown in Figure 2. The rate of arrivals between 8:00 a.m. and 4:00 p.m. at the Time-Life Building did not vary significantly, as shown in Figure 3. The difference between arrivals at curb spaces on adjacent streets and arrivals at dock spaces is also of interest, and activity at curb spaces is a significant proportion of the total.

COMPARISON BETWEEN ACTUAL AND THEORETICAL ARRIVAL CHARACTERISTICS

Several factors may affect truck arrival patterns at loading and unloading areas, thus rendering adequate representation of actual events by theoretical distributions only partly effective. Particularly in city center locations, interruptions to specific arrival

Table 2. Truck service at selected locations.

Location	Observed Daily Truck Arrivals	Daily Truck Arrivals per 1,000 Sq Ft	Approximate Floor Area Served by 1 Truck Bay (sq ft)	Avg Daily Truck Turnover [*]
1	225 ^b	0.150	215,000	12
2	440	0.088	167,000	15
3	175	0.195	75,000	15
4	180	0.120	250,000	25
5	167	0.162	60,000	8
6	183	0.140	186,000	26
7	35	0.135	87,000	12
8	36	0.135	68,000	9
9	34	0.135	50,000	7

^eNumber of trucks per bay per day, ^bIncludes truck deliveries made at street level,

Table 3. Type of service by trucks loading and unloading daily at suburban shopping center store from 8:00 a.m. to 4:00 p.m.

Vehicle Type	Shuttle	Local Supplier	Long- Haul	Cus- tomer Service	Total
Light panel or pickup	-	1	-	3	4
2-axle, 6-tire and larger	2	22	3	_	27
Trailer truck	_	3	1	-	4
Total	2	26	4	3	35

Note: Data were collected at loading dock of suburban department store with 260,000 sq ft of gross floor area on March 15, 1967.

Table 4. Loading activity at Time-Life Building from 7:00 a.m. to 7:00 p.m.

Vehicle Type	Curb	Docks	Total	Percent
Light truck	110	69	179	79.5
30-ft van	35	10	45	19.0
Semi-trailer		_1	1	5
Total	145	80	225	100.0
Percent	64	36	100.0	

Note: Data were collected on November 4, 1966.

Table 5. Loading or unloading durations at Time-Life Building from 7:00 a.m. to 7:00 p.m.

Vehicle Type	0-10 Min	11-20 Min	21-30 Min	31-40 Min	41-50 Min	51-60 Min	Over 60 Min	Total	Avg
Light truck	44	39	33	22	10	7	24	179	27
30-ft van	9	14	11	5	2	-	4	45	25
Semi-trailer	_	_	_	_	_	-	_1		60+
Total	53	53	44	27	12	7	29	225	26
Percent	23.6	23.6	19.5	12.0	5.3	3.1	12.9	100.0	

Note: Data were collected November 4, 1966.

patterns may be caused by nearby construction activities, proximity of traffic signals, or presence of a toll or other factors tending to impose a regulated arrival pattern on the traffic stream.

Probably the most extensively used and the most practical theoretical arrival distribution technique is the Poisson distribution. Data were obtained for truck arrivals in several of the surveys completed for a variety of arrival intervals varying from 2 to 30 min. Mean arrival rates and sample variances were computed, and comparisons were made between observed data and theoretical distributions.

Table 6 gives a comparison of actual and theoretical distributions for truck arrival intervals of 4 min for a 2-hour period at Rockefeller Center. Notation in the table is defined as follows:

- x = number of arrivals during 4-min interval,
- f = frequency of observed arrival intervals,
- F = frequency of theoretical arrival intervals, and
- n = total intervals.

The theoretical arrivals are based on a Poisson distribution where the probability P of arrivals x exceeding a given level c for an average arrival rate during interval m is expressed as

$$P(x \ge c) = 1 - \sum_{x=0}^{c} (m^{x}/x!) \cdot e^{-\omega}$$

A X^2 test for goodness of fit was made for these data to support the hypothesis that the theoretical distribution approximated the actual distribution at the 5 percent level of significance. Actual and theoretical data were plotted (Fig. 4) and, based on cumulative frequency of arrival periods, coincide reasonably well.

Knowledge of truck arrival distributions is essential for properly planning entrance and exit facilities, reservoir space, and internal freight-handling facilities and for assessing likely traffic impacts on the adjacent street network. The distribution of arrivals during a given percentage of intervals can be used to estimate the risk of exceeding an acceptable level of accommodation, and designs can be made accordingly.

Computations

The following equations, relating to data given in Table 6 and shown in Figure 4, illustrate the computation of the sample mean, variation, and X^2 goodness of fit test.

Mean arrival rate, $m = \sum fx / \sum f = 51/30 = 1.7$ trucks/4-min interval

Variance,
$$s^2 = \left\{ \sum fx^2 - \left[(\sum fx)^2 / n \right] \right\} / (n - 1) = 1.39$$

Computed value of $X^2 = (\sum f^2/F) - n = 0.02$

Degrees of freedom = 3 - 2 = 1

Tabulated value X^2 0.05, 1 = 3.84

Essentially, if the computed value $X^2 = (\sum f^2/F) - n$ is less than the tabulated value of X^2 for a given level of significance (in this case 5 percent) and degrees of freedom (in this case 3 - 2 = 1), then the theoretical distribution provides an acceptable approximation of the actual distribution for the mean arrival rate considered.

Because the tabulated χ^2 value of 3.84 is greater than the computed χ^2 value of 0.02, the observed data may be assumed to provide an acceptable fit to the Poisson distribution at the 5 percent level of significance. The Poisson distribution is applicable to arrival patterns in the instance shown but may not be suitable for all arrival interval lengths or all periods of arrival.

46





Figure 3. Freight-delivery arrivals to curb and dock delivery areas at Time-Life Building.



 Table 6. Actual and theoretical truck-arrival distributions at Rockefeller Center.

x	1			F				
	Numl	oer"	Cumulative	Numb	er"		Cumulative	f^2/F^a
0 1	4 }	15	4 15	5.49 9.30	}	14.79	5.49 14.79	15.21
2		8	23			7.92	22.71	8.09
3 4 >4	${}^{4}_{3}$	7	27 30 0	4.50 1.89 0.90	}	7.29	27.21 29.10 30.00	6.72
n		30				30.00		30.02

Note: Data were collected August 17, 1971, between 2:30 and 4:30 p.m.

^eGrouping of individual frequencies to provide values of at least 5 and computations of f^2/F are necessary for completion of χ^2 goodness of fit test.

Figure 4. Comparison of observed and theoretical truck-arrival distributions at **Rockefeller Center.**



Figure 5. Predicted truck arrivals at **Rockefeller Center.**



48

Prediction Curve for Truck Arrivals

After verification was made of an acceptable fit between observed arrival distributions and a Poisson arrival distribution, a curve indicating the number of trucks expected to arrive during given portions of the total arrival period was prepared (Fig. 5). This serves as a planning aid only and should be constructed to suit the mean arrival rate and number of truck arrivals anticipated. This curve makes it possible to determine the likely period during which, say, c or more trucks will arrive and thus provides an indication of design adequacy and probability of design capacity being exceeded.

Example

An example of the use of the curve is the determination of the least period of time during which 3 or more trucks will likely arrive. By selecting the value of 3 trucks on the graph and reading to the curve, one can see that at least 3 trucks per interval will likely arrive during 11 min of the 2-hour period considered. This also means that the probability of 3 or more trucks arriving per interval during the 2-hour period is 0.09, thus indicating the degree to which a design of reservoir space, ingress and egress space, and use of signal systems would be adequate.

PROPOSED PLANNING PROCEDURE

Based on the data presented, it is possible to summarize a preliminary design and planning procedure for off-street service areas as follows:

1. Determine floor areas and likely composition of the building considered;

2. Assess the number of anticipated truck bays and daily arrivals based on typical ratios given in Tables 1 through 5 with due regard to building code requirements (considerable judgment and investigation of special conditions is necessary at this stage, and the tabulated ratios should be only a guide);

3. Determine from observations of facilities in similar locations and environments the pattern of truck arrivals, based on the total number expected per day; and

4. Construct a prediction curve similar to that shown in Figure 5 for the average arrival rate, and provide a design adequate for items affected by truck arrival patterns (the arrival pattern curve may not necessarily approximate a Poisson distribution pattern, as determined by a χ^2 test, but can be constructed empirically, if necessary, to suit the conditions most likely to result based upon the inputs mentioned above).

CONCLUSIONS

From the foregoing observations, the following conclusions appear to be characteristic of truck freight facilities in large cities.

1. A number of functional configurations are possible to provide adequate truck vehicular access-egress for off-street services areas at large building complexes.

2. The need to encourage use of off-street service facilities is strongly demonstrated by the fact that more than 60 percent of daily deliveries and collections are made from curbside parking and illegal double parking, even with off-street loading areas available.

3. Demands for loading-unloading bays are greater on a unit basis for smaller developments than for larger developments, ranging from 1 space per 10,000 sq ft of gross office floor area for relatively small buildings to 1.4 spaces per 100,000 sq ft of gross floor area for larger complexes.

4. Turnover rates at off-street service facilities have been observed to be as many as 25 trucks per bay per day.

5. Duration of stay at a loading dock ranges from approximately 5 min for small vehicles to more than 1 hour for larger semi-trailer trucks at office building locations, the average dwell time being 26 min. Shorter durations are noted at major retail facilities, the average being approximately 15 min/vehicle.

6. These observed characteristics of actual arrival and departure patterns of trucks frequenting off-street service areas can be used to develop theoretical mathematical

50

curves utilizing the Poisson distribution technique. The curves aid in predicting frequency of arrivals when various empirical factors are used. In this paper a recreation of truck arrivals at the Rockefeller Center service area, using Poisson curves and a mean arrival rate of 4-min intervals, produces reliable projections within a 5 percent level of significance.

Emphasis should be placed on proper design, regulation, and enforcement of offstreet truck service areas in future central city and congested suburban locations. Values to be gained from provision of these facilities include higher levels of safety to motorists and pedestrians, less street congestion during peak traffic hours, more efficient transfer of goods to major land uses, and better regulation of loading-unloading operations.

REFERENCES

- 1. Gerlough, D. L., and Barnes, F. C. Poisson and Other Distributions in Traffic. Eno Foundation for Transportation, 1971.
- 2. Various unpublished data surveys. Wilbur Smith and Associates, 1964-1971.