Off-Street Truck-Loading Facilities in Downtown Areas: Requirements and Design

Dennis Christiansen, Texas Transportation Institute, Texas A&M University

The city of Dallas, the Dallas Central Business District Association, and the Texas Transportation Institute undertook a project designed to develop alternative solutions to the goods and services distribution problem in the Dallas central business district. As a part of that project, the adequacy of existing off-street truck-loading requirements and their design were evaluated. Several major U.S. cities were queried about their requirements for off-street loading facilities. In addition, operations at existing off-street loading facilities in Dallas were observed.

The delivery of goods and services in downtown Dallas is a large-scale, intense activity. Cordon counts (1) indicate that, in the 12-h period between 6:30 a.m. and 6:30 p.m., more than 12 000 trucks enter the Dallas central business district (CBD), representing approximately 10 percent of all vehicles entering this area. Due to the availability of a freeway loop around the CBD, it is assumed that virtually all of these vehicles make at least one stop in the CBD.

During an average day, an estimated 9000 delivery/service truck stops occur in the core of the Dallas CBD as part of the goods and services distribution process (2). Because Dallas has few alleys, these stops occur either at the curb or in off-street loading facilities. Of the approximately 1300 available loading spaces in the core, only about 200 (or 15 percent) are located in off-street facilities (2). Therefore, a substantial portion of the truck parking occurs at the curb, and delivery is made across the sidewalk. This activity contributes to both vehicular and pedestrian conflicts in an already congested area.

Interviews with trucking firm personnel in downtown Dallas (2) indicate that locating a loading space is the greatest problem experienced by the trucker in the CBD. Specific problems encountered with off-street loading docks include an inadequate number of dock spaces, a lack of maneuvering space, and poorly designed loading spaces (3).

One of the more disturbing aspects of trucking activity in downtown Dallas is that much of the more severe trucking congestion occurs in the immediate vicinity of some of the larger new buildings. Further observation indicates that the design of many of these off-street spaces is inadequate and places limitations on their use.

Apparently, an evaluation of the zoning code is appropriate. A code that requires an adequate supply of well-designed off-street loading spaces serves both public and private interests and contributes to a long-range solution of the goods distribution problem in the downtown area.

LOADING SPACE REQUIREMENTS

In designing off-street loading facilities for new buildings, guidelines are needed to determine the number of loading spaces to be accommodated in the building. This issue is examined here based on the results of a survey of several U.S. cities. A theoretical determination of space requirements is also presented.

Survey of U.S. Cities, 1974

Cities have long recognized the need for off-street loading facilities; zoning ordinances requiring such facilities have existed since 1927 (4). As a part of this study project, several major U.S. cities were queried in 1974 about their requirements for off-street loading facilities. Of the cities contacted, only Houston had no requirements pertaining to off-street loading.

Because more than 65 percent of the floor space in downtown Dallas is either office or retail, this study focused on these two land uses. Off-street loading requirements for office buildings and retail department stores in various cities are compared in Figures 1 and 2 respectively. Because certain codes overlap, the individual code for each city is not plotted. Rather, the bands in which the different codes fall are plotted, and the cities represented by each band are identified.

Survey results indicate that a wide disparity exists concerning off-street loading requirements. Apparently no general base has been accepted by cities for determining the need for off-street loading facilities. Variations that exist in the codes suggest that either (a) some of the codes are grossly inadequate or (b) others require the provision of too many off-street truck-loading spaces.

Theoretical Determination of Loading Space Requirements

The bold lines on the upper portions of both Figures 1 and 2 are recommended off-street loading requirements based on theoretical analyses. Methodology and supporting data for these analyses are briefly described in this section.

Office Buildings

Two different design objectives were evaluated for typical office buildings. One is a minimum design level that provides sufficient spaces to yield an hourly capacity equal to the number of trucks arriving during the peak hour of an average day. The other is a desirable design level that provides sufficient capacity so that an arriving vehicle seldom has to wait for a space (probability ≤ 0.25) even during the peak hour.

The initial step in determining the number of loading spaces required for a specific building is to estimate the number of daily truck stops needed to serve the building. Several research studies have related daily truck stops to gross floor area. Other data suggest that factors such as gross sales or number of employees are better indicators of the number of truck stops. These variables, however, may be difficult to identify during the building design process. Thus, floor area appears to be the preferred indicator for planning purposes.

Daily truck stops generated by office buildings as determined in eight different studies ranged from 16.14 to 25.82/10 000 m^2. Truck-stop generation rates identified in these studies are reasonably consistent; the mean value (22.73) is used in these analyses (3,5,6,7,8,9,10,11).

Nearly all CBD deliveries to off-street facilities are made during the 9-h period between 8:00 a.m. and 5:00 p.m. Studies of trucking activity (2) indicate that the peak delivery hour generates approximately 25 percent more truck stops than the average hour. Interviews suggested that office buildings do not experience a significant seasonal variation in the level of trucking activity. Hence, the number of peak-hour truck stops occurring at a building housing

Table 3. Recommended number of off-street berths for a light industrial or warehouse building.

Number of Vehicle Arrivals per Day	Upstream Access					Mid-Block Access					Downstream Access				
	$10	$15	$20	$25	$30	$10	$15	$20	$25	$30	$10	$15	$20	$25	$30
Arterial streets															
20	3	3	2	2	2	3	2	2	2	2	3	3	3	2	2
30	4	4	4	4	2	4	3	2	2	2	4	4	4	4	4
40	4	4	4	4	4	4	4	4	3	3	4	4	4	4	4
50	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
60	4	4	4	4	4	4	4	4	4	4	6	4	4	4	4
70	6	4	4	4	4	4	4	4	4	4	6	6	4	4	4
80	6	6	5	5	4	5	5	4	4	4	6	6	6	5	5
90	7	7	6	6	5	6	5	5	4	4	7	7	7	6	5
100	7	7	7	7	7	7	7	7	6	6	7	7	7	7	7
Downtown streets															
20	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3
30	4	4	4	3	3	4	3	3	3	3	4	4	4	4	4
40	4	4	4	4	4	4	4	4	3	3	5	5	4	4	4
50	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
60	5	5	4	4	4	5	4	4	4	4	6	6	5	5	5
70	6	5	5	5	4	6	5	5	4	4	6	6	6	6	5
80	6	6	6	5	5	6	6	5	5	5	6	6	6	6	6
90	7	7	7	5	5	7	5	5	5	4	7	7	7	7	7
100	7	7	7	7	7	7	7	7	7	6	7	7	7	7	7

Notes: $0.09\ m^2 = 1\ ft^2$.
Dollar values refer to annual suitable value per square meter of space.

Source	Values From Examples	Cincinnati	Pittsburgh	Atlanta
Office building, 74 322 m^2 (800 000 ft^2)	5-6	4	6	10
Department store (40 vehicles/d) [assumed size: 13 935 m^2 (150 000 ft^2)]	3-5	5	5	3

The examples indicate that the procedure results in standards that are within the range of values now in use. This range, as presented here, is certainly a wide one, and the availability of applicable standards should improve the process of accommodating goods-vehicles in off-street facilities.

SUMMARY

The basic premise in the space allocation guidelines is that goods movement is a part of a total transportation system. Space allocation for goods movement must recognize and accommodate other urban transportation needs.

We have tried to develop the guidelines in ready-to-use form. The planner requiring detailed information should refer to Crowley and Habib (7) because it contains guidelines for on-street space allocation, in addition to the off-street recommendation presented herein.

REFERENCES

1. P. Habib and K. Crowley. An Economic Approach to the Allocation of Space for Urban Goods Movement. TRB, Transportation Research Record 591, 1976, pp. 18-24.
2. P. Habib and K. Crowley. Economic Rationale for Establishing Off-Street Loading Requirements in the City Center. TRB, Transportation Research Record 591, 1976, pp. 25-31.
3. K. Crowley and others. Facilitation of Urban Goods Movement: First Year Final Report. Polytechnic Institute of New York, Brooklyn, 1974.
4. K. Crowley and P. Habib. Facilitation of Urban Goods Movement: Second Year Final Report. Polytechnic Institute of New York, Brooklyn, 1975.
5. S. Loebl. Aspects of the Demand for Urban Goods Movement. Polytechnic Institute of New York, Brooklyn, PhD dissertation, 1975.
6. P. Habib. Accommodating Goods-Movement Vehicles in the City Center. Polytechnic Institute of New York, Brooklyn, PhD dissertation, 1975.
7. K. Crowley and P. Habib. Urban Goods-Movement Space Allocation Guidelines, Third Year Final Report. Polytechnic Institute of New York, Brooklyn, 1977.

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

Figure 1. Off-street loading requirements for downtown office buildings.

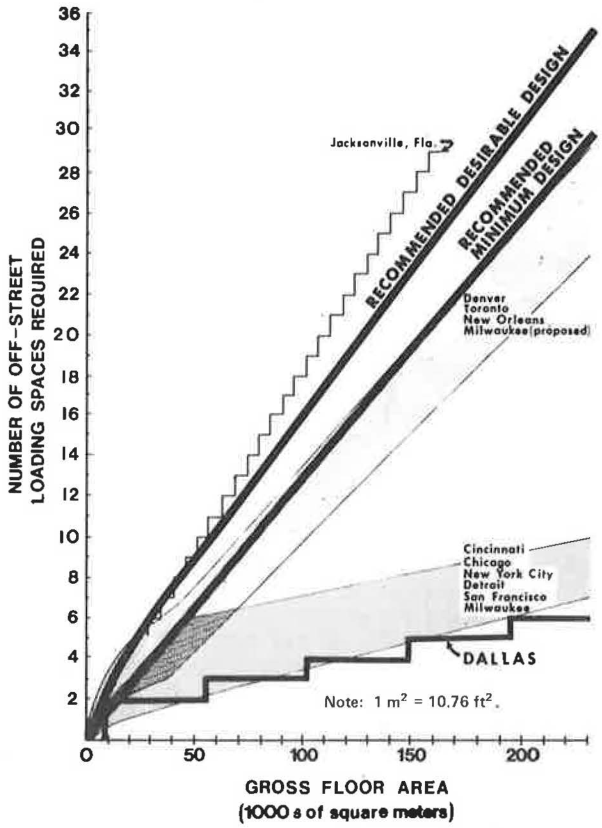
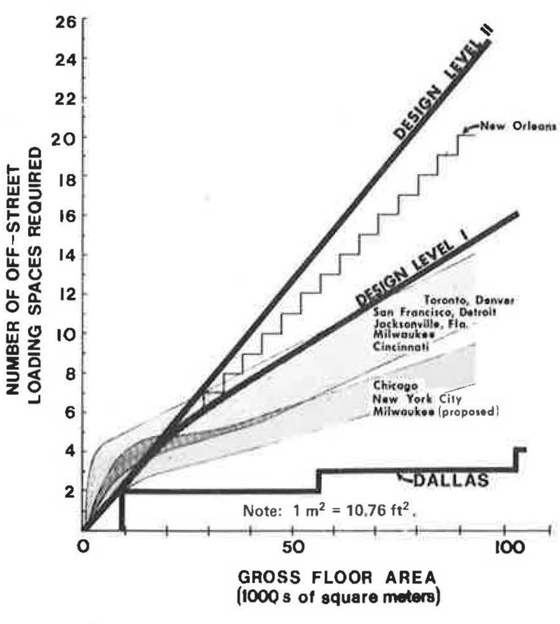


Figure 2. Off-street loading requirements for downtown retail department stores.



office space only can be estimated as follows: peak-hour deliveries = [gross office area (m^2)/10 000] x (22.73/9) x 1.25.

Other studies (8,12) indicate that an average truck stop lasts approximately 22 min. Assuming that an additional 3 min are required for the first vehicle to leave the loading space and a second vehicle to enter the space, a space can serve one vehicle every 25 min, or 2.4 vehicles/h.

Using the "minimum design" approach, the number of off-street loading spaces needed by an office building was calculated as follows: number of loading spaces = peak-hour deliveries/2.4. This procedure results in the relationship depicted by the line (Recommended Minimum Design) in Figure 1.

The minimum design approach provides sufficient spaces to serve the average peak-hour demand in a 1-h period. If all trucks arrived at a uniform rate, such a design would function satisfactorily on most days. However, trucks tend to arrive in a random manner, so a lineup of trucks probably will develop during the peak hour. Time spent waiting in a lineup is costly to the truckers, and when the line extends into the street it creates other traffic problems. Hence, the minimum design approach yields a design that may be considered less than optimum.

Economic considerations tend to prohibit provision of sufficient spaces to ensure that a lineup will never develop. However, a desirable design level might provide sufficient off-street spaces so that the demand for facilities does not exceed the available supply of facilities during the average peak hour for at least 75 percent of the time. A multiple-channel lineup theory was used to determine space requirements under these assumed conditions.

If such time is reduced, then the cost of the delivery is also reduced and the efficiency of downtown delivery is improved. However, the provision of a sufficient number of spaces to reduce waiting time also results in a higher probability of having some unused spaces. For example, at the desirable design level depicted in Figure 1, only an average of about 70 percent of the available loading spaces will be used at any one time during the peak hour.

The space requirements estimated in this report are in basic agreement with those proposed by Whitlock and Schoon (13). That research recommendation is midway between the minimum and the desirable level shown in Figure 1.

Retail Department Stores

The level of retail activity in the CBD of most U.S. cities has been declining since World War II. However, retail department stores with floor areas in the the range of 46 468 m^2 (500 000 ft^2) of gross usable space are still operating successfully in downtown Dallas.

Truck-stop generation rates were also utilized to estimate off-street loading requirements for retail department stores in several studies (4,6,7,9,10). These rates ranged from 15.06 to 39.81 daily truck stops/10 000 m^2 gross floor area, i.e., floor area assigned a specific use. The mean value (25.53) derived from these analyses was assumed to represent the average number of truck stops generated on an average day.

Criteria associated with evaluating off-street loading needs of retail department stores include those itemized below.

1. Virtually all truck stops are assumed to occur between 8:00 a.m. and 5:00 p.m., providing 9 h/d of available delivery time.
2. At a typical Dallas department store, approximately 50 percent of the vehicles using the loading space are owned by the store. Retail store management can reduce the magnitude of the peak hour by controlling arrival times of their vehicles. Consequently, the peak hour associated with retail store trucking activity is assumed to be only 10 percent greater than the average nonpeak hour.

3. A 25-min average service time is assumed for truck spaces at retail department stores, even though the variability is much greater than at office buildings. For example, numerous tractor-trailers serve retail stores, and their dwell time may easily exceed 1 h. On the other hand, smaller vehicles, partially as the result of centralized receiving, require less time per stop at a retail store than at an office building (13).

4. Significant seasonal variation in trucking activity is associated with retail stores. Horwood (14) found that the average daily volume of goods handled in the last 12 weeks of the year is about twice that of the annual daily average. Interviews with retailers in Dallas substantiate that such a peak does exist, although it may occur somewhat earlier in the year. Thus, for the last 12 weeks of the year, downtown Dallas department stores were assumed to generate approximately 51.06 stops/10 000 m^2 (4.8 stops/10 000 ft^2).

Retail department stores might consider either (a) design level 1, which provides sufficient spaces during the average peak hour at the "average" time of the year so that demand for loading spaces will not exceed available supply more than 25 percent of the time, or (b) design level 2, which provides sufficient capacity to serve the average condition during the average peak hour at the "peak" time of the year.

Design level 1 addresses operation during the average time of year. If arrival and service rates are not altered during the peak time of year, this design level will result in severe congestion during that 12-week period. At that time, a city may find it advantageous to take strong steps to assure that lining up on city streets does not occur, e.g., possibly implementing strict enforcement of curb regulations during that time period. This approach will not necessarily hinder the operation of the department store, since a store can take several actions to assure that a line will not develop during the peak time of year.

Design level 1 results in a nonlinear relationship between off-street loading spaces required and gross floor area. It was developed using multiple-channel queueing analysis. Due to the nonlinearity of this design level, it closely approximates design level 2 for stores with floor areas of less than 27 800 m^2 (300 000 ft^2), as shown in Figure 2. Using design level 1, about 9 off-street loading spaces would be required for a 46 468-m^2 (500 000-ft^2) department store.

Design level 2 addresses the average condition during the peak 12 weeks of the year. This approach might be considered economically undesirable because some excess capacity will result during the other 40 weeks of the year. Even at this design level, some congestion and lining up can be expected during the peak time of the year. However, the magnitude of this congestion will be less than that which might occur if design level 1 were utilized.

Design level 2 yields a linear relation between gross building floor area and off-street loading space requirements. A design level of 129.12 spaces/500 000 m^2 (12 spaces/500 000 ft^2) results. Observed operation of an off-street loading facility at a downtown Dallas department store suggests that this is a reasonable design level.

PHYSICAL DESIGN OF LOADING SPACES

Providing the required number of loading spaces does not ensure satisfactory operation of these spaces. In several Dallas buildings, the existing off-street loading facilities function in a less than desirable manner because their design is inadequate. In planning the loading space, consideration should be given to vertical clearance, depth of space, width of space, depth of dock, and height of dock.

Type of Delivery Vehicle

The type of vehicle to be accommodated is a major consideration in the design of an off-street loading facility. The following table shows the distribution of delivery vehicles by type of vehicle operating in the Dallas CBD:

Vehicle Type	Percentage of Total Shipments Carried	Cumulative Percentage
Passenger car	18	18
Pickup truck	10	28
Van	27	55
Single-unit truck	40	95
Tractor-trailer truck	3	98
Other	2	100

Except for moving tenants, there is little need for tractor-trailers to deliver goods to office buildings. Many building policies require major tenant moves to occur in the evening or on weekends, during which time the tractor-trailer is able to park at the curb. As a result, it is suggested that off-street loading facilities for office buildings need not be designed to accommodate tractor-trailers. However, it appears that facilities designed to serve retail department stores need to be designed to accommodate the tractor-trailer. Between 25 and 50 percent of the off-street loading spaces at department stores are occupied by tractor-trailers.

Dimensions of Loading Spaces

Table 1 presents the design standards stipulated in the 1974 zoning ordinances of a sample of various cities. Considerable variation exists among the different codes, and some cities do not specify any criteria for certain design parameters.

Loading spaces must have adequate vertical clearance, depth, and width if they are to function properly; thus, it seems appropriate for a city zoning code to specify minimum values for these parameters. Design details of the loading dock are also important factors in the overall functionality of an off-street

Table 1. Minimum dimensions of downtown loading spaces in selected cities.

City	Description	Vertical Clearance (m)	Depth (m)	Width (m)
Chicago	All spaces	4.27	7.62	3.05
Cincinnati	All spaces	NS	7.62	3.05
Dallas	First space	NS	12.20	3.05
	All other spaces	NS	6.10	3.05
Denver	All spaces	4.27	10.67	3.05
Detroit	First office space	NS	10.67	3.66
	Other office spaces	NS	16.77	3.66
	First three retail spaces	NS	10.67	3.66
	Other retail spaces	NS	16.77	3.66
Houston	All spaces	NS	NS	3.66
Jacksonville	All spaces	NS	NS	3.66
Milwaukee	Existing, all spaces	3.66	12.20	3.66
	Proposed, office	4.27	10.67	3.66
	Proposed, retail	4.27	16.77	3.66
New Orleans	All spaces	4.42	10.67	3.66
New York City	Office spaces	3.66	10.06	3.66
	Retail spaces	4.27	10.06	3.66
San Francisco	First space	3.66	7.62	3.05
	All other spaces	4.27	10.67	3.05
Toronto, Canada	All spaces	4.27	9.15	3.66
Range		3.66-4.42	6.10-16.77	3.05-3.66

Notes: NS = not specified.
1 m = 3.28 ft.

loading area; however, significantly different dock designs can function just as well. Accordingly, it appears more appropriate for a city to require a review of the proposed dock design rather than to specify design details in the code. The design criteria suggested herein are based on the standard design vehicles established by the American Association of State Highway Officials (15). The design values presented in this paper should be considered as minimum requirements.

Vertical Clearance

Vertical clearance should be provided to serve the maximum height of vehicles that are expected to regularly use the off-street loading facility. To accommodate the typical single-unit delivery vehicle, an absolute minimum vertical clearance of 3.66 m (12 ft) is needed, but a clearance of 3.96 m (13 ft) is a more desirable standard. To accommodate a tractor-trailer, a minimum vertical clearance of 4.27 m (14 ft) should be provided. Adequate clearance must be provided throughout the off-street area that trucks are required to use, and this clearance should also be considered in relation to changes in grade at driveways.

Depth of Space

Depth of space is also a function of the type of vehicle that is expected to use the space. A 7.62-m (25-ft) space depth is sufficient to serve smaller vehicles such as an automobile, pickup truck, and panel truck. A 10.67-m (35-ft) space can accommodate the single-unit truck, and a 16.77-m (55-ft) space can serve a tractor-trailer.

In designing space depth for an off-street loading facility, a variety of space depths might be provided based on the vehicle distribution expected to use the facility. If all spaces have the same depth, the control in design will be the depth necessary to serve the largest vehicle expected to regularly use the facility.

Width of Space

A minimum width for each space should be stipulated, even though factors such as column spacing may also influence space width. Width of vehicles varies somewhat; smaller vehicles such as automobiles are about 2.13 m (7 ft) wide and trucks 2.44-2.59 m (8-8.5 ft) wide. For two reasons, a desirable space width is one that leaves approximately 1.22 m (4 ft) between parked vehicles. First, many vehicles are side-loading units. If the shipment to be delivered is most accessible from the side of the vehicle, sufficient space should be available to allow convenient unloading. Second, some delivery vehicles during peak periods may find it convenient to stop behind vehicles parked at the dock and deliver their shipment between these vehicles to the dock. Thus, it is desirable to have sufficient space between vehicles to allow movement of a hand-cart.

Therefore, a minimum width of 3.66 m (12 ft) should be provided to serve single-unit and tractor-trailer trucks. A 3.35-m (11-ft) width is adequate to serve smaller vehicles.

Loading Dock Design

An adequate dock depth provides a loading and unloading area as well as space for travel along the loading dock. A minimum dock depth of 4.57 m (15 ft) appears needed. However, a deeper dock area will be required if goods are to be stored on the dock for extended periods of time (16,17,18).

Table 2. Suggested minimal design criteria for off-street loading spaces.

	Type of Vehicle to Be Accommodated		
Design Criterion	Automobile, Pickup, Panel	Single-Unit Truck	Tractor-Trailer Truck
Vertical clearance (m)	-[a]	3.96	4.27
Depth (m)	7.62	10.67	16.77
Width (m)	3.35	3.66	3.66
Dock height (cm)	61-76	89-127	122-132

Notes: 1 m = 3.28 ft; 1 cm = 0.39 in.
[a]Generally not a controlling design feature.

Since vehicle design is not standardized, no dock height can satisfactorily accommodate all vehicles. One design approach might be to provide several different dock heights in the facility, basing the design on the expected distribution of delivery vehicles. Another approach could be to provide one continuous dock height to serve all vehicles, recognizing the need to possibly provide some type of adjustable dock-height equipment. A tractor-trailer requires a dock height of 1.22-1.32 m (4-4.33 ft); a single-unit truck requires one of 1.02-1.27 m (3.33-4.16 ft); and smaller vehicles such as automobiles and pickups require a dock height of about 0.76 m (2.5 ft).

Table 2 suggests minimum design criteria for off-street loading spaces.

CONCLUSION

Provision of an adequate supply of off-street truck-loading facilities is, perhaps, the optimum long-range solution to the truck loading and unloading problem in major downtown areas. Implementation of an adequate zoning ordinance is a major move toward solving this problem. This paper suggests some guidelines that can be used in formulating zoning ordinances to address the issues of space requirements and design. In addition to the ordinance, cities may find it desirable to review plans for off-street loading facilities to ensure that the maneuvering requirements associated with these facilities do not unnecessarily interfere with on-street traffic.

REFERENCES

1. Dallas Bus Operational Study. Appendix E, Downtown Cordon Count. Wilbur Smith and Associates, 1971.
2. Texas Transportation Institute. Dallas CBD Goods Distribution Project, Final Report. Dallas Central Business District Association, Dallas, 1974.
3. Alan M. Voorhees & Associates, Inc. Summary Report of Preliminary Goods Movement Data. North Central Texas Council of Governments, Dec. 1972.
4. D. R. Levin. Zoning for Truck Loading Facilities. HRB, Bulletin 59, 1952, 101 pp.
5. ITE Project Committee 6D-62. Traffic Considerations in Planning of Central Business Districts. Traffic Engineering Magazine, Vol. 34, No. 9, June 1964, pp. 16-19, 37-51.
6. R. C. Barnstead. Truck Activities in the City Center. The Urban Movement of Goods, Proc., Third Technology Assessment Review, Oct. 1970.
7. W. Marconi. Commercial Vehicles in a Large Central Business District. Traffic Engineering Magazine, Vol. 41, No. 5, Feb. 1971, pp. 44-54.
8. Center City Transportation Study, Phase 2. Wilbur Smith and Associates, Dec. 1970, Appendix, Table A-10.

9. Long Range Transportation Plan for the Central Business District. De Leuw, Cather and Company, Dallas, TX, July 1965.
10. M. V. Bates. Goods Movement by Truck in the Central Area of Selected Canadian Cities. Canadian Trucking Association, 1970.
11. Survey of Usage at the Off-Street Loading Facility, First National Bank Building, Dallas. First National Bank, Dallas, Jan. 1974.
12. Survey of Activity at Republic National Bank Building. Department of Planning and Urban Development, Dallas, 1971.
13. E. M. Whitlock and J. G. Schoon. Planning Criteria for Off-Street Service Areas. HRB, Highway Research Record 399, 1972, pp. 40-50.
14. E. M. Horwood. Center City Goods Movement: An Aspect of Congestion. HRB, Bulletin 203, 1958, pp. 76-98.
15. A Policy on Geometric Design of Rural Highways. American Association of State Highway Officials, Washington, DC, 1965.
16. Shipper-Motor Carrier Dock Planning Manual. American Trucking Associations, Washington, DC, 1973.
17. J. Baerwald, ed. Traffic Engineering Handbook, 3rd ed. Institute of Traffic Engineers, 1965.
18. Thanksgiving Square Feasibility Report for the City of Dallas. Datum Structures Engineering, Inc., 1972.

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

Abridgment

Determinants of Freight Modal Choice

Mark S. Jelavich,* Peat, Marwick, Mitchell and Company, Inc., Washington, D.C.

In studying the transportation of commodities, the objective of any particular research effort should be kept in mind. A researcher may be interested only in some general notion of the overall demand for freight transportation (e.g., the annual cost of shipping goods), in which case the demand for freight services will be closely tied to the level of national output. However, this procedure starts to collapse when interest centers on the demand for freight services by particular modes (e.g., rail and truck) and becomes rather unworkable. This is true especially from the viewpoint of policy analysis—i.e., when the research effort addresses questions related to the movement of particular goods by certain modes.

Input-output analysis, as well as econometric models, allows an economist or transport planner to forecast disaggregate components of national output (e.g., output by industries). This disaggregation has not been extended to direct modeling of freight demand, because a complete data base on modal characteristics is lacking—especially among unregulated carriers. Individual shipper data are also sparse. Thus, freight forecasting lags behind urban and intercity passenger modal split modeling methodologies. For example, Morton (2) has studied the demand for transport by mode by broad commodity groups, while Nazem (3) has focused on the macro-level approach. In addition, Watson and others (5) and Roberts and others (4) have emphasized individual shipper behavior. Morton found that shipment size and average haul length (AHL) were important determinants of modal choice.

Modes of freight transportation cannot be neatly dichotomized into public and private transport, as is sometimes done in passenger studies. While other researchers have confined their examination of freight haulage to two modes, e.g., Kullman's thesis on rail-truck competition (1), any broad study of freight must deal with more than two modes. If there are n modes for any particular commodity (good f) examined, then

$$\sum_{i=1}^{n} p_{if} = 1 \qquad (1)$$

where p_{if} is the probability that a quantity of good f will move by mode i. Dividing both sides of Equation 1 by a nonzero p_{jf}, $i = 1,\ldots,j,\ldots,n$, so that

$$\sum_{i=1}^{n} (p_{if}/p_{jf}) = (1/p_{jf}) \qquad (2)$$

Since $p_{jf}/p_{jf} = 1$, then

$$\sum_{i \neq j} (p_{if}/p_{jf}) = (1/p_{jf}) - 1 \qquad (3)$$

Assuming strict inequalities, so that $0 < p_{if} < 1$ for all i and f, then the ratios p_{if}/p_{jf} are all positive, $1/p_{jf}$ is greater than one, and p_{jf} is greater than zero.

Because of the first equation, there will be only n-1 modal choices in an n-mode case that can be made freely; therefore, there will be only n-1 equations. While the choice of the base mode, p_{jf}, is arbitrary—and, thus, the results possibly sensitive to the base mode choice—it is desirable that the ranking of modes (in terms of lowest to highest probability of choice) remains invariant to the choice of base mode. If three modes—e.g., rail, truck, and "all else" (including water and air freight)—are being studied, with probabilities p_{rk}, p_{tk}, and p_{ok} of hauling good k, then three ratios could be formed: p_{rk}/p_{ok}, p_{tk}/p_{ok}, and $1/p_{ok}$. Such an approach would waste information, however, in that comparatively good data on a commodity-detail basis are available for rail and truck, whereas poor information is available for the remaining modes. Three alternative ratios could be examined: p_{rk}/p_{ok}, p_{tk}/p_{ok}, and $1/p_{ok}$. Note that as $(p_{rk}/p_{tk})\ (p_{tk}/p_{ok}) = p_{rk}/p_{ok}$, one can still use the "all else" mode as a base. This model can be summarized as follows:

$$\ln(p_{rk}/p_{tk}) = f_{rt}(r_{tk};r_{rk};A_k) \qquad (4)$$

$$\ln(p_{tk}/p_{ok}) = f_{to}(r_{tk};r_{rk};A_k) \qquad (5)$$

**Mr. Jelavich was with Jack Faucett Associates, Chevy Chase, Maryland, when this research was performed.*