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Characteristics of Urban Freight Systems

Office of Environment and Planning
Federal Highway Administration
U.S. Department of Transportation
400 Seventh Street S.W.
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NOTICE

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Characteristics of Urban Freight Systems

Final Report
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PREFACE

This report has been developed to support the transportation planning needs for urban goods movement and freight planning as promoted by the Intermodal Surface Transportation Efficiency Act of 1991. *Characteristics of Urban Freight Systems (CUFS)* has been designed to be a compilation of current data that pertain to urban freight movements. Sections I-IX deal with urban truck movement and truck terminals while Sections X-XII are concerned with the intermodal aspects of freight movements — rail intermodal yards, airports and air cargo facilities, and ocean and inland waterway ports. The data were assembled from many different sources and are expected to be of assistance to Metropolitan Planning Organization planners who deal with urban freight issues. Much of the intermodal discussions also focus on truck movements as the primary mode of access to/from intermodal facilities. The information is drawn from U.S. and Canadian experience but is community specific as it is not yet possible to develop generalized relationships. As more data become available from current data collection efforts, it should become possible to develop generalized values that can be transferred to different planning environment. An attempt has been made to include data sources developed since the mid-1980s. Information has been included from some studies dating to the 1970s where more current data were not available. All data were obtained from survey studies and were not synthesized from analytical modeling efforts. All data sources have been identified to assist the planner in assessing their usefulness. Most of the information has been collected from published reports, but some data, particularly in the intermodal freight area, came from internal memos, personal observations, and interviews.

It is hoped that *Characteristics of Urban Freight Systems (CUFS)* will become a starting point for the collection and integration of urban freight data for local planners.

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I. URBAN COMMODITY MOVEMENTS — THE IMPORTANCE OF TRUCKS

A. Introduction

1. Section I highlights the importance of trucking in the movement of urban commodities and the contribution made by these truck movements to the local economy.

2. The economic impact of trucks are highlighted from two origin-destination studies, one conducted in Vancouver, British Columbia, the other in the Metropolitan New York area. The section discusses the characteristics of truck movements within and through the two metropolitan areas and the patterns of selected commodity movements.

B. Economic Significance of Urban Trucking

1. Trucking provides a critical link in the flow of goods into, out of, and within urban areas. Trucks move goods from points of production to warehouses and points of final consumption and play a critical role in the movement of goods to and from intermodal facilities. Trucking is a significant activity in the functioning of the urban economy. In Vancouver, British Columbia, trucking activities represents about 8 percent of the local economy, valued at $2.5 billion annually or almost $1,400 per resident. At an estimated average truck operating cost of $45-$60 per hour, increased traffic congestion and delay translates into a severe economic problem (1). It is estimated trucking costs would increase about $6 million annually for each percentage point increase in truck travel times.

2. A 1985 survey conducted by the Port Authority of New York and New Jersey highlighted that trucks provide a vital role in the New York-New Jersey Metropolitan Area Goods Distribution System (2). "Like many other urban centers, the New York-New Jersey metropolitan area relies on trucks to carry the commodities that support the local economy, meet the everyday needs of its residents, and connect the region to the rest of the continent. Less imposing than a containership or a freight train, the ubiquitous truck is the essential, often unappreciated link that plays a role in virtually all the goods movement activity in the region" (2, p. i).

   - 1985 7.6 million trucks[1] crossed into the area, hauling 65 million tons of goods per year.

[1]Trucks were defined as vehicles having at least two axles and dual rear wheels. Vans were excluded.

- In comparison, 14 million tons of general cargo (import/export) was handled by the port and 1 million tons of import/export air cargo was handled by the airports, as noted in Figure 1.

3. Trucks are "in turn a part of an even larger goods handling system that encompasses all the movements of a commodity from its point of production to its site of consumption or use. This can include air, rail or waterborne transportation as well as truck transportation, or two or more models in combination" (2, p. i).

   - Of the 7.6 million truck trips entering the region, 66 percent had both an origin and destination in the region, while less than 7 percent were long distance movements passing through the area (Figure 2) (2).

   - In San Francisco, 98% of truck trips surveyed at external cordon had either an origin or destination in the nine county bay area (3).

   - In Vancouver, British Columbia, 15 percent of all truck traffic had an origin or destination outside the region (1).

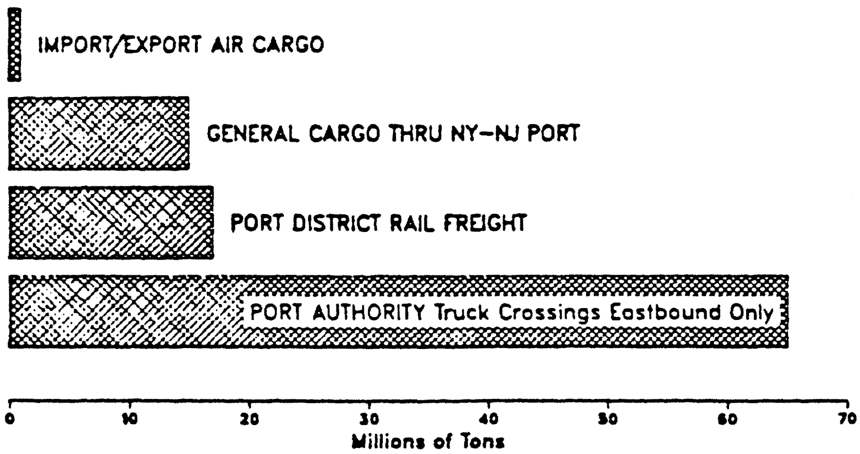
C. **General Characteristics of Urban Truck Movements**

1. The characteristics of through traffic versus regional truck movements vary by origin-destination and peak period travel:

   - "Through-traffic trucks (which tend to travel a longer distance) travelled from factories to warehouses while regional trucks travelled from warehouses to other warehouses and end users. In line with the different types and lengths of trips, almost 90% of the through trucks were large vehicles while only 45% of the regional trucks were classified as large" (2, p. 26).

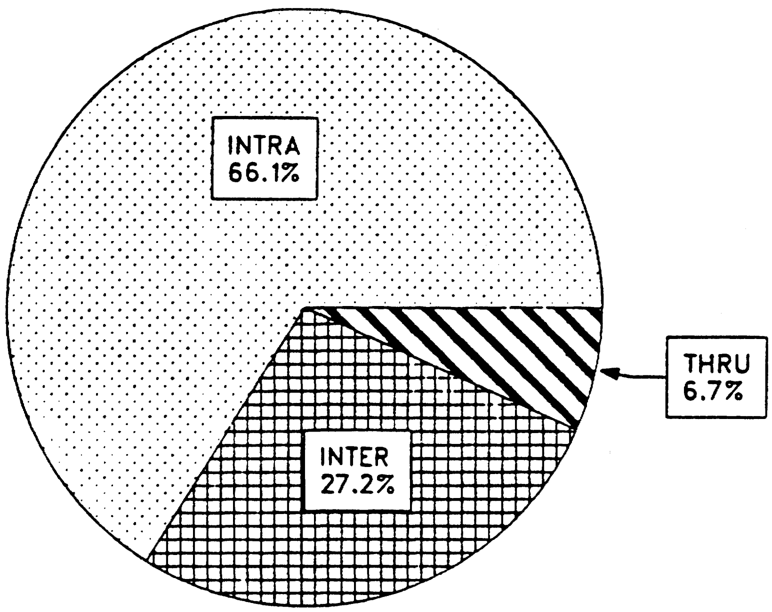
   - "Regional trucks were more peak-period oriented: 40% travelled between 6 and 10 AM. In contrast, under 20% of the through trucks travelled during these hours. Most of the through-traffic travelled late at night. Trip frequency also differed: over 50% of the regional trucks used the crossings daily while only 15% of the through trucks travelled that frequently" (2, p. 26).

2. "Warehouse and distribution centers are intermediary points in the journey of many commodities from producer to consumer. Trucks carry nearly all of the commodities moving from warehouses to points of consumption of retail sale in this metropolitan region" (2, p. 30) (Figure 3). Truck traffic are a part of the "larger goods distribution network on which this region depends to supply all its material needs. That partial picture, however, has suggested the powerful role trucks play in supporting the region's economy — supplying consumers, supporting the service and manufacturing sectors and linking the region's ports-of-entry to their final customers" (2, p. vii).



Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary*. Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, p. i.

Figure 1. 1985 Regional Freight Activities.

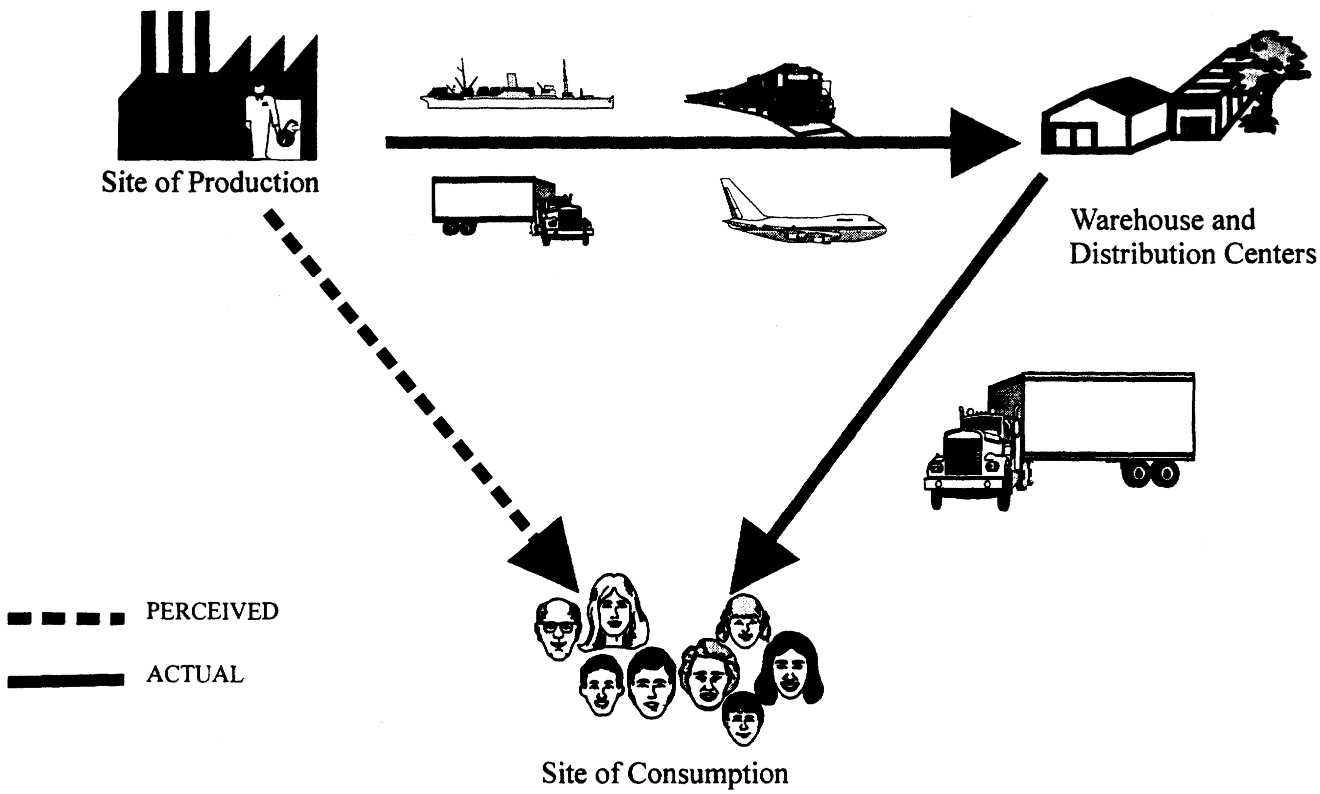


INTRA = Origin and Destination within the Region
INTER = Origin or Destination within the Region
THRU = Origin and Destination outside the Region

Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary.* Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, Chart V-A, p. 27.

Figure 2. Regional Traffic Versus Through Traffic by Crossing.

DISTRIBUTION DEFINED



Source: Based on Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary.* Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, p. ii.

Figure 3. Distribution Defined.

3. The most common commodities carried into the region by trucks "were food, paper, furniture, apparel and miscellaneous freight shipments, a formal designation that covers trucks carrying varying commodities simultaneously" (2, p. v) (Figure 4). "The 7.6 million eastbound trucks carried 65 million tons of freight. [Figure 5] compares the percentage breakdown between the number of truck trips and the tonnage of the leading commodities. Food, paper and misc. freight shipments roughly accounted for the same percentages. However, furniture and apparel each accounted for about one percent in tonnage compared with almost five percent of the truck trips. This is because these two commodity groups tend to take up truck space faster than available truck weight; they "cube out" before they reach truck weight limitations" (2, p. 21).

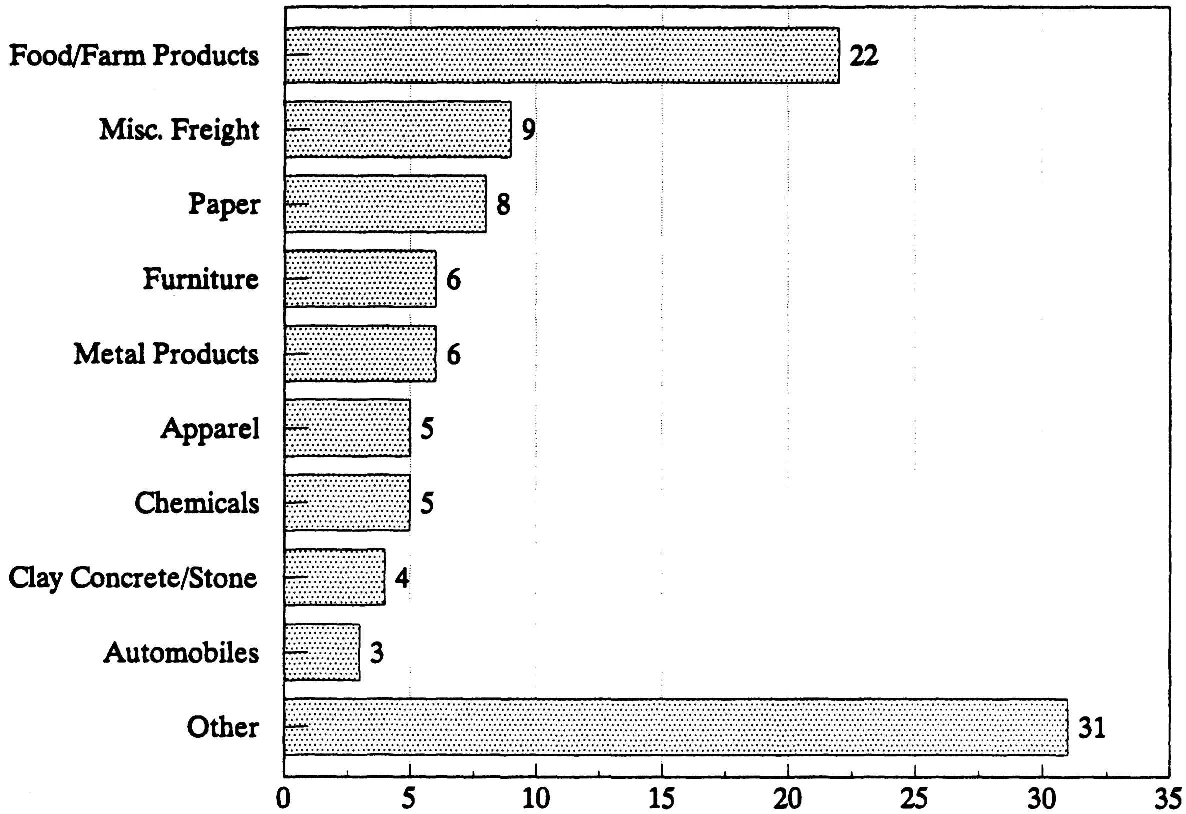
   - "Food was the most common commodity transported. Over 20% of the eastbound trucks carried food products, representing about 17 million tons annually. Movements were heaviest during the early morning hours — going to food and fish markets and supplying the needs of restaurants and supermarkets [Figure 6]. There was a second lesser peak around midday" (2, p. 21).

   - "Almost 10% of the trucks were carrying paper and office supplies, representing about 6 million tons annually. In contrast to food movements, most of the paper movements occurred between 6 AM and 1 PM, peaking between 8 and 11 AM [Figure 7]. Paper movements tended to use the crossings during the early part of the office business day. 30% of the 'paper' trucks (more than the percentage of the overall truck traffic sample) were destined to . . . the major concentration of office activity in the region" (2, p. 21).

   - "Trucks carrying furniture include household moving companies and other furniture-hauling trucks. These trucks accounted for over five percent of the eastbound trucks, representing just under one million tons annually. Furniture trucks used the crossings on a significantly lower frequency than the overall sample, indicating that the movements of furniture tend to be more specialized (e.g., the delivery of furniture to residences is generally a unique, one-time trip). In accordance with this, most of the furniture movements came through the crossings between 8 AM and noon [Figure 8]. The most common destinations were end users and warehouses (each accounting for close to 45% of the furniture movements)" (2, p. 21).

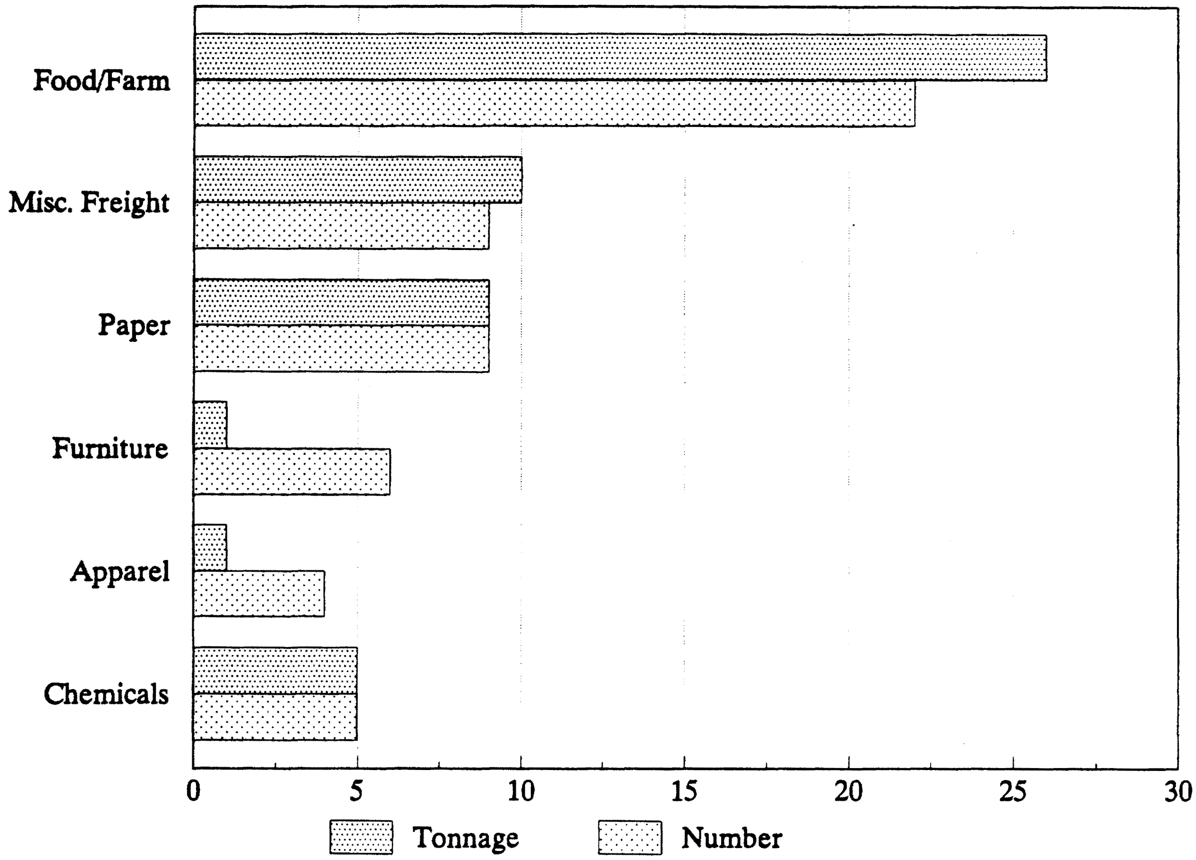
   - "Over five percent of the trucks at the crossing carried apparel, representing close to one million tons annually. In contrast to the other commodity movements, almost 75% of the "apparel" trucks came through the crossings during off-peak hours [Figure 9], reflecting continual activity throughout the business day" (2, p. 21).

   - Nearly five percent of the trucks carried chemical products, representing about 3.5 million tons annually. Chemical shipments include soap and detergents, industrial inorganic material, plastics, drugs and vitamins, paint, agricultural



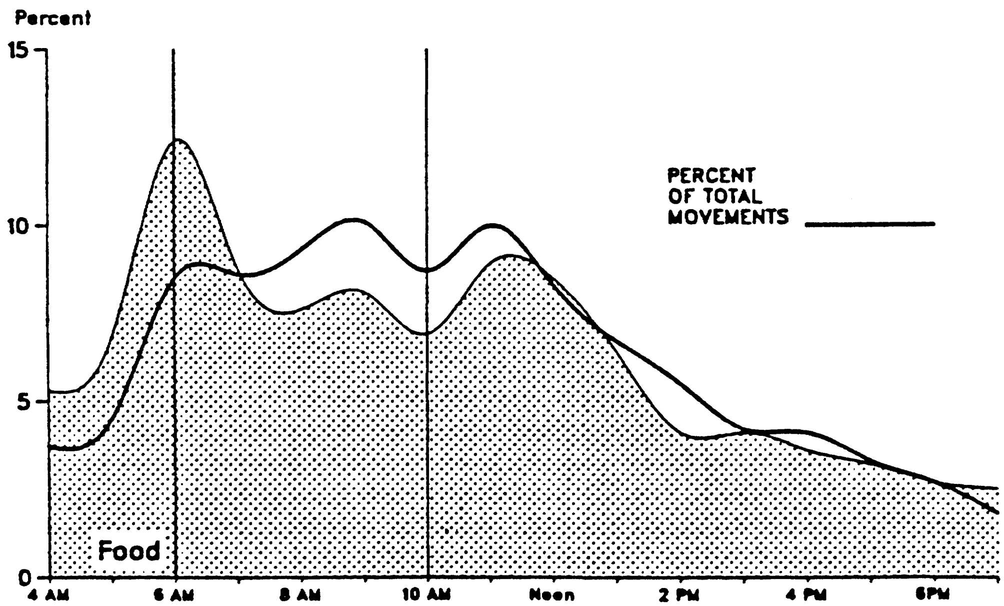
Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary*. Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, p. ii.

Figure 4. Eastbound Truck Survey.



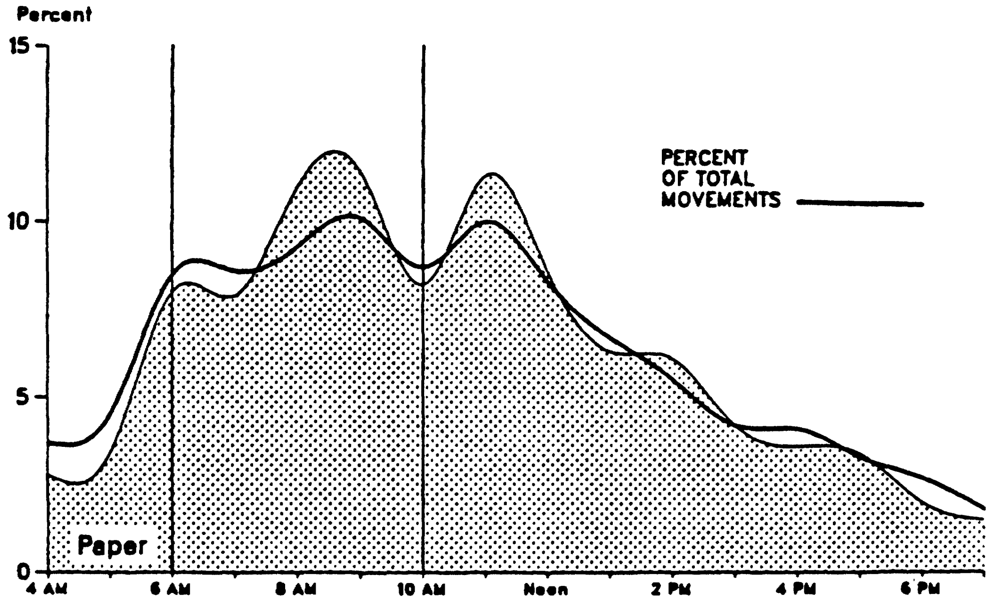
Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary*. Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, Chart IV-A, p. 22.

Figure 5. Comparison Between the Number of Trucks and Tonnage.



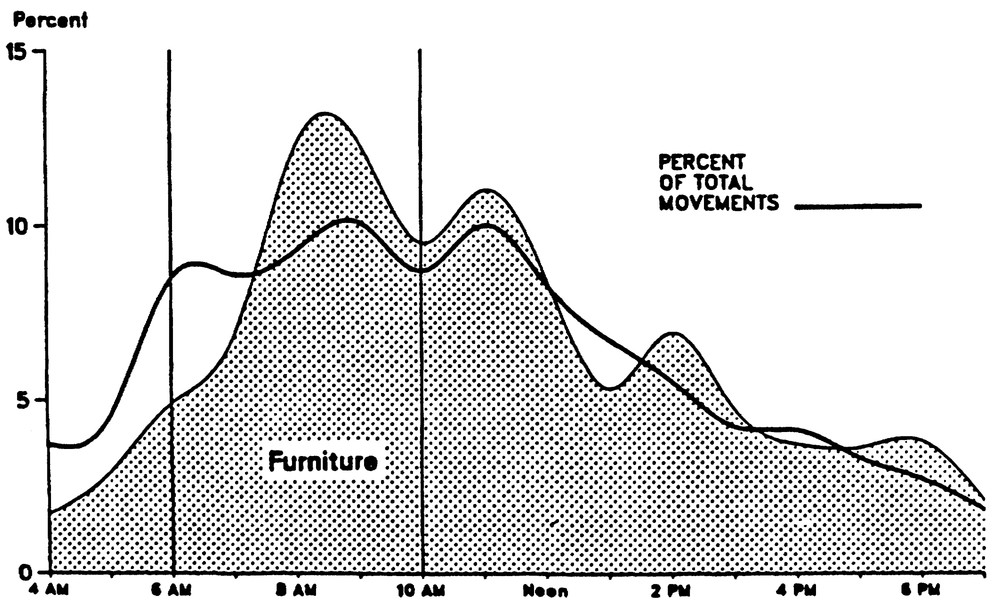
Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary*. Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, Chart IV-B, p. 22.

Figure 6. Food Movements by Hour (Percentage).



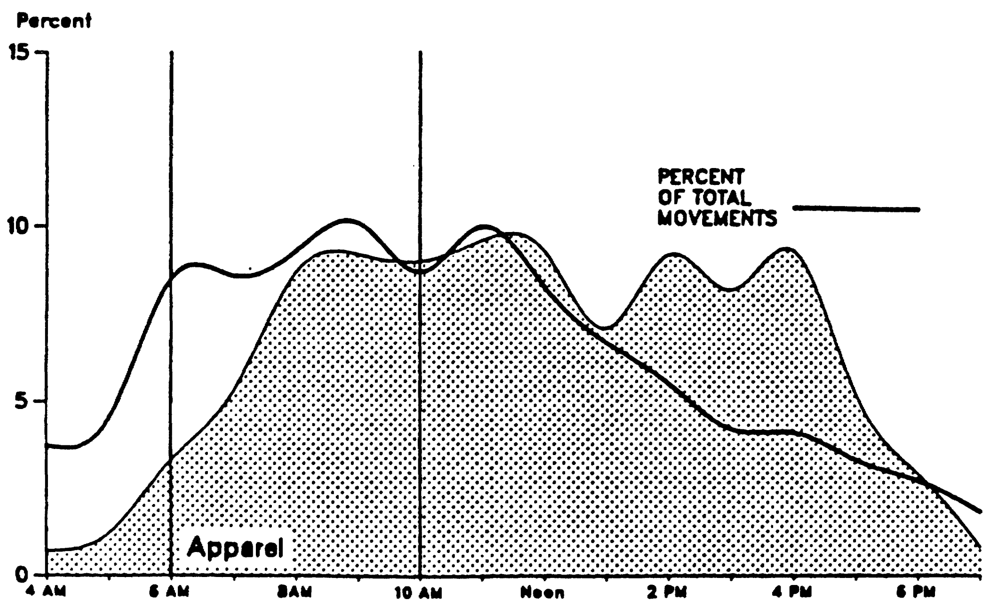
Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary*. Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, Chart IV-C, p. 23.

Figure 7. Paper Movements by Hour (Percentage).



Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary.* Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, Chart IV-D, p. 23.

Figure 8. Furniture Movements by Hour (Percentage).



Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary.* Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, Chart IV-E, p. 25.

Figure 9. Apparel Movements by Hour (Percentage).

chemicals and other chemical materials. In contrast to apparel, close to 60% of the chemical movements were in large trucks . . . carrying industrial chemicals. Small trucks in this category were carrying soaps, detergents or pharmaceutical products. . . . In line with this commodity's industrial orientation, 40% of the movements began at factories (a much larger percent than the overall sample). Most of the chemical movements occurred between 6 AM and 2 PM [Figure 10]" (2, p. 24).

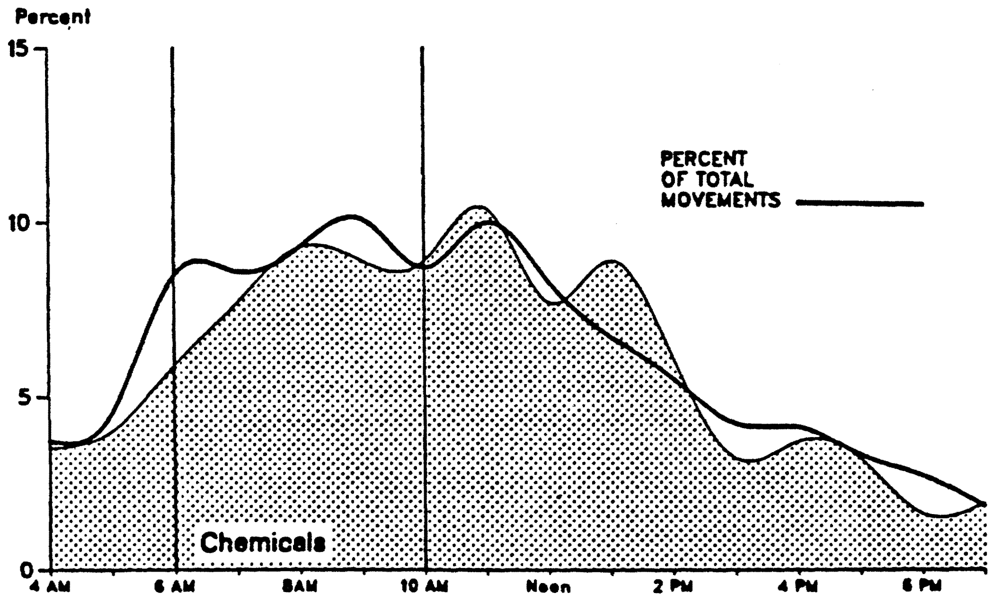
D. Role of Commodity Movement Support of the Economic Base

1. The role of these commodity movements support the economic base and consumers of the New York and New Jersey region.

- "Trucks . . . are integral to the daily operation of the region's businesses. The requirements of the office-based service economy were demonstrated through the movements of paper and office supplies by nearly ten percent of the eastbound trucks. Express mail and packages from Newark Airport were moved to the Manhattan Central Business District for distribution. . . . Retail stores were supplied with apparel, car dealerships with automobiles and restaurants with food products" (2, p. 5).

- "The New York-New Jersey region has a population of fifteen million. Serving the needs of this large and affluent consumer base are trucks carrying food, furniture and retail items. Food was the leading commodity movement, handled by over 20 percent of the trucks. These trucks supplied supermarkets, restaurants and food markets. The role of trucks in food delivery exemplifies how freight is a derived demand — meeting the needs and time constraints of businesses. These food products were delivered just in time to provide fresh products for breakfasts, lunches and dinners and supply supermarkets when employees can be present to accept deliveries. Furniture and household moving company vehicles, representing another consumer-related activity, accounted for over five percent of the eastbound truck traffic" (2, p. 5).

- "In spite of the decline of employment in the manufacturing-based industries, particularly in Manhattan, trucks . . . play an important role in supporting this industry. New York City still remains one of the largest manufacturing centers in the United States, with more than 16,000 manufactures employing almost 400,000 workers who make everything from nuts and bolts to sophisticated high-technology products. Almost 30 percent of the eastbound trucks carried manufacturing-related products such as metal products, chemicals and machinery. The most common facility types of movements were either New Jersey factory/plant to New York consumers and warehouses or New Jersey warehouses to New York warehouses. Over 70 percent of these movements were handled by large trucks and most of these trucks were fully or partially loaded" (2, p. 5).



Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary.* Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, Chart IV-F, p. 25.

Figure 10. Chemical Movements by Hour (Percentage).

- "In 1985, the port and airports in the metropolitan area handled nearly fourteen million tons of general oceanborne export/import cargo and close to 1 million tons of import/export air cargo. Almost ten percent of the trucks either originated or terminated at these port area facilities. . . . Trucks originating at port areas, particularly Port Newark/Elizabeth, carried food, automobiles, apparel, paper and electrical machinery. Similarly, 'airport trucks' carried express mail and apparel, along with other air cargo shipments. The imbalance between imports and exports was also illustrated. Nearly ten percent of the 'port area trucks' were returning empty containers to pier facilities" (2, p. 5).

2. The New York example highlights that trucks are a key complementary supporting mode in urban area freight movement, and this example will be repeated for each urban area in the United States. Also, the New York survey indicates that freight movement is a "derived demand — derived from the schedules, business practices, and product requirements of a particular business. Freight moves when and how a shipper needs it and not when and how a freight company finds it convenient. For example, goods must be delivered during business hours, when there is someone there to receive and sign for them or just-in-time to meet a production schedule because of a shortage of inventory space" (2, p. 21).

II. CHARACTERISTICS OF THE NATIONAL COMMERCIAL TRUCK FLEET

A. Introduction

1. Section II presents information on the characteristics of the national truck fleet.

2. Trucks can be classified in different manners, such as by size, body type, axles, weight, or truck-trailer configurations. Some sample classification schemes are presented along with national truck registration data.

3. Trucks are of interest to planners based on their use for the movement of goods and services. Statistics are presented on the extent and characteristics of truck use within urban areas.

4. The final subsection highlights the characteristics of truck use of urban freeways from a number of studies conducted in Texas and California.

B. Classification of Trucks

1. Trucks represent all vehicle types involved in the movement of goods and the provision of services which can include postal vehicles and government vehicles.

2. Trucks may be classified in different ways — size, body type, axles, weight, tractor-trailer, configurations.

3. The Motor Vehicle Manufacturers Association define trucks by eight weight classes as noted in Figure 11 (4).

4. A study in Phoenix (5) used a very specific vehicle classification system (Figure 12). When considering the definition of trucks involved in urban goods movement functions, the pickup truck (J), pickup with shell (K), or stationwagon (B) are vehicles that may be included. However, increasingly pickup trucks are used in private transportation not related to goods movement. When considering the use of loading docks or curb space, vehicles involved in providing services such as copier repair, may involve automobiles (A).

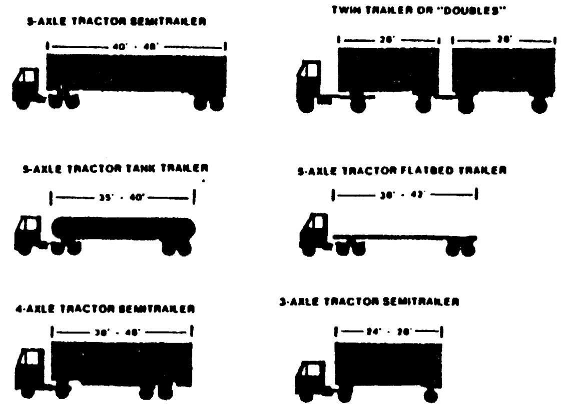
5. An important determination of truck classification is weight of the vehicle. One classification scheme classifies vehicles by size and weight. Resulting is definitions such as light, medium, and heavy trucks (Table 1) (6).

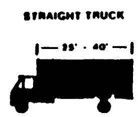
C. Truck Registration — National Data

1. In the United States there were over 44 million truck registrations in 1991 (7).

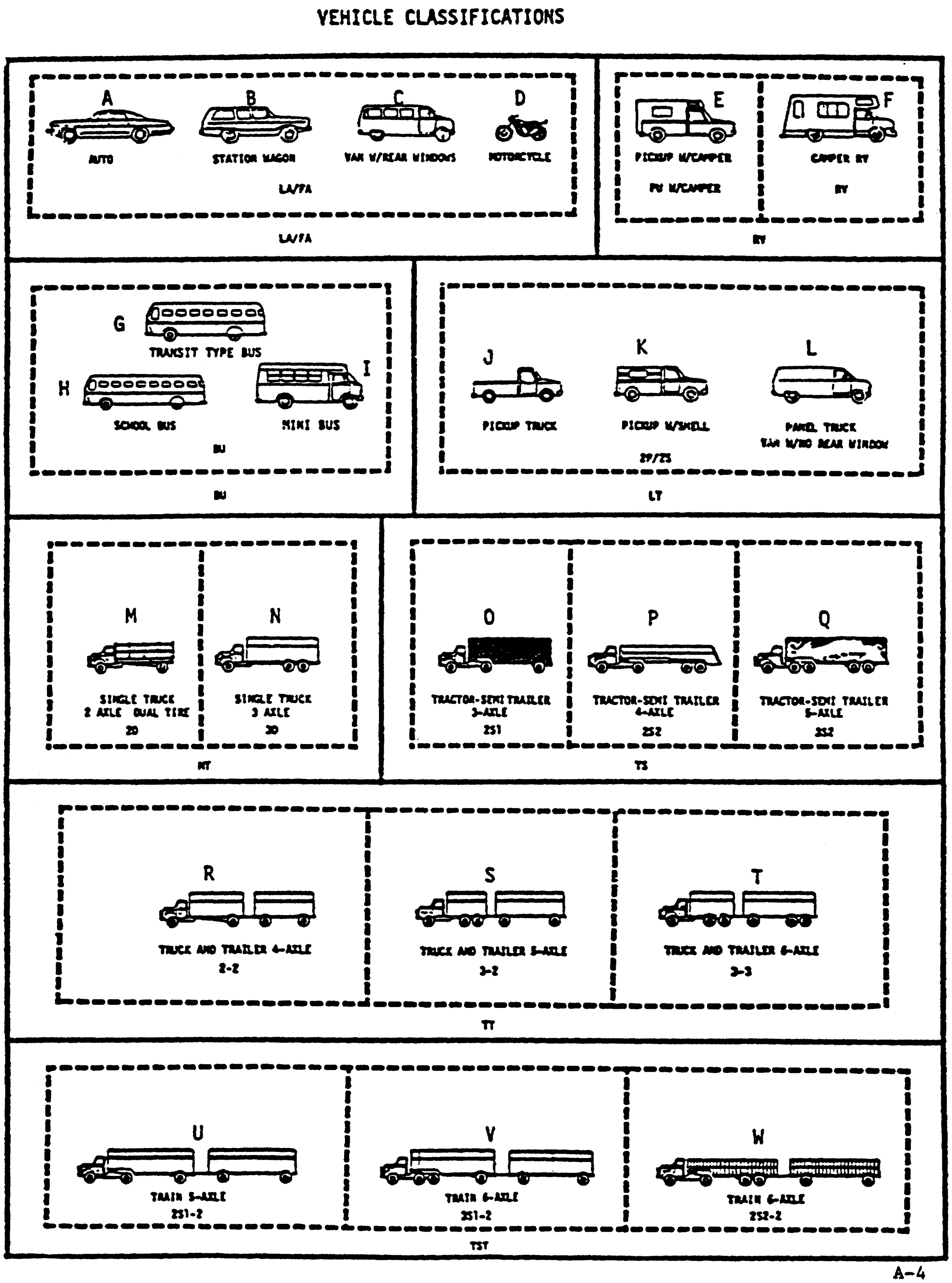
URBAN FREEWAY GRIDLOCK STUDY "LARGE" TRUCK
3+ Axles, Straight or Combination Trucks
(Includes 4- and 5- axle trucks)
Weight Classes 7 and 8 ($\geq$ 26,000 lbs. GVW)

Size Class	Weight Class	Gross Vehicle Weight (lbs)	Axles/Tires	Examples
Heavy-Heavy	8	>33,000	7/22+	Multi-trailer trucks
			6/18+	
			5/18	Tractor-semitrailers and doubles
			4/14	
			3/10	Concrete mixers and dump trucks
Heavy	7	26,000 - 33,000	3/10	City tractor with 28-foot pup trailer
Light-Heavy	6	19,500 - 26,000	2/6	Beverage truck
				Home heating fuel truck
	5	16,000 - 19,500	2/6	Stake truck
	4	14,000 - 16,000	2/6	Flat bed
Medium	3	10,000 - 14,000	2/6	Metro van (UPS)
	2	6,000 - 10,000	2/4	Step van (Mail)
Light	1	<6,000	2/4	Pickup truck, Van





Source: *Urban Freeway Gridlock Study: Summary Report*. Prepared for California Department of Transportation. Cambridge Systematics, Inc., Cambridge, Massachusetts, 1988, Table 1, p. 3.



Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ92-314. Arizona Department of Transportation, Phoenix, February 1992, Appendix A, p. A-4.

Figure 12. Vehicle Classification Used in a Study in Phoenix, Arizona.

Table 1. Example Technique for Classifying Trucks by Size and Weight.

Size Class	Weight Class: Number	Weight Class: Gross Vehicle Weight (pounds)	Vehicle Representative of Class; axles/tires
Light	1	<6,000	1/2 ton pickup; 2/4
	2	6,000-10,000	step van; 2/4
Medium	3	10,000-14,000	metro van; 2/6
	4	14,000-16,000	flat bed; 2/6
	5	16,000-19,500	stake truck; 2/6
Light-Heavy	6	19,500-26,000	beverage truck and home heating oil truck; 2/6
Heavy	7	26,000-33,000	dump truck and small tractor-trailer; 3/10
	8	>33,000	concrete truck; 3/10 tractor-trailer; 3+/10+

Note: 1 pound = 0.45 kg.

Source: Christiansen, Dennis L. *Urban Transportation Planning for Goods and Services — A Reference Guide.* Office of Highway Planning, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., June 1979, Table II-2, p. II-9.

2. About 96 percent are owned by private and commercial interests, while 4 percent are owned and operated by governmental units (8).

3. The 1991 data show a 0.2 percent increase over 1990 and a 375 percent increase over 1960 (Figure 13) (7,8).

4. Of 45 million trucks in 1992, 1.7 million were registered as farm trucks, which mainly operate on rural highways and 38 million were classified as light vehicles (less than 10,000 pounds gross vehicle weight) (9). These light trucks represent the greatest growth in trucks, but these vehicles are not all used in goods movement functions; many are used as passenger cars.

5. Completing the inventory are 1.3 million truck trailers which pull 3.8 million commercial trailers (9).

6. The National Truck Trip Information Survey work conducted at the University of Michigan Transportation Research Institute estimated the distribution of medium and heavy trucks by power type and fuel type trucks (excludes trucks of less than 10,000 pounds gross vehicle weight) for 1983 (10) (Table 2).

7. The truck registration by state in 1991 are noted in Figure 14 (7).

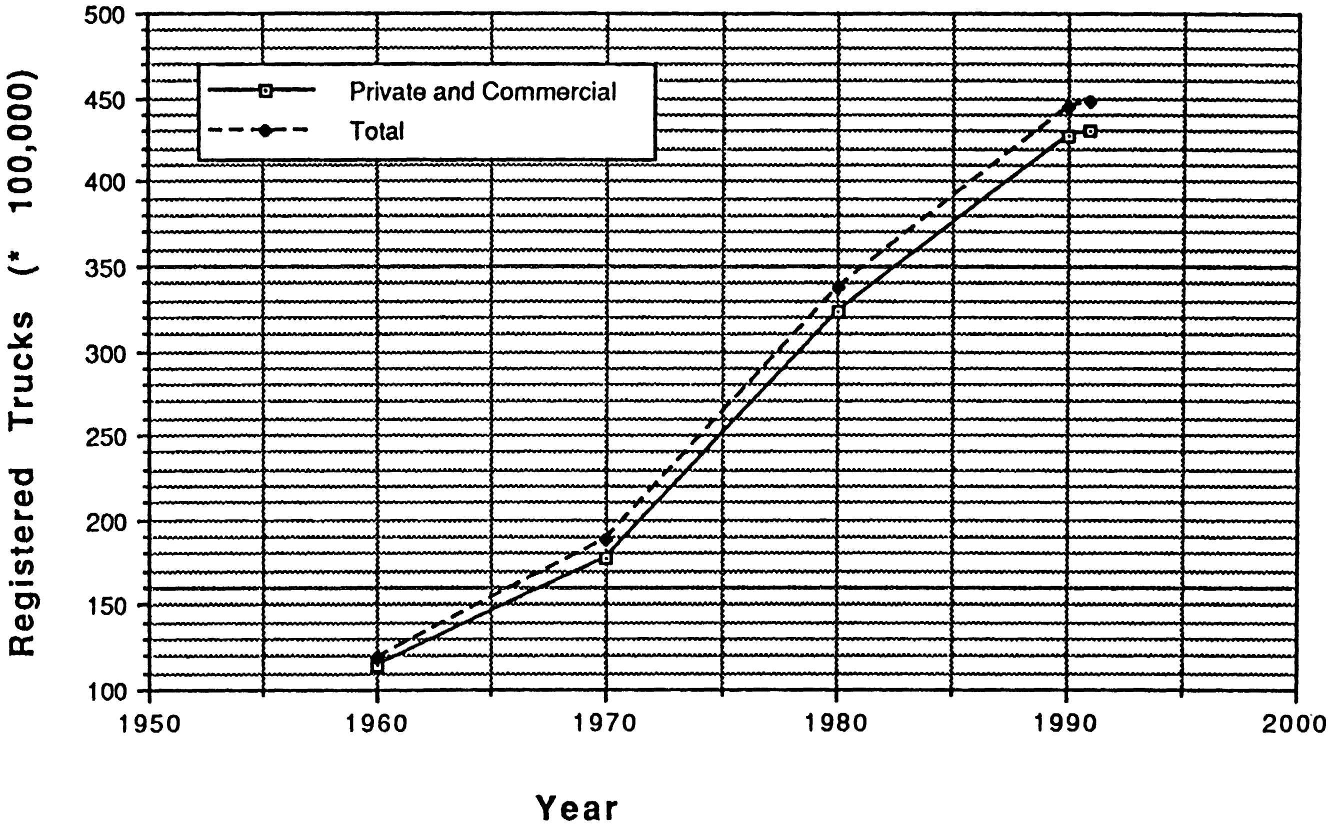
D. Truck Usage — National Characteristics

1. At the national level, the domestic intercity portion of freight movement measured as ton-miles represents about 11,000 ton-miles per capita in 1990. The freight ton-miles has increased 47 percent since 1950, which indicates Americans are producing and consuming more goods each year (Figure 15) (9).

2. A clarification indicates that the increase in ton-miles of freight represent more miles of travel as the freight tons per capita has a slower rate of growth than the number of ton-miles. For example, in 1990 the freight tons per capita was a little over 25 tons, which is only a 25 percent increase since 1950 (Figure 15) (9).

3. Intercity trucking in modal tonnage and ton-miles has shown a continual and steady gain in market share from 16 percent in 1950 to 26-27 percent in 1993 (Figure 16) (9).

4. While it is not possible to directly determine the travel associated with urban goods movement, over half of the truck vehicle-miles are made on the urban highway system (urban being urban areas with population of 5,000 or more). As noted in Figure 17, the greatest increase in vehicle-miles of travel has been in urban rather than rural areas.



Source: Based on data from Larson, Thomas D. *Highway Statistics 1991*, Report No. FHWA-PL-92-025. Federal Highway Administration, U.S. Department of Transportation, n.d.

Figure 13. Relationship for Rural and Urban Truck Inventories, 1960-1991.

Table 2. Distribution of Medium and Heavy Trucks.

Truck Type[1]	n	Trucks	Percent
Straight Trucks			
Class 3-5 Gas	421	365,787	11.78
Class 3-5 Diesel	9	5,053	0.16
Class 6 Gas	1,419	1,075,054	34.62
Class 6 Diesel	127	73,316	2.36
Class 7 Gas	333	132,469	4.27
Class 7 Diesel	295	110,069	3.54
Class 8 Gas	230	90,283	2.91
Class 8 Diesel	719	283,213	9.12
Other/Unknown	148	50,069	1.61
All Straight	3,701	2,185,313	70.38
Tractors			
Class 3-6 Gas	75	36,241	1.17
Class 3-6 Diesel	47	17,459	0.56
Class 7 Gas	43	16,174	0.52
Class 7 Diesel	215	68,915	2.22
Class 8 Gas	16	6,648	0.21
Class 8 Diesel	2,188	771,333	24.84
Other/Unknown	8	3,055	0.10
All Tractors	2,592	919,825	29.62
Total	6,293	3,105,138	100.00

[1]See Figure 11 and Table 1 for truck class definitions.

Source: Blower, Daniel F., and Kenneth L. Campbell. *Analysis of Heavy-Duty Truck Use in Urban Areas*, Report No. UMTRI-88-31. Transportation Research Institute, The University of Michigan, Ann Arbor, MI, June 30, 1988, Table 1, p. 15.

TRUCK AND TRUCK-TRACTOR REGISTRATIONS - 1991 [1]

COMPILED FOR THE CALENDAR YEAR FROM REPORTS OF STATE AUTHORITIES AND OTHER SOURCES

TABLE MV-9
SEPTEMBER 1992

STATE	PRIVATE AND COMMERCIAL	FEDERAL	STATE, COUNTY, AND MUNICIPAL	TOTAL TRUCKS REGIS-TERED 1991	COMPARISON OF TOTAL TRUCK REGISTRATIONS, 1990-1991: TOTAL 1990 TRUCK REGIS-TRATIONS	INCREASE OR DECREASE 1991	PERCENT-AGE CHANGE	PARTIAL CLASSIFICATION OF PRIVATE AND COMMERCIAL TRUCKS REGISTERED IN 1991 2/: TRUCK TRACTORS 3/	LIGHT TRUCKS 3/	FARM TRUCKS 4/
ALABAMA	954.462	3.804	20.136	978.402	1.003.191	-24.789	-2.5	37.470	876.392	17.453
ALASKA	165.413	2.473	4.157	172.043	173.060	-1.017	-0.6	2.639	155.888	405
ARIZONA	805.523	7.146	8.159	820.828	818.977	1.851	0.2	11.614	771.650	-
ARKANSAS	506.370	2.128	8.033	516.531	508.144	8.387	1.7	13.954	488.867	15.509
CALIFORNIA	4.762.176	34.586	184.082	4.980.844	4.913.898	66.946	1.4	113.541	3.787.868	-
COLORADO	797.731	6.796	15.505	820.032	849.726	-29.694	-3.5	5.743	723.878	90.754
CONNECTICUT	113.840	3.383	19.382	136.605	142.746	-6.141	-4.3	3.028	105.395	4/ -
DELAWARE	118.619	599	1.574	120.792	117.645	3.147	2.7	7.270	103.631	3.422
DIST. OF COL.	9.650	2.920	2.400	14.970	14.239	731	5.1	113	8.614	-
FLORIDA	1.910.644	11.589	110.088	2.032.321	2.218.108	-185.787	-8.4	54.752	1.557.525	-
GEORGIA	1.655.908	5.648	46.445	1.708.001	1.640.852	67.149	4.1	59.937	1.528.072	5/ -
HAWAII	94.173	1.335	5.140	100.648	95.301	5.347	5.6	1.491	89.136	-
IDAHO	389.835	3.806	16.452	410.093	413.463	-3.370	-0.8	6.140	346.526	-
ILLINOIS	1.528.957	8.246	10.762	1.547.965	1.556.414	-8.449	-0.5	68.974	1.249.525	49.165
INDIANA	1.124.803	3.433	30.045	1.158.281	1.147.694	10.587	0.9	41.511	957.549	41.937
IOWA	727.853	2.543	22.280	752.676	742.528	10.148	1.4	30.229	585.950	24.150
KANSAS	616.511	2.450	13.950	632.911	603.839	29.072	4.8	19.891	506.279	75.893
KENTUCKY 6/	962.250	3.380	44.887	1.010.517	984.290	26.227	2.7	20.959	858.192	105.414
LOUISIANA	1.006.282	3.735	14.128	1.024.145	976.739	47.406	4.9	25.363	936.142	68.427
MAINE	211.658	935	8.106	220.699	231.937	-11.238	-4.8	6.233	182.362	6.071
MARYLAND	590.998	5.309	14.379	610.686	625.263	-14.577	-2.3	16.612	534.525	9.822
MASSACHUSETTS	464.417	5.294	23.569	493.280	490.999	2.281	0.5	16.433	420.223	8.441
MICHIGAN	1.509.698	6.755	61.519	1.577.972	1.573.475	4.497	0.3	50.569	1.306.146	57.908
MINNESOTA	671.897	4.229	18.782	694.908	751.686	-56.778	-7.6	26.590	504.584	38.047
MISSISSIPPI	420.189	2.688	12.863	435.740	432.659	3.081	0.7	8.073	392.143	5/ -
MISSOURI	1.135.627	3.654	10.961	1.150.242	1.132.998	17.244	1.5	37.849	999.670	90.661
MONTANA	300.727	3.815	8.943	313.485	323.535	-10.050	-3.1	10.411	261.549	72.587
NEBRASKA	455.846	2.110	12.642	470.598	466.132	4.466	1.0	21.506	357.855	149.448
NEVADA	265.062	4.906	7.455	277.423	259.569	17.854	6.9	3.990	235.258	-
NEW HAMPSHIRE	185.852	840	8.679	195.371	192.721	2.650	1.4	4.698	169.116	4/ 1.780
NEW JERSEY	360.818	7.839	74.194	442.851	454.867	-12.016	-2.6	22.627	315.973	4/ 14.718
NEW MEXICO	474.817	5.176	12.604	492.597	491.639	958	0.2	3.889	445.213	15.490
NEW YORK	1.167.857	13.877	62.282	1.244.016	1.332.381	-88.365	-6.6	13.686	1.047.014	4/ 45.904
NORTH CAROLINA	1.414.033	4.098	50.391	1.468.522	1.450.660	17.862	1.2	52.749	1.238.190	96.186
NORTH DAKOTA	245.457	1.459	6.035	252.951	256.135	-3.184	-1.2	7.335	181.891	40.393
OHIO	1.538.756	6.866	51.185	1.596.807	1.561.812	34.995	2.2	43.087	1.350.214	35.438
OKLAHOMA	909.801	3.698	33.870	947.369	925.137	22.232	2.4	11.805	816.408	128.309
OREGON	588.225	6.864	16.992	612.081	595.880	16.201	2.7	16.090	497.800	19.253
PENNSYLVANIA	1.523.042	9.669	43.411	1.576.122	1.556.508	19.614	1.3	54.017	1.222.898	4/ -
RHODE ISLAND	100.956	843	4.619	106.418	106.867	-449	-0.4	2.884	89.496	4/ -
SOUTH CAROLINA	566.809	3.720	17.226	587.755	628.400	-40.645	-6.5	13.167	521.370	15.609
SOUTH DAKOTA	267.927	2.016	9.347	279.290	276.938	2.352	0.8	7.597	236.535	-
TENNESSEE	840.618	7.254	37.191	885.063	877.413	7.650	0.9	32.724	780.692	41.719
TEXAS	3.763.496	17.588	187.613	3.968.697	4.024.375	-55.678	-1.4	118.289	3.548.472	185.440
UTAH	416.809	3.378	8.894	429.081	415.006	14.075	3.4	10.784	388.120	6.000
VERMONT	111.668	365	5.409	117.442	118.813	-1.371	-1.2	2.041	102.519	3.061
VIRGINIA	1.148.914	6.704	24.624	1.180.242	1.145.524	34.718	3.0	27.525	1.023.325	21.885
WASHINGTON	1.278.988	9.534	18.541	1.307.063	1.270.433	36.630	2.9	32.284	1.156.676	28.887
WEST VIRGINIA	455.421	1.516	34.173	491.110	468.402	22.708	4.8	6.565	420.703	2.533
WISCONSIN	1.161.210	3.613	33.476	1.198.299	1.141.592	56.707	5.0	26.369	1.017.303	113.986
WYOMING	215.161	2.212	4.875	222.248	217.277	4.971	2.3	3.051	191.872	-
TOTAL	43.013.754	268.824	1.502.455	44.785.033	44.717.887	67.146	0.2	1.236.148	37.603.194	1.742.105

1/ THE REGISTRATIONS GIVEN IN THIS TABLE ARE AS REPORTED BY THE STATES IN MOST INSTANCES, BUT HAVE BEEN SUPPLEMENTED IN SOME CASES BY ESTIMATES BASED ON DATA FROM OTHER SOURCES.

2/ IN THIS PARTIAL CLASSIFICATION A VEHICLE MAY BE INCLUDED MORE THAN ONCE: FOR INSTANCE, A TRUCK-TRACTOR IN FARM USE COULD APPEAR IN BOTH COLUMNS.

3/ THE FIGURES IN THESE COLUMNS MAY VARY SUBSTANTIALLY FROM THE NUMBERS SHOWN FOR PRIOR YEARS. THIS RESULTS FROM NEW INFORMATION, SUCH AS THE 1987 CENSUS OF TRANSPORTATION TRUCK INVENTORY AND USE SURVEY, AND CHANGES IN THE ESTIMATING PROCEDURES, AND IS NOT BECAUSE OF SUBSTANTIAL VEHICLE REGISTRATION CHANGES DURING 1989. WHERE DATA REPORTED BY THE STATES WERE INCOMPLETE FOR THESE VEHICLES, ESTIMATES WERE MADE BY THE FEDERAL HIGHWAY ADMINISTRATION. TRUCK TRACTORS MAY INCLUDE SOME LARGE TRUCKS USED REGULARLY IN COMBINATION WITH FULL TRAILERS. LIGHT TRUCKS INCLUDES PICKUPS, PANELS, AND DELIVERY VANS GENERALLY OF 10.000 POUNDS OR LESS GROSS VEHICLE WEIGHT.

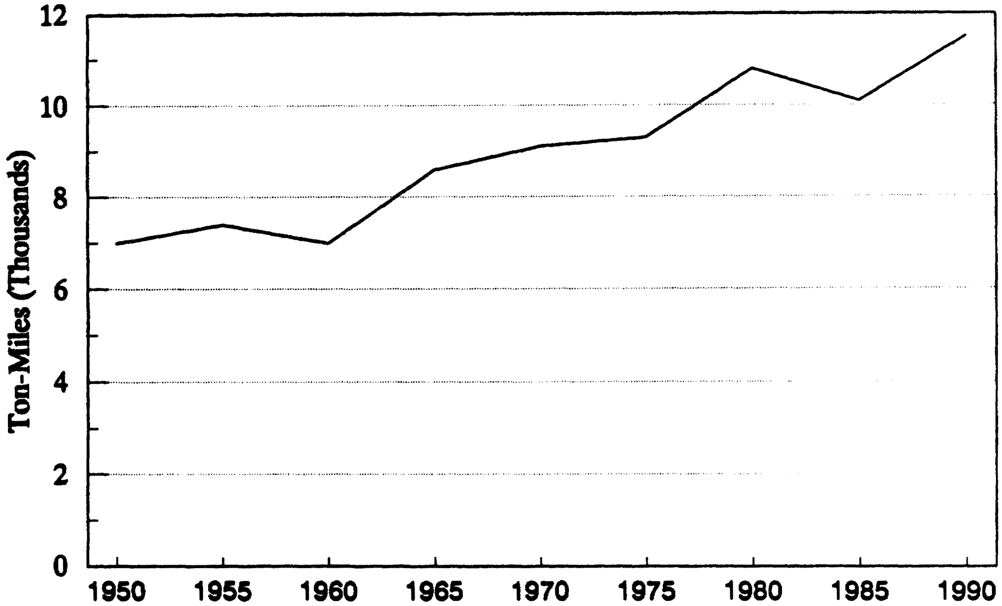
4/ EXCEPT FOR GEORGIA AND MISSISSIPPI (FOOTNOTE 5), FARM REGISTRATIONS ARE SHOWN FOR ALL STATES THAT HAVE A SPECIAL "FARM" CLASSIFICATION. THE NUMBERS OF VEHICLES SHOWN DO NOT NECESSARILY REPRESENT THE TOTAL NUMBER OF REGISTERED VEHICLES USED ON THE FARM. THE FOLLOWING FARM TRUCKS, REGISTERED AT A NOMINAL FEE AND RESTRICTED TO USE IN THE VICINITY OF THE OWNER'S FARM, ARE NOT INCLUDED IN THIS TABLE: CONNECTICUT, 8.102; NEW HAMPSHIRE, 3.259; NEW JERSEY, 5.839; NEW YORK, 26.923; PENNSYLVANIA, 22.161; AND RHODE ISLAND, 971.

5/ ALTHOUGH GEORGIA AND MISSISSIPPI HAVE A SPECIAL "FARM" CLASSIFICATION, THEIR REGISTRATION REPORTS DO NOT SHOW A COMPLETE SEGREGATION OF FARM TRUCKS FROM PRIVATE CARRIERS.

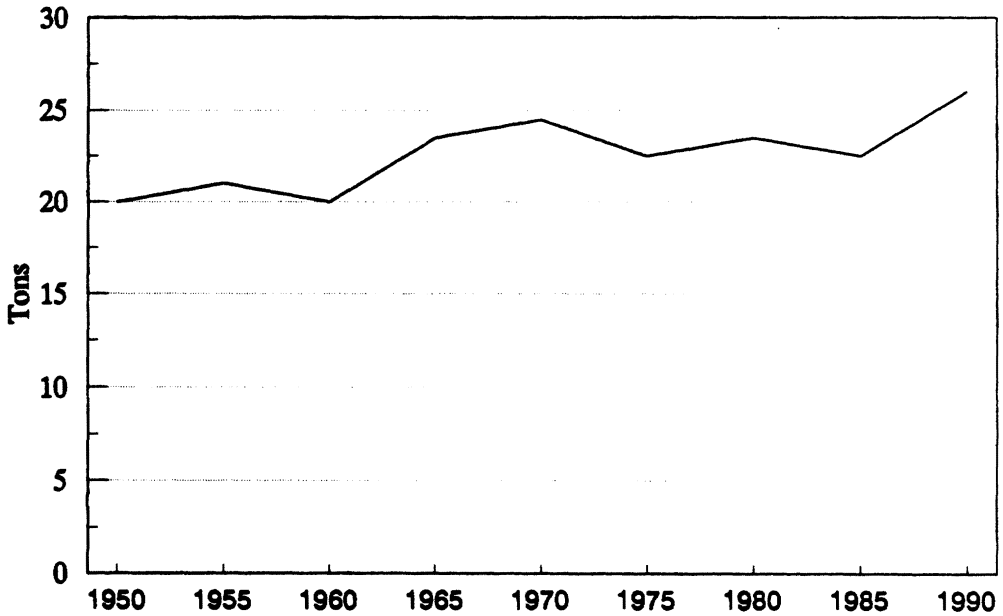
5/ THE STATE WAS UNABLE TO PROVIDE MOTOR-VEHICLE REGISTRATION DATA FOR 1991. THE FIGURES SHOWN HERE ARE ESTIMATES BY THE FEDERAL HIGHWAY ADMINISTRATION.

Source: Larson, Thomas D. *Highway Statistics 1991*, Report No. FHWA-PL-92-025. Federal Highway Administration, U.S. Department of Transportation, n.d., p. 19.

Figure 14. Truck and Truck-Tractor Registrations, 1991.



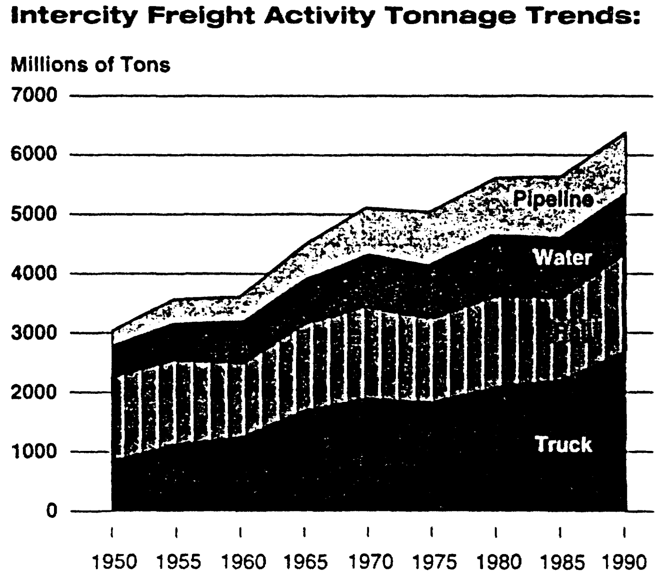
Freight Ton-Miles per Capita



Freight Tons per Capita

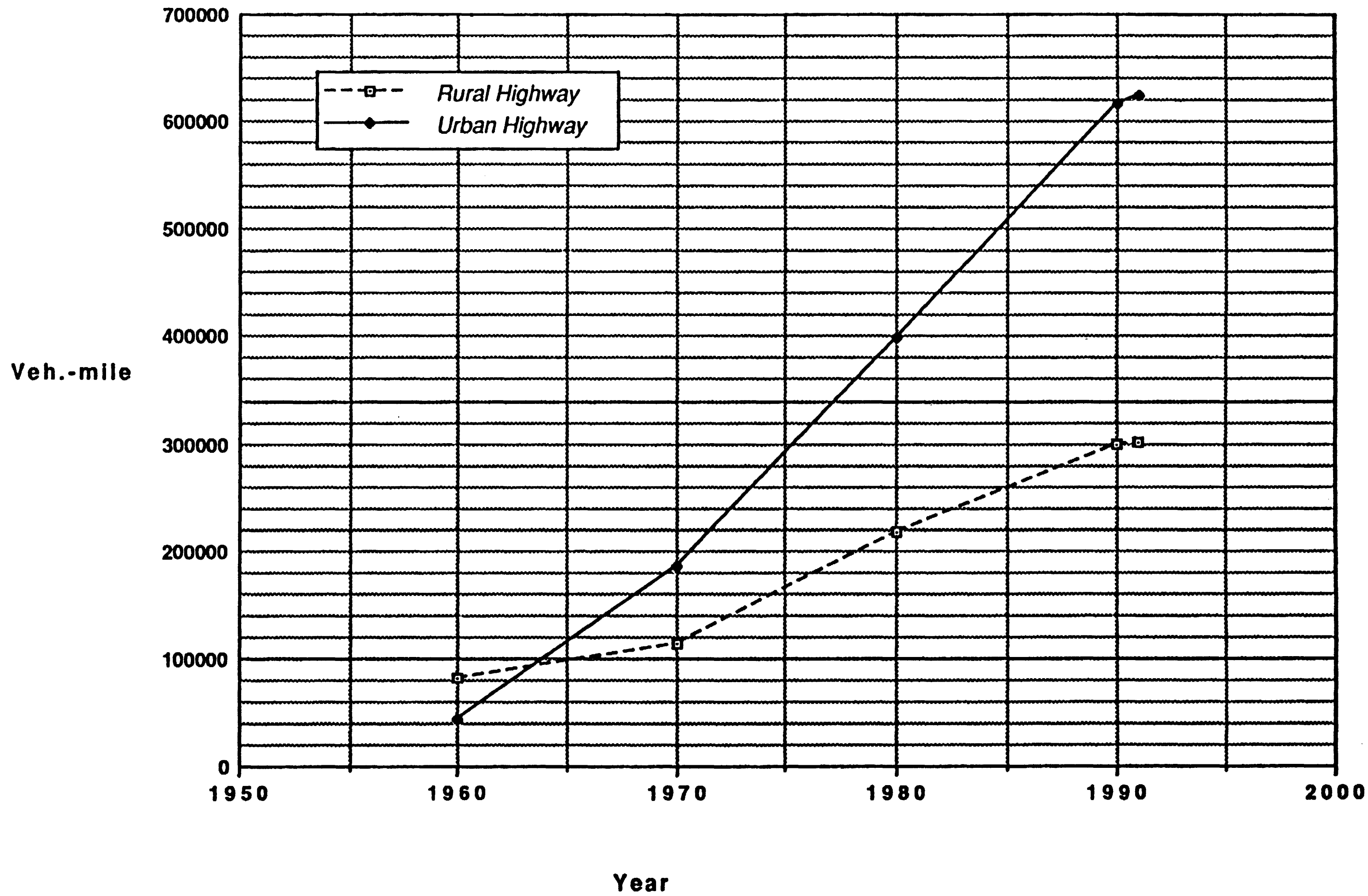
Transportation Statistics, Annual Report 1994. Bureau of Transportation Statistics, U.S. Department of Transportation, Washington, D.C., January 1994, Figure 3-12, p. 58.

Figure 15. Freight Movements per Capita.



Transportation Statistics, Annual Report 1994. Bureau of Transportation Statistics, U.S. Department of Transportation, Washington, D.C., January 1994, Figure 3-13, p. 59.

Figure 16. Modal Shares of Freight.



Source: *National Transportation Statistics, Annual Report, September 1993*, Report No. DOT-VNTSC-BTS-93-1. Bureau of Transportation Statistics, U.S. Department of Transportation, Washington, D.C., 1973, Figure 7, p. 26.

Figure 17. Relationship for Rural and Urban Truck Vehicle-Miles of Travel.

E. **Truck Usage — Urban Characteristics**

1. Table 3 identifies the distribution of truck travel (over 10,000 pounds gross vehicle weight) by truck type and area type (10).

   - Of all truck trips, 6.6 percent are made in small urban areas and 30.9 percent are made in large urban areas.

   - 15 percent of all truck trips are made by straight trucks in urban areas.

   - 22 percent of all truck trips are made by tractors in urban areas.

2. The distribution of truck travel by area type (Table 4) indicates 66 percent of all truck trips in both small and large urban areas are made by Class 8 diesel vehicles (53 percent tractors and 13 percent straight trucks) (10).

3. Within large areas 66 percent of all tractor trips are made on limited access highways as are 31 percent of all straight truck trips (Table 5) (10). Straight truck trips are more evenly distributed across all urban road classes — 27.1 percent major artery, 41.2 percent other road class — while tractors are concentrated on limited access roads (10).

4. About 76 of all truck trips in large urban areas are made on urban limited access roads, and Class 8 diesel tractors alone make 71 percent of the truck trips on limited access roads (Table 6) (10).

5. The distribution of truck trips on major arterials is almost equally split between straight trucks and tractors, but the largest single segment (43.6 percent) is Class 8 diesel trucks (10).

6. The predominant gross combination weight of Class 8 diesel trucks operating in urban areas is 25K-30K, followed by 70K-75K (Table 7). The predominant gross combination weight for Class 3-7 diesel trucks is 20K-35K.

7. Diesel straight trucks generally have lower gross combination weight than Class 8 diesel trucks (Table 8).

8. The predominant gross combination weight for Class 8 diesel trucks on all large urban area roadways is 25K-30K (Table 9). This is also true for Class 8 diesel straight trucks (Table 10).

F. **Truck Use of Urban Freeways**

1. Trucks typically account for 5 percent or less of peak hour travel (Table 11) (4,11).

Table 3. Distribution of Total Truck Travel by Truck Type and Area Type.

Truck Type[1]	n (trips)	Percent			
		Rural	Small Urban	Large Urban	Total
Straight Trucks					
Class 3-5 Gas	299	1.08	0.32	1.16	2.56
Class 3-5 Diesel	22	0.08	0.00	0.15	0.24
Class 6 Gas	1,037	6.00	0.98	3.35	10.33
Class 6 Diesel	249	0.53	0.12	0.92	1.57
Class 7 Gas	256	0.70	0.11	0.65	1.46
Class 7 Diesel	778	1.26	0.22	1.57	3.06
Class 8 Gas	175	0.66	0.16	0.28	1.10
Class 8 Diesel	1,987	4.56	0.89	4.00	9.46
Other/Unknown	145	0.49	0.04	0.32	0.85
All Straight	4,948	15.37	2.84	12.41	30.62
Tractors					
Class 3-6 Gas	83	0.36	0.04	0.08	0.48
Class 3-6 Diesel	152	0.53	0.05	0.34	0.92
Class 7 Gas	54	0.03	0.01	0.07	0.11
Class 7 Diesel	629	1.13	0.15	1.32	2.61
Class 8 Gas	23	0.35	0.01	0.03	0.39
Class 8 Diesel	7,187	44.70	3.53	16.56	64.79
Other/Unknown	13	0.03	0.00	0.04	0.07
All Tractors	8,141	47.14	3.79	18.45	69.38
Total	13,089	62.51	6.63	30.86	

[1]See Figure 11 and Table 1 for truck class definitions.

Source: Blower, Daniel F., and Kenneth L. Campbell. *Analysis of Heavy-Duty Truck Use in Urban Areas*, Report No. UMTRI-88-31. Transportation Research Institute, The University of Michigan, Ann Arbor, MI, June 30, 1988, Table 2, p. 16.

Table 4. Distribution of Travel by Truck Type and Area Type.

		Column Percent by Area Type		
Truck Type[1]	n (trips)	Rural	Small Urban	Large Urban
Straight Trucks				
Class 3-5 Gas	299	1.73	4.77	3.76
Class 3-5 Diesel	22	0.13	0.03	0.49
Class 6 Gas	1,037	9.59	14.81	10.85
Class 6 Diesel	249	0.84	1.76	2.99
Class 7 Gas	256	1.12	1.69	2.12
Class 7 Diesel	778	2.02	3.26	5.10
Class 8 Gas	175	1.06	2.46	0.90
Class 8 Diesel	1,987	7.30	13.48	12.98
Other/Unknown	145	0.79	0.60	1.04
All Straight	4,948	24.59	42.86	40.23
Tractors				
Class 3-6 Gas	83	0.58	0.54	0.26
Class 3-6 Diesel	152	0.85	0.83	1.09
Class 7 Gas	54	0.05	0.08	0.23
Class 7 Diesel	629	1.82	2.26	4.29
Class 8 Gas	23	0.56	0.15	0.10
Class 8 Diesel	7,187	71.50	53.28	53.67
Other/Unknown	13	0.05	0.00	0.13
All Tractors	8,141	75.41	57.14	59.77
Total	13,089			

[1]See Figure 11 and Table 1 for truck class definitions.

Source: Blower, Daniel F., and Kenneth L. Campbell. *Analysis of Heavy-Duty Truck Use in Urban Areas*, Report No. UMTRI-88-31. Transportation Research Institute, The University of Michigan, Ann Arbor, MI, June 30, 1988, Table 4, p. 18.

Table 5. Truck Class Travel by Road Class.

Truck Type[1]	n (trips)	Row Percent by Road Class		
		Limited Access	Major Artery	Other
Straight Trucks				
Class 3-5 Gas	299	13.2	29.4	57.4
Class 3-5 Diesel	22	56.5	3.8	39.7
Class 6 Gas	1,037	36.6	23.0	40.4
Class 6 Diesel	249	34.8	34.8	30.4
Class 7 Gas	256	21.7	25.4	53.0
Class 7 Diesel	778	34.5	26.8	38.7
Class 8 Gas	175	23.7	31.0	45.3
Class 8 Diesel	2,009	34.2	29.9	36.0
Other/Unknown	145	13.3	25.6	61.1
All Straight	4,970	31.7	27.1	41.2
Tractors				
Class 3-6 Gas	83	28.5	51.2	20.4
Class 3-6 Diesel	152	49.5	17.1	33.4
Class 7 Gas	54	27.7	40.6	31.8
Class 7 Diesel	629	37.6	23.0	39.5
Class 8 Gas	23	55.9	31.3	12.9
Class 8 Diesel	7,215	69.3	17.4	13.2
Other/Unknown	13	8.9	68.6	22.5
All Tractors	8,169	66.1	18.2	15.6

[1]See Figure 11 and Table 1 for truck class definitions.

Source: Blower, Daniel F., and Kenneth L. Campbell. *Analysis of Heavy-Duty Truck Use in Urban Areas*, Report No. UMTRI-88-31. Transportation Research Institute, The University of Michigan, Ann Arbor, MI, June 30, 1988, Table 12, p. 29.

Table 6. Truck Class Travel Percentage of Total Truck Travel on Road Class.

Truck Type[1]	n (trips)	Column Percent for Road Class		
		Limited Access	Major Artery	Other
Straight Trucks				
Class 3-5 Gas	299	1.0	5.5	9.1
Class 3-5 Diesel	22	0.6	0.1	0.9
Class 6 Gas	1,037	8.1	12.3	18.2
Class 6 Diesel	249	1.9	4.5	3.3
Class 7 Gas	256	0.8	2.3	4.0
Class 7 Diesel	778	2.9	5.5	6.7
Class 8 Gas	175	0.4	1.3	1.5
Class 8 Diesel	2,009	7.7	16.4	16.3
Other/Unknown	145	0.3	1.3	2.6
All Straight	4,970	23.7	49.0	63.1
Tractors				
Class 3-6 Gas	83	0.2	0.7	0.2
Class 3-6 Diesel	152	1.1	0.9	1.5
Class 7 Gas	54	0.1	0.5	0.3
Class 7 Diesel	629	3.1	4.6	6.7
Class 8 Gas	23	0.1	0.2	0.1
Class 8 Diesel	7,215	71.6	43.6	27.9
Other/Unknown	13	0.0	0.4	0.1
All Tractors	8,169	76.3	50.9	36.9
Total	13,139			

[1]See Figure 11 and Table 1 for truck class definitions.

Source: Blower, Daniel F., and Kenneth L. Campbell. *Analysis of Heavy-Duty Truck Use in Urban Areas*, Report No. UMTRI-88-31. Transportation Research Institute, The University of Michigan, Ann Arbor, MI, June 30, 1988, Table 13, p. 30.

Table 7. Distribution of Truck Travel by Gross Vehicle Weight and Area Type for Diesel Tractors.

Gross Combination Weight[1]	n (trips)	Column Percent by Area Type			Total Percent
		Rural	Small Urban	Large Urban	
Class 8 Diesel Trucks					
10K-15K	73	0.5	0.4	0.9	0.6
15K-20K	147	0.8	0.9	1.7	1.1
20K-25K	405	4.9	5.4	4.9	4.9
25K-30K	1,530	17.1	20.3	17.3	17.3
30K-35K	777	7.2	7.5	9.4	7.8
35K-40K	456	4.9	5.5	6.1	5.3
40K-45K	313	3.9	4.7	5.8	4.4
45K-50K	370	4.7	5.5	5.9	5.1
50K-55K	272	3.0	3.4	4.0	3.3
55K-60K	275	4.2	4.0	4.7	4.3
60K-65K	231	4.3	3.2	3.5	4.1
65K-70K	374	7.5	6.9	6.5	7.2
70K-75K	604	14.1	11.2	10.8	13.1
75K-80K	672	14.6	11.9	9.7	13.2
Over 80K	262	4.0	4.0	3.3	3.8
Unknown	422	4.3	5.1	5.7	4.7
Total	7,183				
Class 3-7 Diesel Tractors					
10K-20K	107	14.8	8.3	8.9	11.7
20K-35K	395	42.4	42.4	51.2	46.5
35K-50K	141	18.0	18.0	20.9	19.3
Over 50K	68	20.3	18.6	6.8	13.9
Unknown	64	4.5	12.7	12.2	8.6
Total	775				

[1]See Figure 11 and Table 1 for truck class definitions.

Source: Blower, Daniel F., and Kenneth L. Campbell. *Analysis of Heavy-Duty Truck Use in Urban Areas*, Report No. UMTRI-88-31. Transportation Research Institute, The University of Michigan, Ann Arbor, MI, June 30, 1988, Table 35, p. 58.

Table 8. Distribution of Truck Travel by Gross Vehicle Weight and Area Type for Diesel Straight Trucks.

Gross Combination Weight[1]	n (trips)	Column Percent by Area Type			
		Rural	Small Urban	Large Urban	Total Percent
Class 8 Diesel Straight Trucks					
10K-20K	245	12.4	11.3	10.0	11.3
20K-30K	711	32.8	35.1	32.7	33.0
30K-40K	279	11.0	5.8	13.8	11.7
40K-50K	234	12.4	17.3	12.5	12.9
50K-60K	173	8.5	13.6	10.6	9.9
60K-70K	102	6.6	7.4	6.4	6.6
70K-80K	107	8.8	5.0	3.8	6.3
Over 80K	40	3.0	1.0	0.9	1.9
Unknown	118	4.5	3.5	9.4	6.5
Total	2,009				
Class 3-7 Diesel Straight Trucks					
10K-15K	268	28.3	26.9	25.9	26.9
15K-20K	302	25.6	33.6	34.4	30.9
20K-25K	165	12.0	8.8	14.0	12.9
25K-30K	103	9.7	5.6	9.5	9.3
Over 30K	88	10.5	15.2	5.3	7.9
Unknown	123	13.9	9.9	10.9	12.0
Total	1,049				

[1]See Figure 11 and Table 1 for truck class definitions.

Source: Blower, Daniel F., and Kenneth L. Campbell. *Analysis of Heavy-Duty Truck Use in Urban Areas*, Report No. UMTRI-88-31. Transportation Research Institute, The University of Michigan, Ann Arbor, MI, June 30, 1988, Table 36, p. 59.

Table 9. Distribution of Truck Travel by Gross Vehicle Weight and Road Type for Diesel Tractors, Large Urban Areas Only.

Gross Combination Weight[1]	n (trips)	Column Percent by Road Type			Total Percent
		Limited Access	Major Artery	Other	
Class 8 Diesel Tractors					
10K-15K	73	0.5	1.5	1.8	0.9
15K-20K	147	1.8	0.9	1.8	1.7
20K-25K	405	4.7	5.7	5.3	4.9
25K-30K	1,530	16.0	21.2	19.2	17.3
30K-35K	777	8.4	11.1	12.1	9.4
35K-40K	456	5.7	5.8	8.4	6.1
40K-45K	313	5.7	5.0	7.6	5.8
45K-50K	370	5.9	5.7	6.1	5.9
50K-55K	272	3.9	4.2	4.0	4.0
55K-60K	275	5.5	3.3	2.6	4.7
60K-65K	231	4.0	2.4	2.9	3.5
65K-70K	374	7.7	4.8	2.3	6.5
70K-75K	604	12.2	9.1	5.4	10.8
75K-80K	672	10.6	8.3	6.5	9.7
Over 80K	262	3.0	3.6	4.4	3.3
Unknown	422	4.5	7.4	9.5	5.7
Total	7,183				
Class 3-7 Diesel Tractors					
10K-20K	107	12.6	10.0	4.5	8.9
20K-35K	395	41.7	53.4	59.8	51.2
35K-50K	141	25.9	19.2	16.6	20.9
Over 50K	68	11.7	7.0	1.6	6.8
Unknown	64	8.1	10.4	17.5	12.2
Total	775				

[1]See Figure 11 and Table 1 for truck class definitions.

Source: Blower, Daniel F., and Kenneth L. Campbell. *Analysis of Heavy-Duty Truck Use in Urban Areas*, Report No. UMTRI-88-31. Transportation Research Institute, The University of Michigan, Ann Arbor, MI, June 30, 1988, Table 43, p. 66.

Table 10. Distribution of Truck Travel by Gross Vehicle Weight and Road Type for Diesel Straight Trucks, Large Urban Areas Only.

Gross Combination Weight[1]	n (trips)	Column Percent by Road Type			
		Limited Access	Major Artery	Other	Total Percent
Class 8 Diesel Straight Trucks					
10K-20K	245	10.2	11.8	8.4	10.0
20K-30K	711	35.6	33.3	29.5	32.7
30K-40K	279	11.0	15.2	15.3	13.8
40K-50K	234	10.0	12.8	14.5	12.5
50K-60K	173	7.0	11.2	13.4	10.6
60K-70K	102	9.6	4.8	4.7	6.4
70K-80K	107	6.7	2.3	2.3	3.8
Over 80K	40	0.6	1.4	0.6	0.9
Unknown	118	9.3	7.1	11.3	9.4
Total	2,009				
Class 3-7 Diesel Straight Trucks					
10K-15K	268	32.9	26.5	18.4	25.9
15K-20K	302	29.8	30.7	41.9	34.4
20K-25K	165	9.8	19.6	14.0	14.0
25K-30K	103	8.3	10.9	9.6	9.5
Over 30K	88	9.3	2.2	3.6	5.2
Unknown	123	9.9	10.2	12.5	10.9
Total	1,049				

[1]See Figure 11 and Table 1 for truck class definitions.

Source: Blower, Daniel F., and Kenneth L. Campbell. *Analysis of Heavy-Duty Truck Use in Urban Areas*, Report No. UMTRI-88-31. Transportation Research Institute, The University of Michigan, Ann Arbor, MI, June 30, 1988, Table 44, p. 67.

Table 11. Large Trucks[1] as a Percentage of Total Vehicles (One Direction).

	Los Angeles	San Francisco	San Diego	Houston
Morning Peak (7-9 a.m.)				
Weighted Average[2]	3.8	4.2	1.8	2.8
Observed Range	0.5-17.2	0.8-13.2	0.7-5.7	2.2-3.2
Midday Offpeak (11 a.m.-1 p.m.)				
Weighted Average[2]	5.5	5.4	2.5	9.4
Observed Range	0.7-16.2	0.6-12.1	0.6-4.8	7.1-11.0
Afternoon Peak (4-6 p.m.)				
Weighted Average[2]	2.6	2.4	0.8	5.3
Observed Range	0.2-13.2	0.3-6.8	0.1-1.9	1.9-12.4

[1]Large trucks are defined as having three or more axles and a gross vehicle weight of 26,000 pounds or more.

[2]Weighted by volume, all sites.

Sources: *Urban Freeway Gridlock Study: Summary Report.* Prepared for California Department of Transportation. Cambridge Systematics, Inc., Cambridge, Massachusetts, 1988. McCasland, William R., and Robert W. Stokes. *Truck Operations and Regulations on Urban Freeways*, Research Report 338-1F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1984.

2. Truck traffic does not coincide with the commuter peak period, it peaks either "mid-morning" or "mid-afternoon" (11).

   - In 14 sections of the Houston freeway system studied in 1983, the peak hour of truck traffic did not coincide with the traditional commuter peak period.

   - Truck traffic peaks tend to be observed in the mid-morning (9-11 a.m. and mid-afternoon between 12 p.m. and 3 p.m.).

   - It is suggested the nature of truck operations is such that truck travel demands are greatest during off-peak periods.

   - The percentage of large trucks using California urban freeways increase from 5 to 10 percent in the morning to a high of 15 percent during the mid-day and then declines to 5 percent in the evening peak (Figure 18) (4).

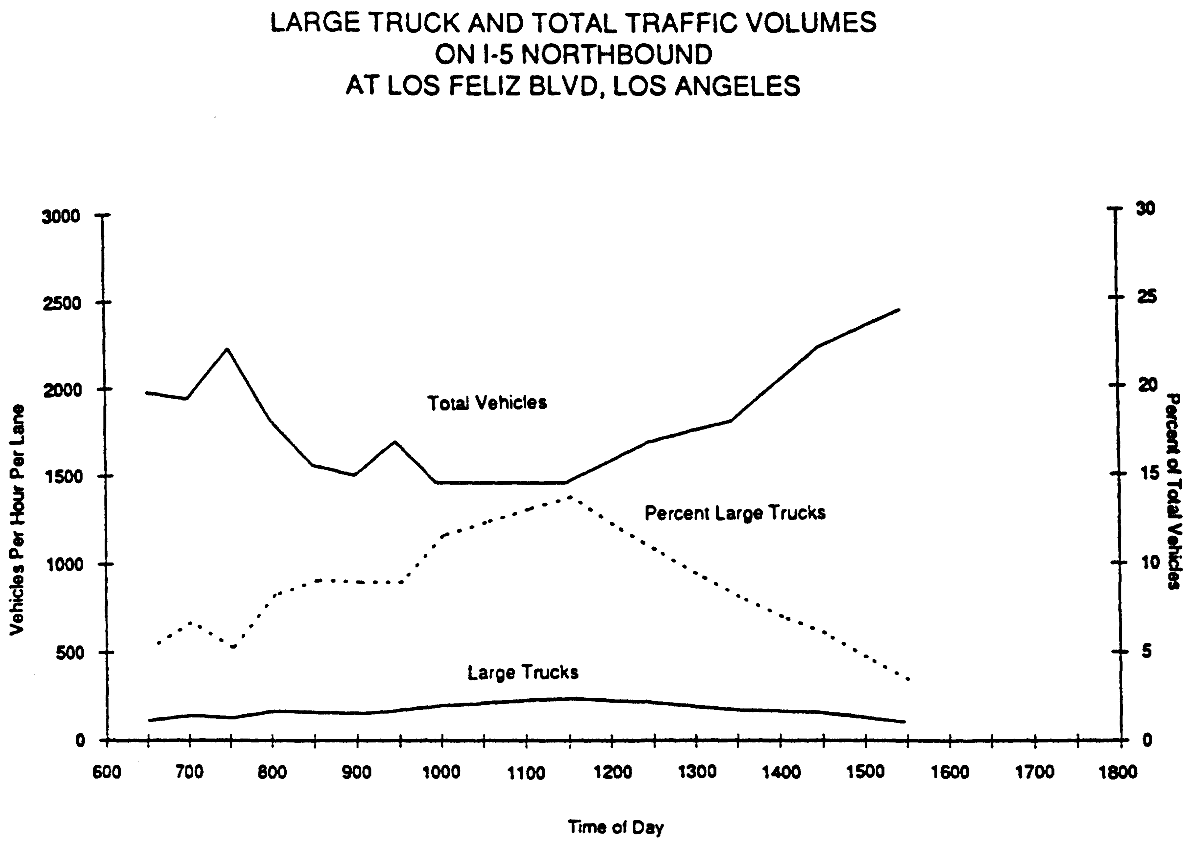
3. Heavy trucks are a major component of truck traffic on freeways.

   - In Texas, as much as 6 percent of all freeway traffic is comprised of heavy trucks (Figure 19) (11).

   - In Los Angeles, heavy trucks represent 80-90 percent of all truck-miles on freeways (4).

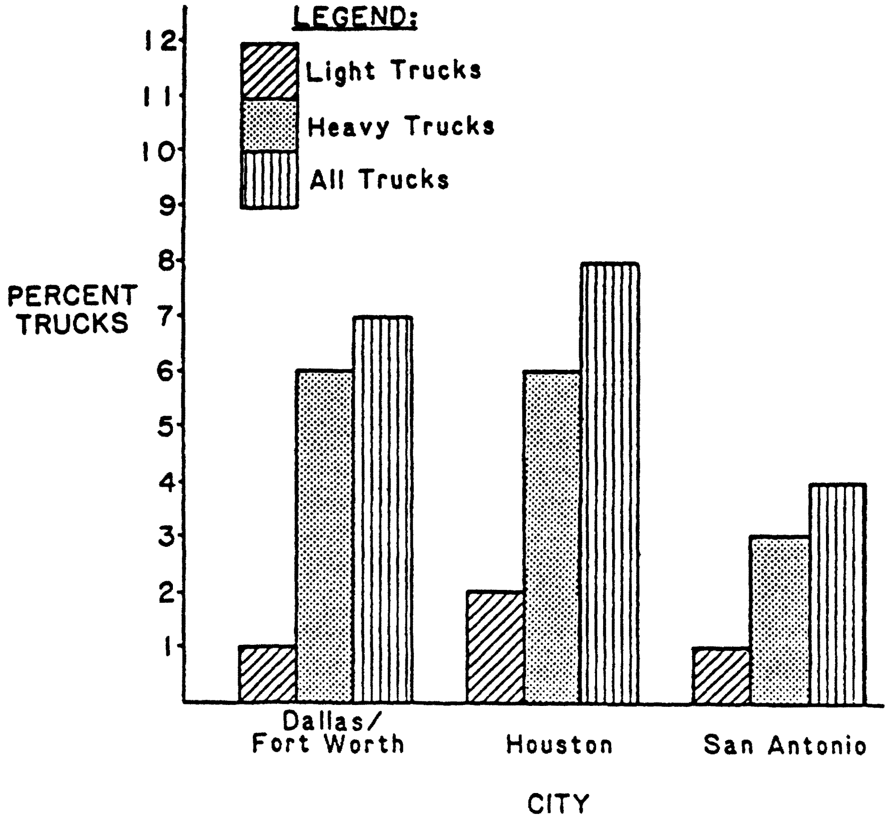
   - On the California freeways for three urban areas during the peak period, 65 percent of large trucks were tractors hauling a single trailer, 20 percent were tractors hauling double trailers, 12 percent were single unit straight trucks, and 3 percent were other configurations.

   - By body type, 55 percent of large trucks were vans, 25 percent were refrigerated vans, 10 percent were flat beds, and 10 percent were tankers and construction equipment.



Source: *Urban Freeway Gridlock Study: Summary Report*. Prepared for California Department of Transportation. Cambridge Systematics, Inc., Cambridge, Massachusetts, 1988, Figure 1, not paginated.

Figure 18. Large Trucks as Percentage of Total Vehicles by Time of Day, I-5, Los Angeles.



Source: McCasland, William R., and Robert W. Stokes. *Truck Operations and Regulations on Urban Freeways*, Research Report 338-1F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1984, Figure 2, p. 7.

Figure 19. Trucks as a Percentage of Total Traffic, Texas Cities.

III. URBAN TRUCK TRAVEL RELATIONSHIPS

A. Introduction

1. In Section III information is provided on the definition of the truck fleet by weight and type of vehicles as surveyed in a number of urban origins-destination studies. Also considered are the number of fleet vehicles in an urban area, such as postal vehicles and municipal vehicles. In urban areas, the definition of trucks is complicated by the fact that many trucks are used for personal transportation, are not involved in commercial purpose, or on any given day may not be used within a given urban area.

2. Section III presents typical areawide commercial vehicle utilization characteristics such as average daily trips per truck, truck travel as a percentage of total travel, truck trip lengths, distribution of trips/day per truck by size, land use at the trip, and the characteristics of trucks crossing an urban cordon line.

B. Characteristics of the Urban Truck Fleet

1. In a 1988 study in Maricopa County (Phoenix), Arizona, commercial vehicles identified in vehicle registration files were distributed as follows (12):

Vehicle Weight (lbs)	Percentage of Total Commercial Vehicles
0-8,000	82
8,000-28,000	13
28,000-64,000	3
64,000+	2

2. Table 12 presents a classification of commercial vehicles by weight based on vehicle registration files for the six-county Chicago area (13). The totals include local cartage companies as United Parcel Service and Waste Management and international registration programs such as Yellow Freight.

3. The definition of the vehicle population in an urban area must consider vehicles operating in the local area, not just registered in the area. For example, in the Ottawa/Hull area in Canada, the total commercial vehicles active in the National Capital Region (NCR) were 24,028 registered in NCR and 5,800 externally registered but active in the NCR (14). So 20 percent of the vehicles active in the NCR were not locally registered.

4. Postal service (USPS) vehicles or government fleet vehicles may not be included in registration files. USPS vehicles tend to weight less than 8,000 lbs. However, in both the six-county Chicago area and Maricopa County, Arizona, the USPS operates over 1 percent of the total commercial vehicles in the region (Table 13) (12,15).

Table 12. Commercial Vehicle Registrations in Northeastern Illinois.

Vehicle Class	Gross Vehicle Weight (lbs.)	Number Vehicles Registered	Percent of Total Commercial Vehicles
B Truck	0-8,000	237,400	67
Light	8,000-28,000	47,882	13
Medium	28,000-64,000	21,000	6
Heavy	64,000-80,000	48,501	14
Total		355,583	

Source: Vehicle registration data from Reilly, John P., and Jeffery J. Hochmuth. "Effects of Truck Restrictions on Regional Transportation Demand Estimates." *Transportation Research Record*, No. 1256, 1990, Table 1, p. 39.

Table 13. Commercial Vehicles by Weight in Chicago and Maricopa County, Arizona.

Vehicle Weight (lbs.)	Chicago Area		Maricopa County	
	Commercial Vehicles Registered[1]	USPS Vehicles	Commercial Vehicles Registered	USPS Vehicles
0-8,000	237,400	3,200	127,427	2,180
8,000-28,000	47,882	300	19,440	101
28,000-64,000	21,800	0	4,830	0
64,000+	48,501	300	4,948	0
Total	355,503	3,800	156,645	2,281

[1]Excludes municipal and local government fleet vehicles, federal and military vehicles, and other trucks and vehicles not registered in six-county area.

Sources: Rawlings, F. Gerald, and John P. Reilly. "CATS Commercial Vehicle Survey of 1986: A Discussion of Project Management Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 5-27; Ruiter, Earl R. "Phoenix Commercial Vehicle Survey and Travel Models." Paper prepared for 1992 annual meeting of the Transportation Research Board. Cambridge Systematics, Cambridge, MA, July 25, 1991.

5. In southeastern Wisconsin, municipal trucks represent 7.9 percent of all commercial trucks (16).

6. In the seven-county metropolitan area of the twin cities of Minneapolis and St. Paul, tax-exempt trucks comprised 6.55 percent of all heavy (>15,000 lbs.) trucks. Heavy trucks represented 44 percent of the local city and county truck fleets (17).

7. Commercial vehicles include of different weights and types. In Maricopa County, Arizona, pickup trucks represented over half of all commercial vehicles followed by single trucks, autos and vans, and panel trucks (Table 14) (12).

C. What is the Appropriate Definition of a Truck Used for Urban Goods Movement?

1. Trucks are increasing as a percentage of vehicles, but light trucks are increasingly used for personal transportation.

2. Only 40-50 percent of all trucks registered in an urban area are used for commercial purposes (Table 15).

3. In Vancouver, a survey of how trucks were employed revealed that 68.9 percent of light trucks (defined as gross vehicle weight of 9,900-44,000 lbs. or 4,500-20,000 kg) were active on a given day, 16.5 were out of service for repairs, 8.6 percent were assigned out of the region, and 5.1 percent were out of service for other reasons (18). The comparable percentages for heavy trucks (over 44,000 lbs.) were 64.6 percent active, 15.6 percent out of service for repairs, 18.5 percent out of the region, and 13.1 percent out of service for other reasons. As fleet size increased from single-truck fleets to fleets of 2-30 vehicles to fleets of 30+ vehicles, the percentage of active vehicles decreased from 73.9 percent to 71.2 percent, to 60.1 percent, respectively. As fleets became larger there were more heavier trucks, which tended to be sent out of town more and resulting in a lower usage in the region (Table 16).

4. Light vehicles such as vans and pickup trucks are most commonly used for personal transportation (Table 17).

5. The commercial vehicle fleet has been changing in composition with increases in medium trucks. In Southeastern Wisconsin the number of medium size trucks (gross weight greater than 10,000 pounds for farm trucks and greater than 8,000 pounds for all other trucks, but less than 50,000 pounds) showed consistent growth from 1963 to 1991 (Table 18) (16).

D. Areawide Commercial Vehicle Utilization and Trip Rate Characteristics

1. Table 19 shows overall daily trip rates for various urban areas.

Table 14. Commercial Vehicles by Type, Maricopa County, Arizona.

Vehicle Type	Vehicle Weight (lbs.) 0-8,000 (%)[1]	8,000-28,000 (%)[1]	28,000-64,000 (%)[1]	>64,000 (%)[1]	Total (%)[1]
Autos and Vans	11.7	3.6	0.0	0.0	10.1
Campers	4.4	0.0	0.0	0.0	3.6
Buses	0.0	0.8	1.7	0.0	0.2
Pickups	63.8	15.0	0.4	0.0	54.3
Panels	10.3	8.0	0.0	0.0	9.5
Single Trucks	9.8	69.7	85.5	51.8	20.3
Tractor/Semitrailer	0.0	0.7	7.4	13.3	0.7
Truck/Trailer	0.0	2.2	4.9	38.5	1.3
Average Vehicle Weight (lbs.)	7,960	15,520	43,600	74,080	12,010

[1]Percentage of total vehicles by class.

Source: Ruiter, Earl R. "Phoenix Commercial Vehicle Survey and Travel Models." Paper prepared for 1992 annual meeting of the Transportation Research Board. Cambridge Systematics, Cambridge, MA, July 25, 1991.

Table 15. Truck Use for Commercial and Personal Purposes.

	Southeastern Wisconsin			Chicago	Ottawa/ Hull
	1963	1972	1991	1986	1990
Regular Trucks	58,500	77,250	168,100	359,383	59,600
Percent of All Vehicles	10.0	9.6	13.1	-	-
Percent Used for Personal Use	9	23	48	51[1]	-
Trucks Used in Commercial Use	53,100	59,150	87,500	182,769	24,028[2]
Trucks Percent of All Vehicles Used in Commercial Ventures	9	7.4	6.9	-	-

[1]The Chicago Area Transportation Study used the definition "working vehicles" which is the average number of vehicles operating in commercial activity on an average day. It can be assumed this represents personal use as well as commercial vehicles not used.

[2]After considering "out of scope," which are vehicles no longer in operation or personal use.

Sources: Delcan Corporation and Goss, Gilroy and Associates, Ltd. *National Capital Region Goods Movement Study, Technical Report*. TRANS — A Joint Technical Committee on Transportation Systems Planning, Ottawa, Canada; Rawlings, F. Gerald, and John P. Reilly. "CATS Commercial Vehicle Survey of 1986: A Discussion of Project Management Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 5-27; unpublished draft manuscript identified as Chapter V, Travel Habits and Patterns, from *A Regional Transportation System Plan for Southeastern Wisconsin*, SEWRPC Planning Report No. 41, June 8, 1994.

Table 16. Frequency of Trips for Vancouver, BC.

Fleet Category	Weight Category (lbs.)	Active Trucks	Number of Trips	Mean	Standard Deviation
Uncategorized		97	734	7.57	6.33
1	9,000-12,120	49	334	6.82	6.87
	12,120-44,000	92	575	6.25	5.75
	>44,000	43	340	7.91	5.79
	All	184	1,249	6.79	-
2	9,000-12,120	57	605	10.61	9.28
	12,120-44,000	177	1,796	10.15	8.76
	>44,000	147	1,027	6.99	5.45
	All	381	3,428	9.0	-
3	9,000-12,120	40	238	5.95	6.05
	12,120-44,000	105	763	7.27	6.60
	>44,000	120	698	5.82	4.75
	All	265	1,699	6.41	-
Light Trucks		520	4,311	8.29	-
Heavy Trucks		310	2,065	6.66	-
Overall		-	-	7.7	-

Source: Vancouver City Engineering Department. *Truck Study*. Greater Vancouver Regional District, Vancouver, BC, August 1990, Table 4.4, p. 24.

Table 17. Truck Use by Vehicle Weight.

Vehicle Weight (lbs.)	Maricopa Co., Arizona (1989)		Chicago (1986)		Minneapolis-St. Paul (1981)	Houston (1994) No Travel Within Study Area		Vancouver (1990)
	Used for Home-to-Work Travel (%)	Not Used for Commercial Use (%)	Working Vehicles[1] (%)	Not Making a Trip on Survey Day (%)	Commercial Trucks in Use (%)	Week Day (%)	Weekend Day (%)	No Travel Within Study Area (%)
0-8,000	48.5	22.9	46.2	17.6	-	-	-	-
8,000-28,000	14.4	13.8	41.3	6.9	-	-	-	-
28,000-64,000	1.3	4.1	43.8	4.7	-	-	-	-
>64,000	1.8	3.4	73.7	3.7	-	-	-	-
>15,000	-	-	-	-	59	-	-	-
Total	41.9	20.6	49.1	15.4	-	22	46	32

[1]Working vehicle is defined as the number of vehicles operating in commercial activity on a given day — excludes vehicles not making any trips.

Sources: Freir, Morris. "Twin Cities Metropolitan Area Heavy Truck Study." *Transportation Research Record 920*. Transportation Research Board, National Research Council, Washington, D.C., 1983, pp. 39-45; Reilly, John P., and Jeffery J. Hochmuth. "Effects of Truck Restrictions on Regional Transportation Demand Estimates." *Transportation Research Record*, No. 1256, 1990, pp. 38-48; Ruiter, Earl R. "Phoenix Commercial Vehicle Survey and Travel Models." Paper prepared for 1992 annual meeting of the Transportation Research Board. Cambridge Systematics, Cambridge, MA, July 25, 1991; Vancouver City Engineering Department. *Truck Study*. Greater Vancouver Regional District, Vancouver, BC, August 1990; Wilbur Smith Associates, Sylva Engineering Corp., and Epsilon Engineering, Inc. *Commercial Vehicle Survey*. Prepared for Houston-Galveston Area Council. Wilbur Smith Associates, Houston, TX, July 5, 1995.

Table 18. Distribution of Commercial Use Truck Availability and Average Weekday Internal Truck Trips by Truck Type.

		Trucks			Truck Trips			
Type of Truck[1]	Year	Number	Percent of Total	Percent Change	Number	Percent of Total	Percent Change	Average Trips per Truck
Light	1963	33,800	57.8	-	169,500	57.8	-	5.0
	1972	51,000	60.0	50.9	185,800	50.1	9.6	3.6
	1991	49,100	56.1	-3.7	214,300	41.1	15.3	4.4
Medium	1963	20,500	35.0	-	110,900	37.8	-	5.4
	1972	22,850	29.6	11.5	173,500	46.8	56.4	7.6
	1991	28,400	32.5	24.3	259,700	49.8	49.7	9.1
Heavy	1963	4,200	7.2	-	13,000	4.4	-	3.1
	1972	3,400	4.4	-19.0	11,700	3.1	-10.0	3.4
	1991	3,100	3.5	-8.8	17,500	3.6	49.6	5.6
Municipal	1991	6,900	7.9	-	28,600	5.5	-	4.1
Total	1963	58,500	100.0	-	293,400	100.0	-	5.0
	1972	77,250	100.0	32.1	371,000	100.0	26.4	4.8
	1991	87,500	100.0	13.3	520,100	100.0	40.2	5.9

[1]A light truck is defined as one having a gross weight of 10,000 pounds or less for farm trucks and 8,000 pounds or less for all other trucks. A medium truck is defined as having a gross weight greater than 10,000 pounds but no more than 50,000 pounds for farm trucks and greater than 8,000 pounds but no more; 50,000 pounds for all other trucks. A heavy truck is defined as one having a gross weight of more than 50,000 pounds. Municipal trucks have no weight classification.

Source: Unpublished draft manuscript identified as Chapter V, Travel Habits and Patterns, from *A Regional Transportation System Plan for Southeastern Wisconsin*, SEWRPC Planning Report No. 41, June 8, 1994.

Table 19. Overall Trip Rates for Various Urban Areas.

Urban Area	Number of Commercial Vehicles	Commercial Vehicle Trips	Percent of Total Travel	Average Daily Trips per Truck
Amarillo, TX (1990)				5.22
Brownsville, TX (1991)				8.33
Chicago, IL (1986)	182,769[1]	11,135,914 14,800,000[3]	9.4 12.5	7.1[2]
Minneapolis-St. Paul, MN (1981)	25,394[4]			4.02 6.77[5]
Ottawa/Hull, Ont./Que. (1989)	24,028	153,100	11	8.7 12.0 Int. 3.5 Ext.
Phoenix, AZ (1991)				7.7
San Antonio, TX (1990)				8.32
Toronto, Ont. (1987)				9.7
Vancouver, BC (1990)			3.0	7.7
Southeast Wisconsin (1991)	87,500	520,100	11.3	5.9

[1]Referred to as working vehicles only.
[2]Weighted average calculated from data.
[3]Total equivalent vehicle-miles of travel in a 24-hour period.
[4]Includes only heavy vehicles >15,000 lbs. gross vehicle weight.
[5]Includes only trucks that traveled on a given day.

Sources: Delcan Corporation and Goss, Gilroy and Associates, Ltd. *National Capital Region Goods Movement Study, Technical Report*. TRANS — A Joint Technical Committee on Transportation Systems Planning, Ottawa, Canada; Freir, Morris. "Twin Cities Metropolitan Area Heavy Truck Study." *Transportation Research Record*, No. 920, 1983, pp. 39-45; *Metropolitan Toronto Goods Movement Study*. Metropolitan Toronto Roads and Traffic Department, Municipality of Metropolitan Toronto, Toronto, Ont., December 1987; Rawlings, F. Gerald, and John P. Reilly. "CATS Commercial Vehicle Survey of 1986: A Discussion of Project Management Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 5-27; Reeder, Phillip R., and Lisa G. Nungesser. "A Review of a Comprehensive Commercial Truck Survey." Paper presented at the Fourth National Conference on Transportation Solutions for Small and Medium-Sized Areas. Parsons Brinckerhoff Quade & Douglas, Inc., Austin, TX, n.d.; John P. Reilly, Arnold Rosenbluh, and F. Gerald Rawlings. "Factoring and Analysis of the Commercial Vehicle Survey Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 29-46; Ruiter, Earl R. "Phoenix Commercial Vehicle Survey and Travel Models." Paper prepared for 1992 annual meeting of the Transportation Research Board. Cambridge Systematics, Cambridge, MA, July 25, 1991; Vancouver City Engineering Department. *Truck Study*. Greater Vancouver Regional District, Vancouver, BC, August 1990.

2. Table 20 shows commercial vehicle utilization by type of truck. Average trips per truck generally increase with vehicle weight, except for heavy trucks.

3. Government vehicles have lower trip rates than private vehicles, as seen below in an example from the seven-county Minneapolis-St. Paul metropolitan area (17):

	Trip Rate/Day
City	4.43
County	2.89
Overall Average All Trucks	6.77

Only heavy vehicles greater than 15,000 pounds that traveled on a given day were included in the study.

4. In Vancouver, vehicles in the municipal fleet averages 8.1 trips per day compared to 7.7 trips per day for all truck fleets in the study area (18).

5. In Toronto it was determined that the trip rate per business establishment is evenly distributed across super zones, but the trip rate in the CBD is twice the trip rate of the urban area and six times the trip rate of suburban areas (Table 21) (19).

6. The average trip rates per day in the Toronto area by firm type are shown below (18).

SIC Classification	Trip Rate/Day
Wholesale Industry	11
Retail Industry	16
Food and Beverage Industry	33
Light Industry	18
Chemical Industry	10
Heavy Industry	15
Average	15

The food and beverage industry is the highest generator of trips.

7. Truck trip rates.

   - Truck trip rates in the Ottawa/Hull area in Canada are shown below (14):

Table 20. Commercial Vehicle Utilization (Average Trips per Truck per Day) by Type of Truck.

Urban Area	Truck Class	Class Definition	Average Trips per Truck
Chicago, IL (1986)	B Truck	0-8,000 lbs.	6.9
	Light	8,000-28,000 lbs.	7.9
	Medium	28,000-64,000 lbs.	9.3
	Heavy	>64,000 lbs.	5.9
Phoenix, AZ (1988)		0-8,000 lbs.	7.2
		8,000-28,000 lbs.	12.1
		28,000-64,000 lbs.	8.0
		>64,000 lbs.	4.7
Ottawa/Hull, Ont./Que. (1987)			
Internal Only, Ontario	Light	≤2,000 kg	11.8
	Medium	2,000-7,000 kg	12.6
	Heavy	>7,000 kg	10.1
	Total		12.1
Internal Only, Quebec	F	Commercial, ≤3,000 kg	3.5
	L	General merchandise trans., >3,000 kg	8.1
	VR	Bulk transport, >3,000 kg	12.9
	Total		10.6
Internal/External Ontario	Light	≤2,000 kg	9.7
	Medium	2,000-7,000 kg	10.3
	Heavy	>7,000 kg	5.4
	Total		9.1
Internal/External, Quebec	F	Commercial, ≤3,000 kg	4.2
	L	General merchandise trans., >3,000 kg	7.4
	VR	Bulk transport, >3,000 kg	6.0
	Total		5.9
Toronto, Ont. (1987)	Light	2 axles, 4 tires	11.6
	Medium	2 axles, more than 4 tires	11.1
	Heavy	3 or more axles	7.2
	Total		9.7

Table 20. (continued).

Urban Area	Truck Class	Class Definition	Average Trips per Truck
Southeast Wisconsin (1991)	Light	<10,000 lbs. for farm trucks and <8,000 for other trucks	4.4
	Medium	10,000-50,000 lbs.	9.1
	Heavy	>50,000 lbs.	5.6

Sources: Delcan Corporation and Goss, Gilroy and Associates, Ltd. *National Capital Region Goods Movement Study, Technical Report*. TRANS — A Joint Technical Committee on Transportation Systems Planning, Ottawa, Canada; *Metropolitan Toronto Goods Movement Study*. Metropolitan Toronto Roads and Traffic Department, Municipality of Metropolitan Toronto, Toronto, Ont., December 1987; Rawlings, F. Gerald, and John P. Reilly. "CATS Commercial Vehicle Survey of 1986: A Discussion of Project Management Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 5-27; John P. Reilly, Arnold Rosenbluh, and F. Gerald Rawlings. "Factoring and Analysis of the Commercial Vehicle Survey Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 29-46; Ruiter, Earl R. "Phoenix Commercial Vehicle Survey and Travel Models." Paper prepared for 1992 annual meeting of the Transportation Research Board. Cambridge Systematics, Cambridge, MA, July 25, 1991; unpublished draft manuscript identified as Chapter V, Travel Habits and Patterns, from *A Regional Transportation System Plan for Southeastern Wisconsin*, SEWRPC Planning Report No. 41, June 8, 1994.

Table 21. Daily Trip Productions in the Greater Toronto Area.

Super Zone	Trips	Area (sq. km)	Trips/ sq. km	Trips/ sq. mi.	Trips/ Firm
CBD	67,450	38.40	1,757	4,550	14
Urban	146,580	190.00	771	1,997	15
Suburban	126,860	403.50	314	813	14
Metro Toronto Subtotal/Average	340,870	631.90	539	1,396	14
Outlying Areas	328,390	3,242.51	101	261	14
Total/Average	669,280	3,874.41	173	448	14

Source: *Metropolitan Toronto Goods Movement Study*. Metropolitan Toronto Roads and Traffic Department, Municipality of Metropolitan Toronto, Toronto, Ont., December 1987.

	Daily Truck Trips/Capita	Daily Truck Trips/Employee
Ontario (Ottawa)	.18	.34
Quebec (Hull)	.07	.20
National Capital Region	.16	.32

- Table 22 shows trip rates by truck type in the San Francisco Bay area (20).

E. Truck Trip Lengths

1. Some average truck trip lengths are listed below:

Urban Area	Average Miles per Truck Trip
Amarillo, TX (1990) (21)	3.6
Brownsville, TX (1990) (21)	2.7
Chicago, IL (1986) (13)	17.2
Ottawa/Hull, Ont./Que. (1991) (14)	
External Trips	44.2
Internal trips	6.5
Average All Trips	12.4
Phoenix, AZ (12)	10.2
San Antonio, TX (1990) (21)	4.5
Southeastern Wisconsin (1991) (16)	8.4

2. In southeastern Wisconsin on average trip lengths increased over time from 4.9 miles per trip in 1963 to 7.3 miles per trip in 1972, to 8.4 miles per trip in 1991 (16).

3. Vehicles in the 8,000 to 28,000 pounds range make many short trips for refuse pickup and package delivery. Vehicles in the heavy category make a few long trips and generate more vehicle-miles of travel than light vehicles.

4. Heavy trucks have the longest trip lengths in miles per trip and miles per truck (Table 23).

5. In Vancouver, heavy trucks have a longer mean trip duration of 18.5 minutes compared to a mean trip duration of 12.1 minutes for light trucks. Interzonal trips are included in these calculations as well as trips to the external zones. Thus heavy trucks make fewer trips with longer trip lengths that light vehicles (18).

6. Distribution of trip lengths and trip frequencies by truck weight vary somewhat by region.

Table 22. Trip Rates by Trip Type and Truck Type — Trips per 1,000 Employees.

	Truck Type			
Trip Type	2-Axle	3-Axle	4+ Axle	All Trucks
Garage-Based	23	2	4	29
Linked	32	4	7	43
Internal-External	4	1	7	12
All Types	60	6	19	85

Source: Schlappi, Mark L., Roger D. Marshall, and Irene T. Itamura. "Truck Travel in the San Francisco Bay Area," Paper No. 930477. Paper presented at 72nd annual meeting of the Transportation Research Record, January 10-14, 1993, Table 4, p. 14.

Table 23. Miles per Trip and Miles per Truck.

	Chicago			Phoenix	
Vehicle Weight (lbs.)	Average Miles/Trip	Median Miles/Trip	Average Miles/Truck	Average Miles/Trip	Average Miles/Truck
0-8,000	11.1	7.4	56.1	11.0	79.0
8,000-28,000	9.6	7.3	56.8	4.7	56.2
28,000-64,000	10.5	8.4	72.4	9.2	74.0
64,000+	24.9	22.4	107.7	33.4	158.8
All Trucks	-	-	-	-	78.5

Sources: Rawlings, F. Gerald, and John P. Reilly. "CATS Commercial Vehicle Survey of 1986: A Discussion of Project Management Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 5-27; John P. Reilly, Arnold Rosenbluh, and F. Gerald Rawlings. "Factoring and Analysis of the Commercial Vehicle Survey Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 29-46; Ruiter, Earl R. "Phoenix Commercial Vehicle Survey and Travel Models." Paper prepared for 1992 annual meeting of the Transportation Research Board. Cambridge Systematics, Cambridge, MA, July 25, 1991.

- In Vancouver, trucks in fleets in the range 2-30 vehicles made more trips than trucks in single vehicle fleets where the truck may only be used for special purpose trips. Large fleets involve institutions which make less intensive use of their trucks. Lighter trucks are more involved in delivery functions and thus make more trips than heavy trucks (18).

- In Chicago, the distribution of truck trips per day for large trucks shows a pronounced peak at low trip frequencies, while the distribution for medium truck trips is flatter (22).

- Table 24 shows the number of trips per day for light trucks and heavy trucks in Vancouver and Chicago.

- In Chicago, for trip lengths, heavy trucks have a flat distribution across all trip lengths, while the lighter weight truck classes are show substantial peaks at short trip lengths (Figure 20).

- Figures 21-25 show the trip distance distributions by truck weight for Maricopa County (Phoenix), Arizona.

F. Truck Utilization Trends Over Time

1. In southeastern Wisconsin commercial truck trips increased 40 percent from 1972 to 1991. The trip rates for medium and heavy trucks showed the greater increase in the use of these vehicles in 1991 versus 1972 or 1963. However, the increase was not uniform by time period (15).

2. Trucks are being used more intensely. In Southeast Wisconsin internal truck trips remained at about 11 percent of all average weekday internal trips between 1963 and 1991 while the total number of vehicle trips doubled. However, trucks as percentage of total vehicles decreased from 10 percent to 7 percent (16).

3. A Texas review of three urban transportation planning studies found the trip rate (trips per truck) increased between 1964 and 1990 for the large cities and decreased for a smaller city (population less than 200,000). However, the trip estimates in 1990 had less variance than original origin-destination studies (21). Table 25 compares trip rates in the three Texas cities and two other urban areas.

G. Time of Day Distributions

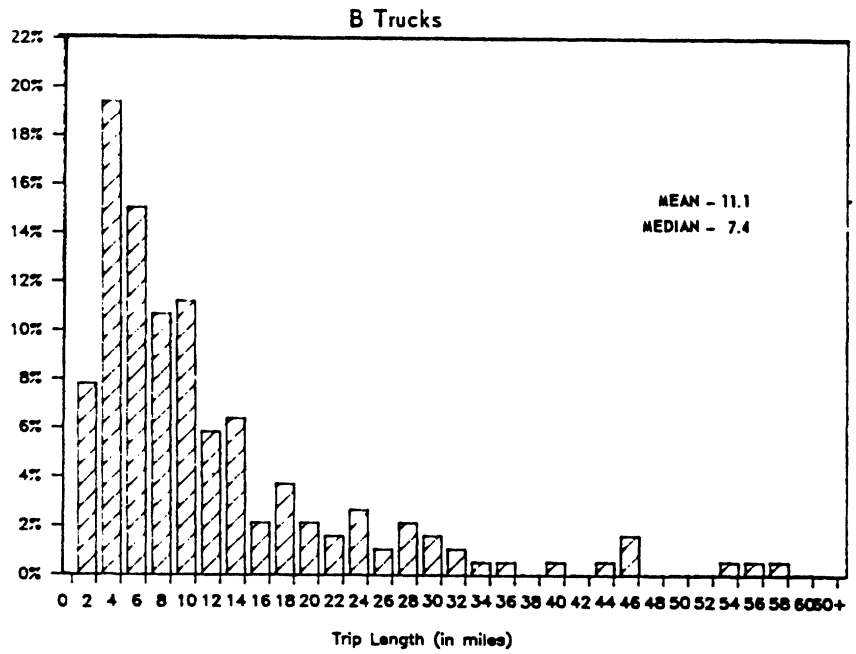
1. Most vehicles are first used between 6:00 and 9:00 a.m. on a weekday. Lighter vehicles are less likely to be used before 6:00 a.m. and after 2:00 p.m. for the first trip (Table 26) (5).

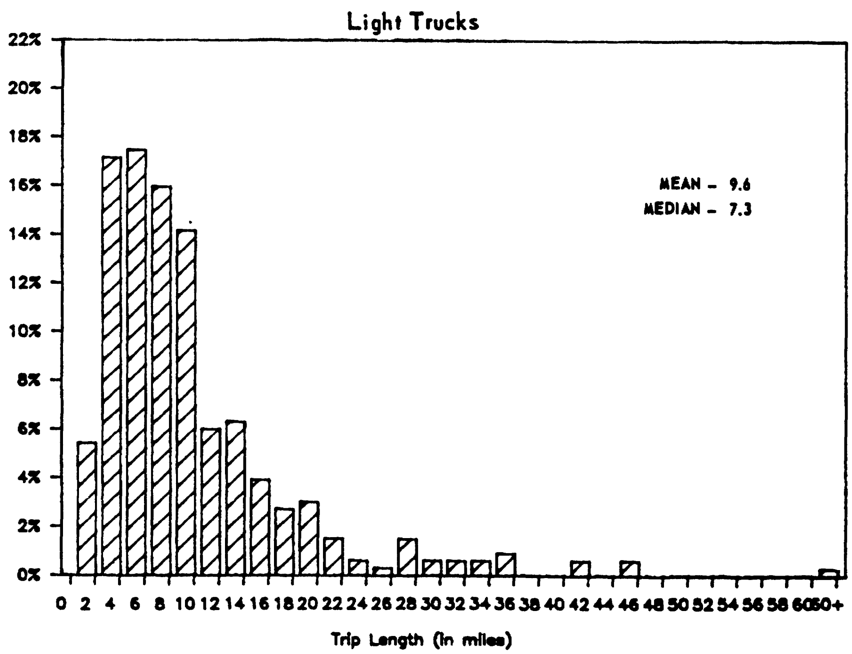
2. In Maricopa County (Phoenix), Arizona, the peak period of truck travel is 12:00 noon to 2:00 p.m., which represents 13 percent daily commercial vehicle travel

Table 24. Distribution of Number of Trips per Day.

No of Trips per Day	Vancouver, BC Light Trucks (%)	Vancouver, BC Heavy trucks (%)	Chicago, IL B Trucks (%)	Chicago, IL Light Trucks (%)	Chicago, IL Medium Trucks (%)	Chicago, IL Large Trucks (%)
1	13.2	6.1	0.3	0.3	0.5	5.0
2	11.9	9.3	20.6	17.1	5.5	26.6
3	6.6	9.3	5.8	9.6	5.5	16.8
4	6.8	12.0	13.2	8.5	12.0	14.4
5	7.2	8.8	9.1	9.0	3.2	7.0
6	6.8	12.1	6.9	10.9	9.5	4.7
7	6.1	9.1	7.2	7.0	5.2	4.8
8	6.8	5.8	5.0	5.7	7.9	4.7
9	3.7	4.9	2.9	4.2	9.2	2.7
10	3.1	7.0	3.8	4.3	8.0	3.7
11	2.2	3.6	3.6	6.2	6.0	1.8
12	1.0	2.7	2.9	3.9	6.0	0.9
13	3.0	0.7	2.3	1.3	2.5	1.9
14	2.2	1.7	2.1	2.1	2.4	1.7
15	2.2	1.7	1.7	1.3	1.7	0.9
16	2.6	2.2	1.0	1.0	3.9	0.6
17	1.6	0.7	0.9	0.3	1.8	0.9
18	1.6	0.7	1.0	0.5	2.5	0.1
19	0.8	0.2	0.0	0.0	1.0	0.2
20	2.0	0.7	4.0	1.0	1.0	0.5
20+	8.6	0.7	5.7	5.8	4.7	0.1
Mean			6.9	7.9	9.3	5.9
Median			5.0	6.0	8.5	4.8

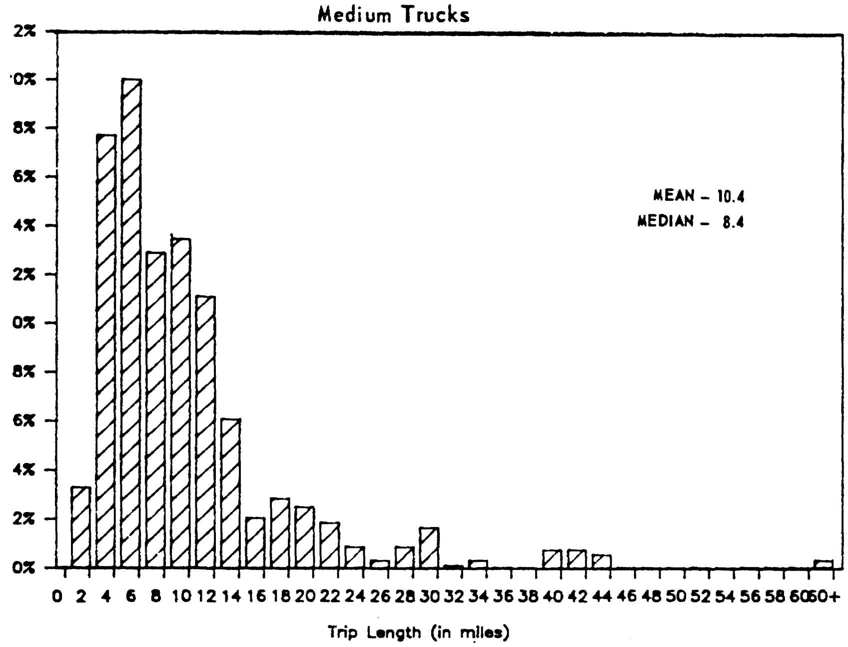
Sources: John P. Reilly, Arnold Rosenbluh, and F. Gerald Rawlings. "Factoring and Analysis of the Commercial Vehicle Survey Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987; Vancouver City Engineering Department. *Truck Study*. Greater Vancouver Regional District, Vancouver, BC, August 1990.

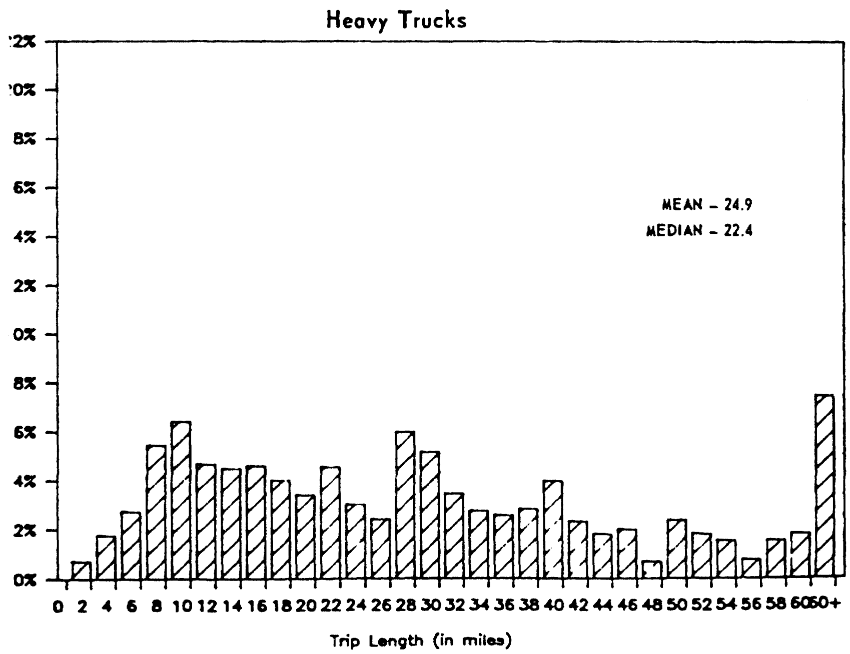




Source: John P. Reilly, Arnold Rosenbluh, and F. Gerald Rawlings. "Factoring and Analysis of the Commercial Vehicle Survey Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, Figures 6 and 7, p. 39.

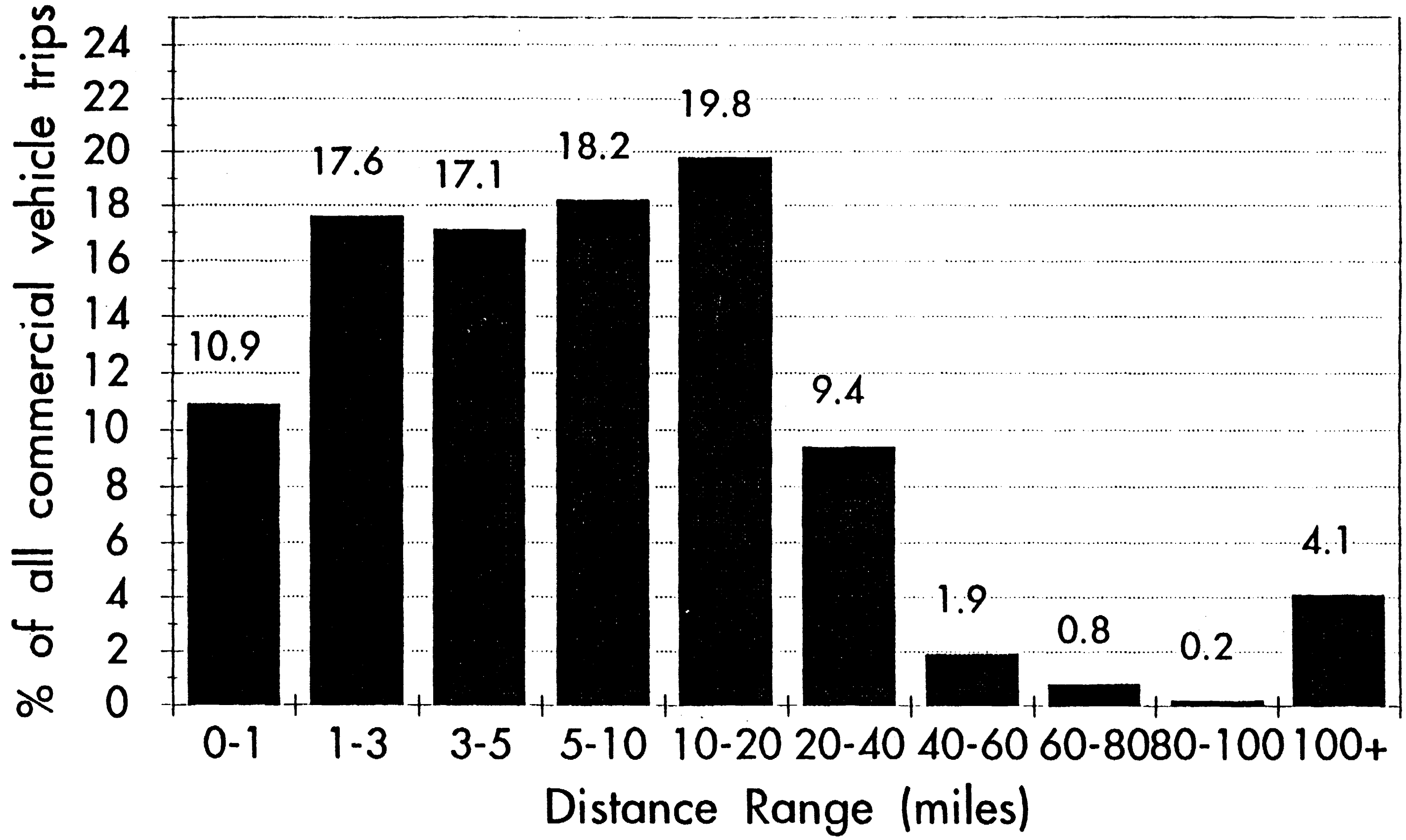
Figure 20. Truck Trip Length Distribution by Truck Class in the Chicago Region.





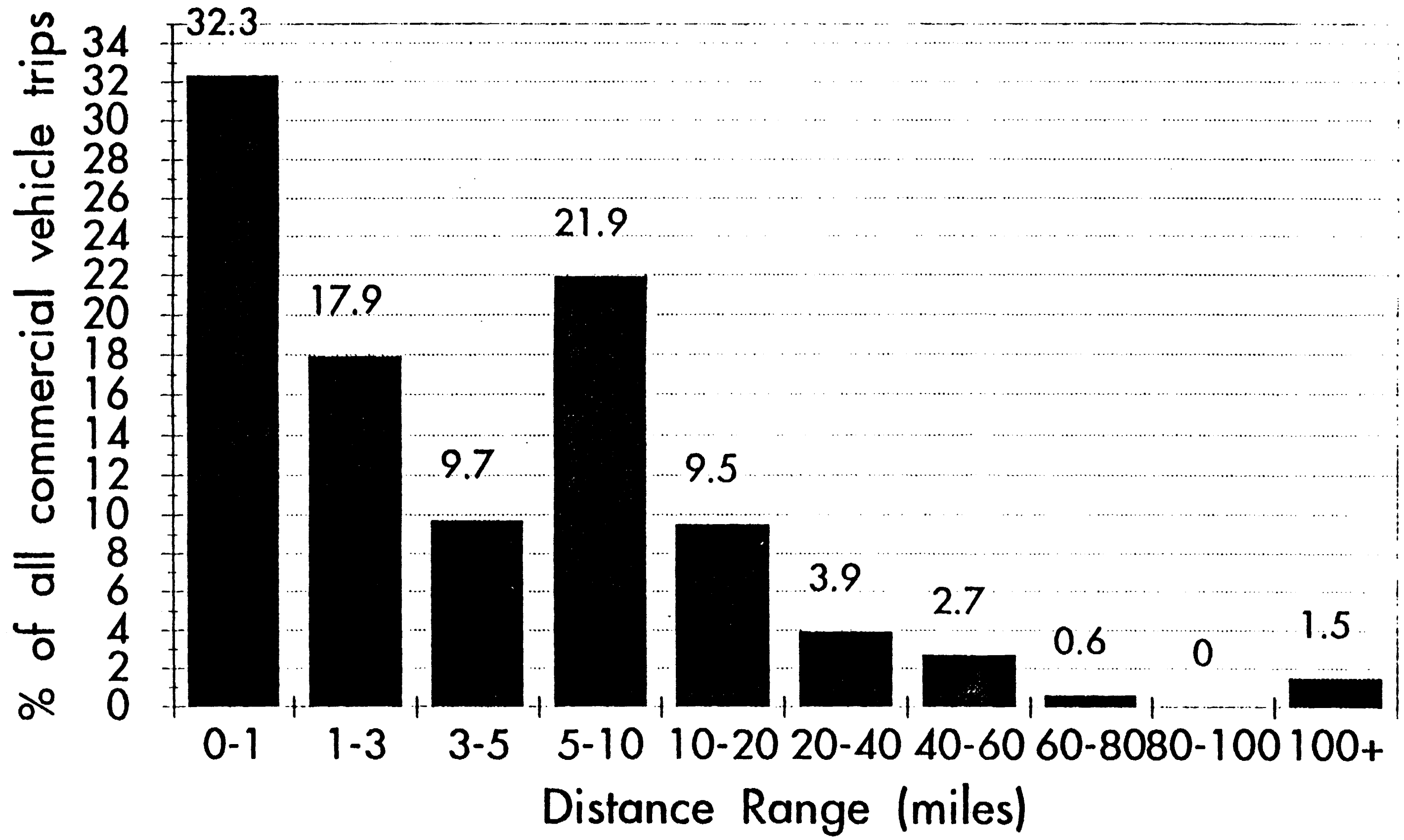
Source: John P. Reilly, Arnold Rosenbluh, and F. Gerald Rawlings. "Factoring and Analysis of the Commercial Vehicle Survey Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, Figures 8 and 9, p. 40.

Figure 20. (continued).



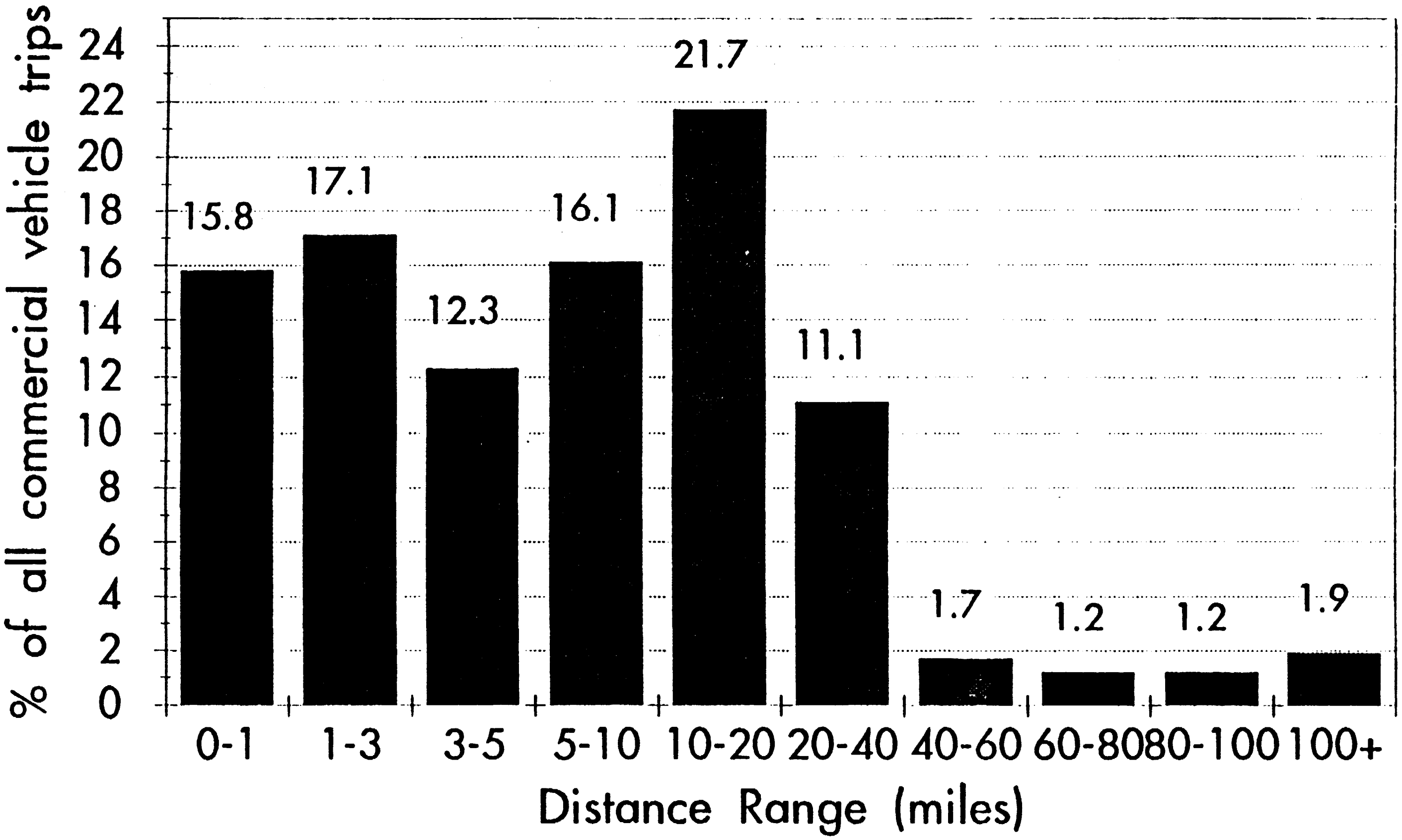
Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.16, p. 3-17.

Figure 21. Truck Trip Length Distribution for 0-8,000 Lb. Trucks in Maricopa County (Phoenix), Arizona.



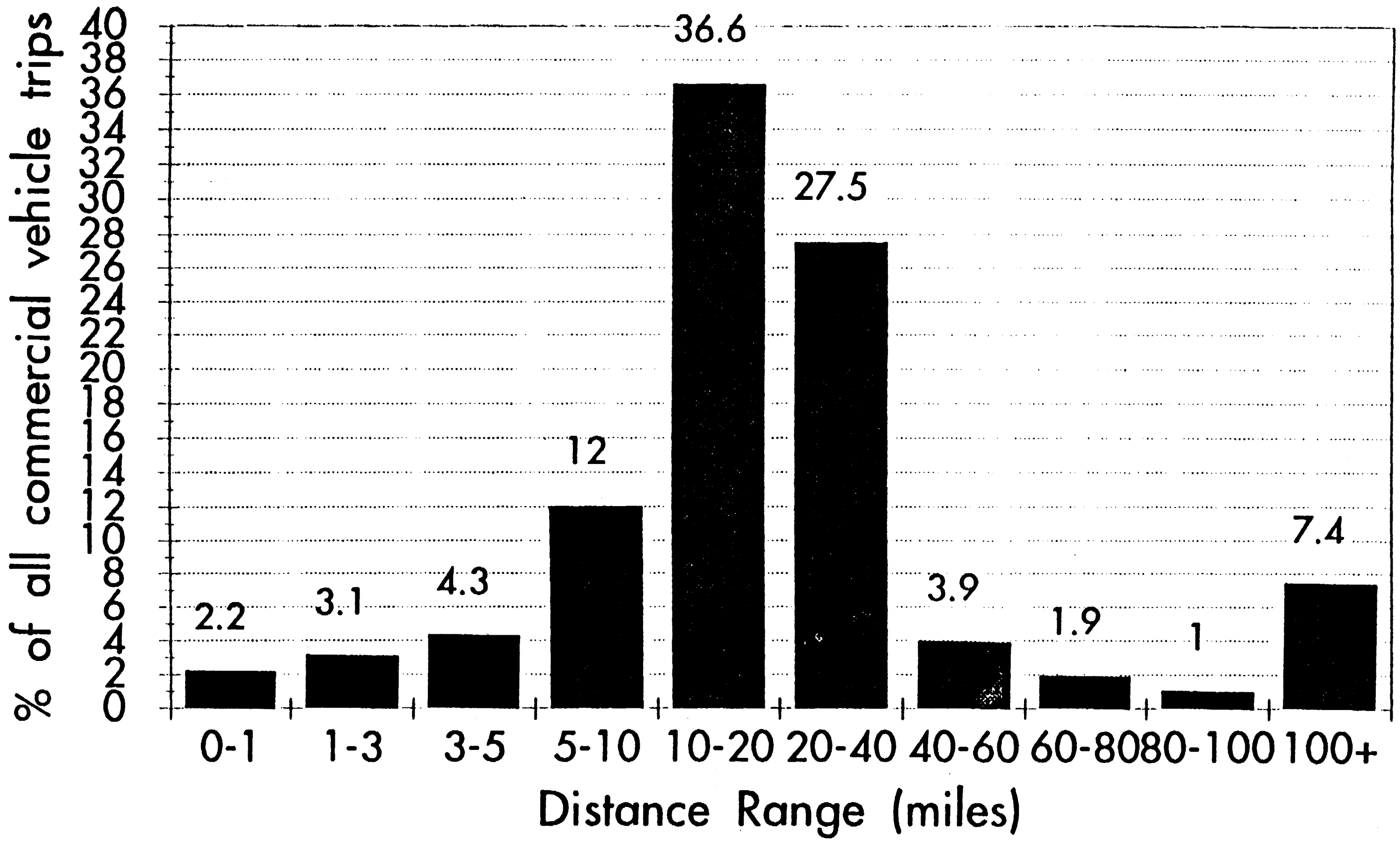
Source: Ruiter, Earl R. ***Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area***, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.16, p. 3-17.

Figure 22. Truck Trip Length Distribution for 8,000-28,000 Lb. Trucks in Maricopa County (Phoenix), Arizona.



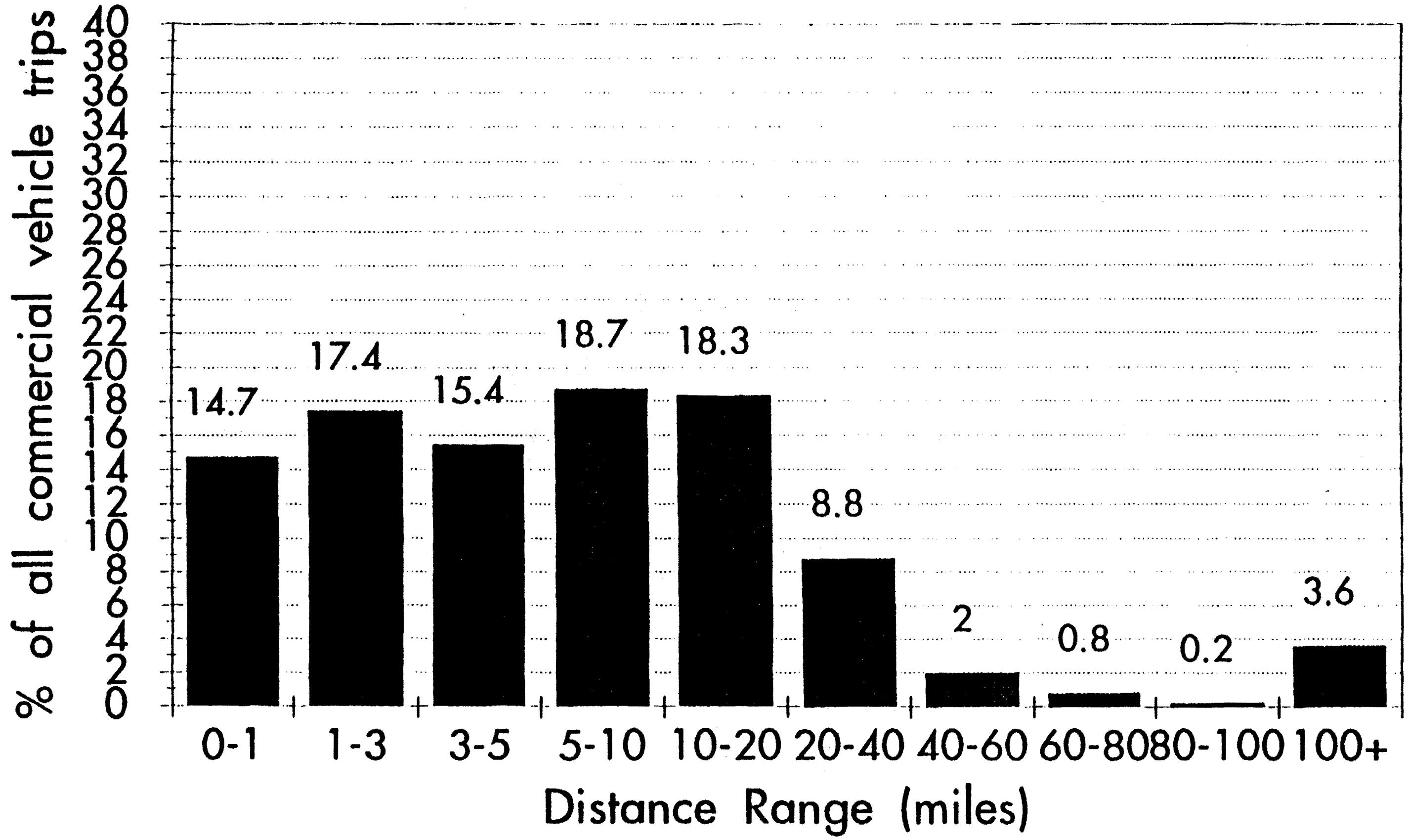
Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.16, p. 3-17.

Figure 23. Truck Trip Length Distribution for 28,000-64,000 Lb. Trucks in Maricopa County (Phoenix), Arizona.



Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.16, p. 3-17.

Figure 24. Truck Trip Length Distribution for >64,000 Lb. Trucks in Maricopa County (Phoenix), Arizona.



Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.16, p. 3-17.

Figure 25. Truck Trip Length Distribution for All Trucks in Maricopa County (Phoenix), Arizona.

Table 25. Trips per Truck.

Urban Area	Trip Rate	Standard Deviation
Amarillo, TX (1964)	7.49	10.36
Amarillo, TX (1990)	5.22	4.22
Brownsville, TX (1970)	6.93	6.92
Brownsville, TX (1991)	8.33	4.65
San Antonio, TX (1969)	7.96	11.83
San Antonio, TX (1990)	8.32	5.31
Chicago, IL (1970)	5.6	
Chicago, IL (1986)	7.1	
Southeastern Wisconsin (1963)	5.0	
Southeastern Wisconsin (1972)	4.8	
Southeastern Wisconsin (1991)	5.9	

Sources: Reeder, Phillip R., and Lisa G. Nungesser. "A Review of a Comprehensive Commercial Truck Survey." Paper presented at the Fourth National Conference on Transportation Solutions for Small and Medium-Sized Areas. Parsons Brinckerhoff Quade & Douglas, Inc., Austin, TX, n.d.; John P. Reilly, Arnold Rosenbluh, and F. Gerald Rawlings. "Factoring and Analysis of the Commercial Vehicle Survey Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 29-46; unpublished draft manuscript identified as Chapter V, Travel Habits and Patterns, from *A Regional Transportation System Plan for Southeastern Wisconsin*, SEWRPC Planning Report No. 41, June 8, 1994.

Table 26. Time of First Trip.

Time of Day	Vehicle Weight (lbs.) 0-8,000 (%)[1]	8,000-28,000 (%)[1]	28,000-64,000 (%)[1]	>64,000 (%)[1]	Total (%)[1]
Before 6:00 a.m.	12.9	17.9	30.1	51.8	15.5
6:00-9:00 a.m.	65.2	44.5	54.8	35.2	61.0
9:00 a.m.-2:00 p.m.	20.0	31.0	10.2	11.1	20.9
After 2:00 p.m.	1.9	6.6	5.0	1.9	2.7

[1]Percentage of total vehicles by class.

Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.4, p. 3-3.

(Table 27) (5). In Houston, the highest number of commercial truck trips occurs 8:00-9:00 a.m. and 9:00-10:00 a.m. with 10.1 percent of daily weekday truck trips (23). On weekends, the highest number of commercial trips also peaked at these two times. The start times of truck trips in Vancouver, BC, are shown in Table 28.

3. Figures 26-30 show the time of day distribution for vehicle trips by truck weight class in Maricopa County (Phoenix), Arizona.

4. During the peak hours, especially the afternoon peak, commercial vehicles represent a lower percentage of travel than private vehicles traveling in the same period (5).

	Percent of Daily Vehicle-Hours	
	6:00-9:00 a.m.	3:00-6:00 p.m.
Truck Travel	17%	10%
Private Vehicle Travel	18%	24%

5. Goods movements coincide with the normal business day not the peak commuter hours (Figures 31-33) (14,18,20).

6. The morning peak tends to be utilized by heavy/medium weight trucks (5).

Truck Weight	Percent of Daily Vehicle-Hours	
(lbs.)	6:00-9:00 a.m.	3:00-6:00 p.m.
0-8,000	15	11
8,000-28,000	22	7
28,000-64,000	32	3
64,000+	23	11

7. In Vancouver, BC, 9 percent of truck trips are made during the 7:30-8:30 a.m. hour. Fifteen percent of truck trips are made during the 3:00-6:00 p.m. peak period. Heavy trucks have a higher percentage of total trips during the peak hour (11.2%) than light trucks (8.0%) (18).

H. Land Use and Functions at Trip Ends

1. The most common land uses at the truck trip ends are residential, retail, manufacturing, and warehousing (Table 29).

2. Trip end land use functions vary with vehicle weight (Table 30). Lighter vehicles have more trip ends at office/service land uses. Heavy vehicles have fewer trip ends at retail land uses and more at garaging. All vehicle classes have a high percentage of trip ends at residential land uses. However, the large variation between the urban areas may depend on their specific economic bases.

Table 27. Time of Day Distribution, Maricopa County, Arizona.

	Vehicle Weight (lbs.)				
Hour Ending	0-8,000 (%)[1]	8,000-28,000 (%)[1]	28,000-64,000 (%)[1]	>64,000 (%)[1]	Total (%)[1]
1:00 a.m.	0	0	0	0	0
2:00 a.m.	0	1	1	0	0
3:00 a.m.	1	2	1	0	1
4:00 a.m.	0	0	1	0	0
5:00 a.m.	2	2	2	1	2
6:00 a.m.	5	4	5	4	5
7:00 a.m.	4	6	9	7	5
8:00 a.m.	5	7	11	9	6
9:00 a.m.	5	10	12	8	7
10:00 a.m.	8	9	10	10	9
11:00 a.m.	8	11	11	11	9
12:00 Noon	10	13	8	10	11
1:00 p.m.	14	11	8	9	13
2:00 p.m.	15	8	8	11	13
3:00 p.m.	6	7	6	9	7
4:00 p.m.	5	4	2	6	5
5:00 p.m.	3	2	1	4	3
6:00 p.m.	3	1	0	1	2
7:00 p.m.	1	1	2	0	1
8:00 p.m.	1	0	1	0	1
9:00 p.m.	1	0	1	0	1
10:00 p.m.	1	0	0	0	1
11:00 p.m.	0	0	0	0	0
12:00 Midnight	0	0	0	0	0

[1]Percentage of daily vehicle-hours occurring in the specified hour for all vehicles reporting each of their daily trips.

Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992,, Table 3.9, p. 3-9.

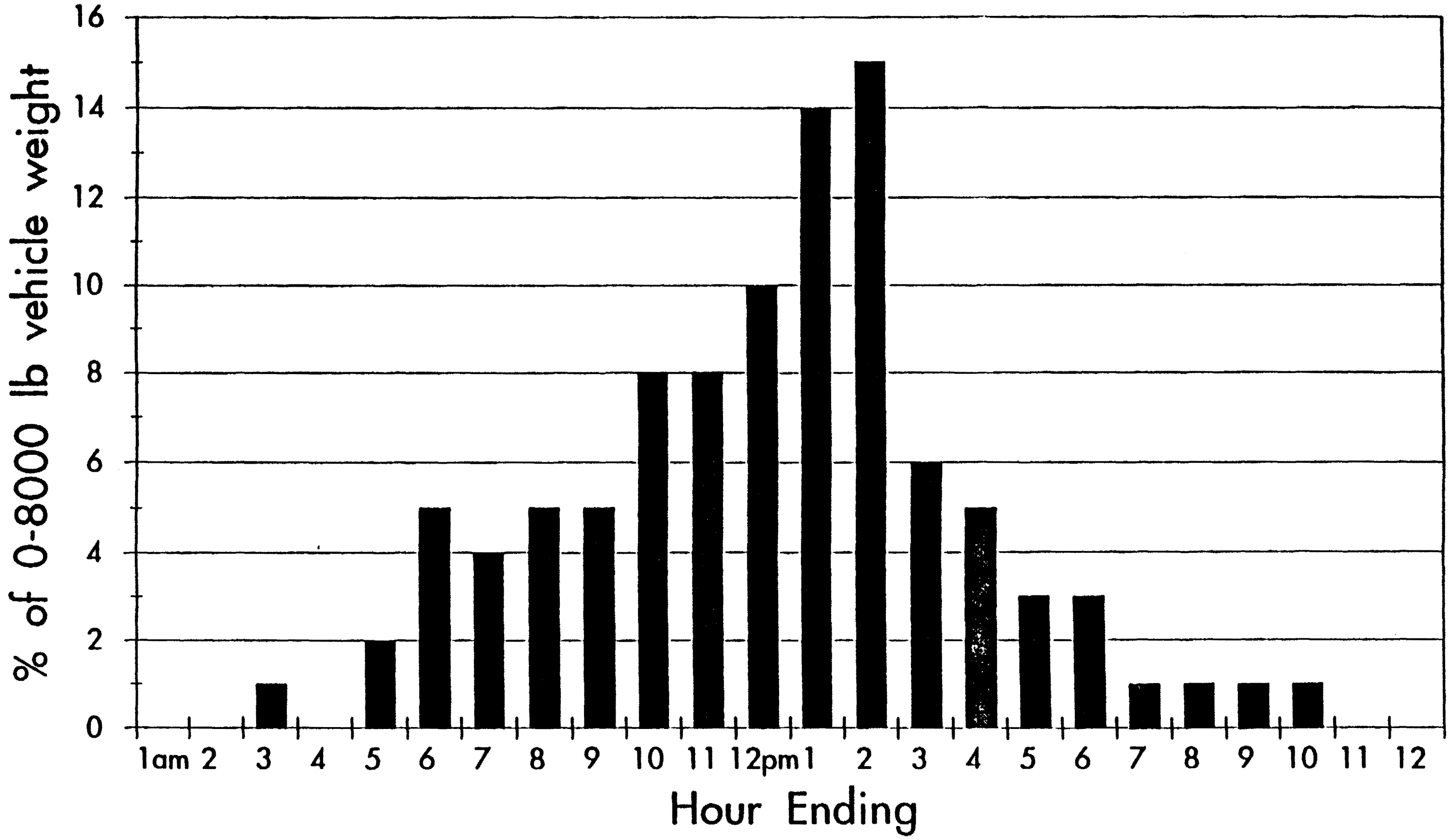
Table 28. Trip Start Times in Vancouver, BC.

Time Period	Light Trucks[1]	Heavy Trucks[2]
1:00 a.m.	0.1	0.2
2:00 a.m.	0.5	0.2
3:00 a.m.	0.7	0.4
4:00 a.m.	0.8	0.6
5:00 a.m.	0.6	0.7
6:00 a.m.	0.7	1.3
7:00 a.m.	1.2	2.5
8:00 a.m.	4.8	8.5
9:00 a.m.	9.4	9.1
10:00 a.m.	11.5	10.0
11:00 a.m.	12.6	10.2
12:00 p.m.	11.1	10.1
1:00 p.m.	10.9	9.5
2:00 p.m.	10.8	9.5
3:00 p.m.	9.6	9.5
4:00 p.m.	7.3	7.9
5:00 p.m.	3.9	4.0
6:00 p.m.	1.7	1.7
7:00 p.m.	0.5	1.2
8:00 p.m.	0.5	0.8
9:00 p.m.	0.1	0.6
10:00 p.m.	0.2	0.7
11:00 p.m.	0.2	0.5
12:00 a.m.	0.3	0.3

[1]Light trucks are vehicles with a gross vehicle weight of 9,000-44,000 lbs. (4,500-20,000 Kg).

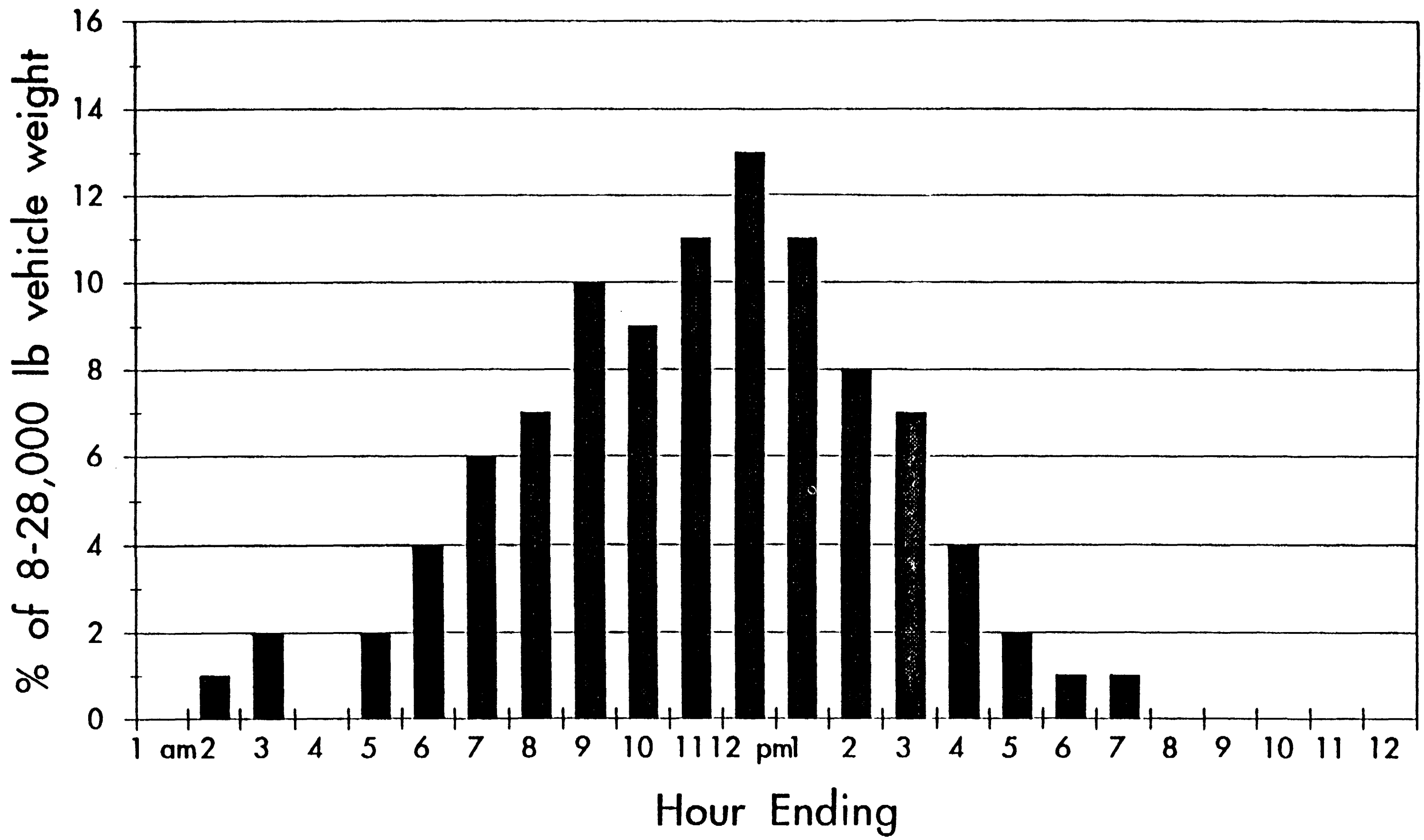
[2]Heavy trucks are vehicles with a gross vehicle weight of greater than 44,000 lbs. (20,000 Kg).

Vancouver City Engineering Department. *Truck Study*. Greater Vancouver Regional District, Vancouver, BC, August 1990, estimates based on Figures 26 and 27.



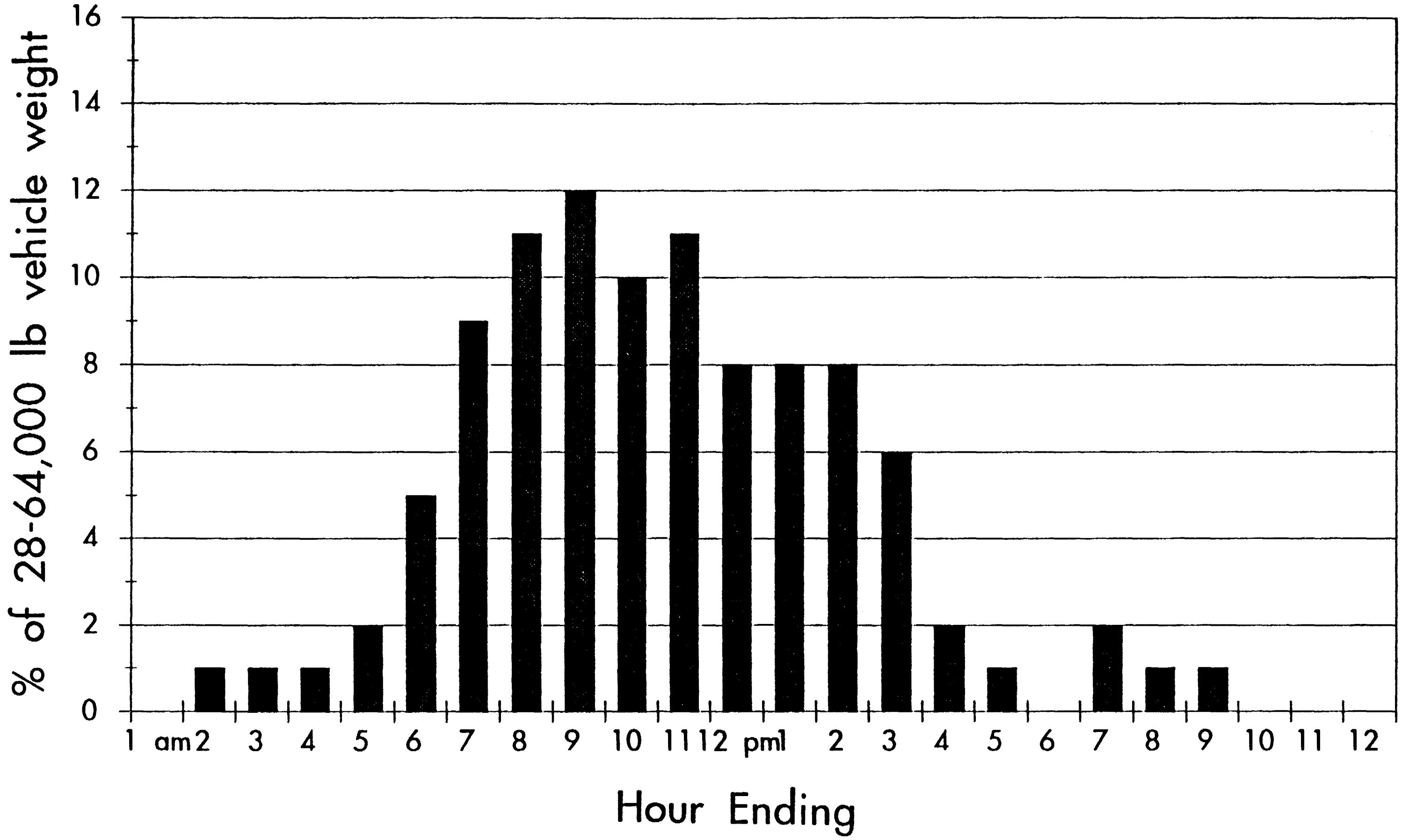
Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992,, Table 3.9, p. 3-9.

Figure 26. Truck Trip Time of Day Distribution for 0-8,000 Lb. Trucks in Maricopa County (Phoenix), Arizona.



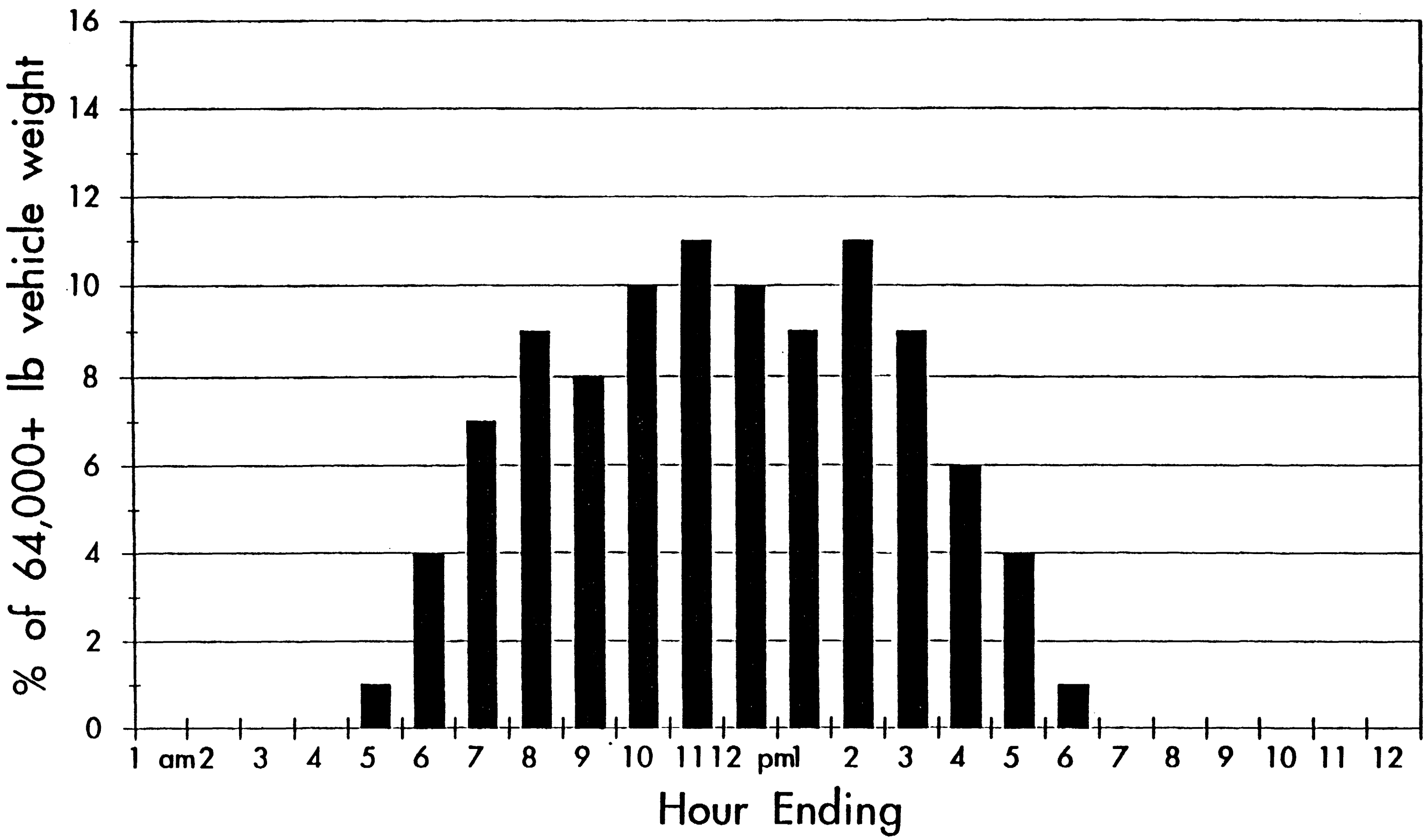
Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992,, Table 3.9, p. 3-9.

Figure 27. Truck Trip Time of Day Distribution for 8,000-28,000 Lb. Trucks in Maricopa County (Phoenix), Arizona.



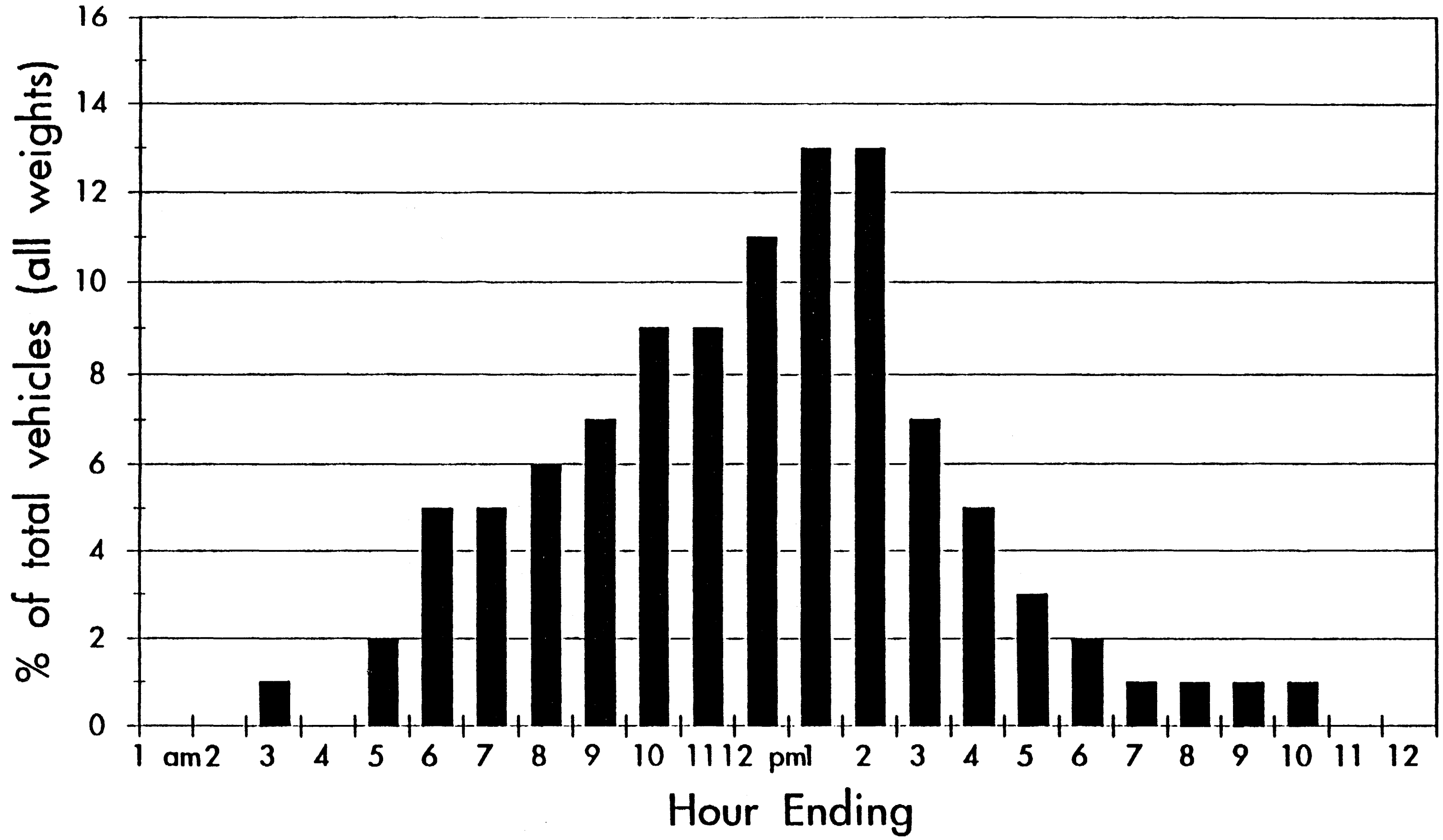
Source: Ruiter, Earl R. ***Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area***, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992,, Table 3.9, p. 3-9.

Figure 28. Truck Trip Time of Day Distribution for 28,000-64,000 Lb. Trucks in Maricopa County (Phoenix), Arizona.



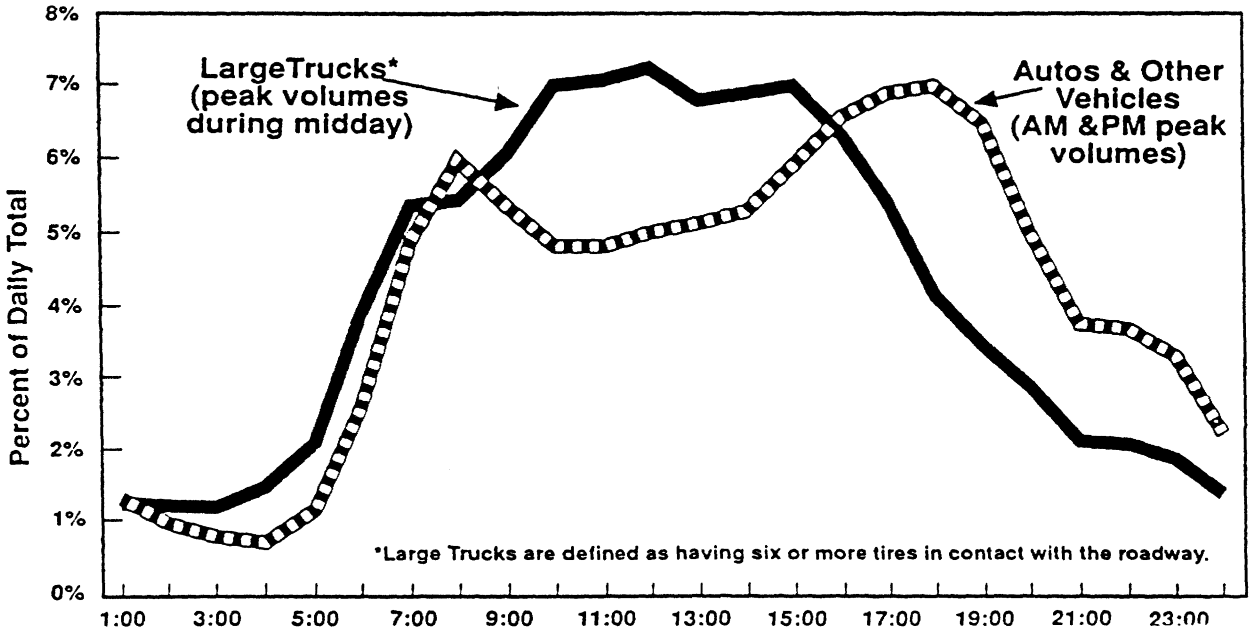
Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992,, Table 3.9, p. 3-9.

Figure 29. Truck Trip Time of Day Distribution for >64,000 Lb. Trucks in Maricopa County (Phoenix), Arizona.



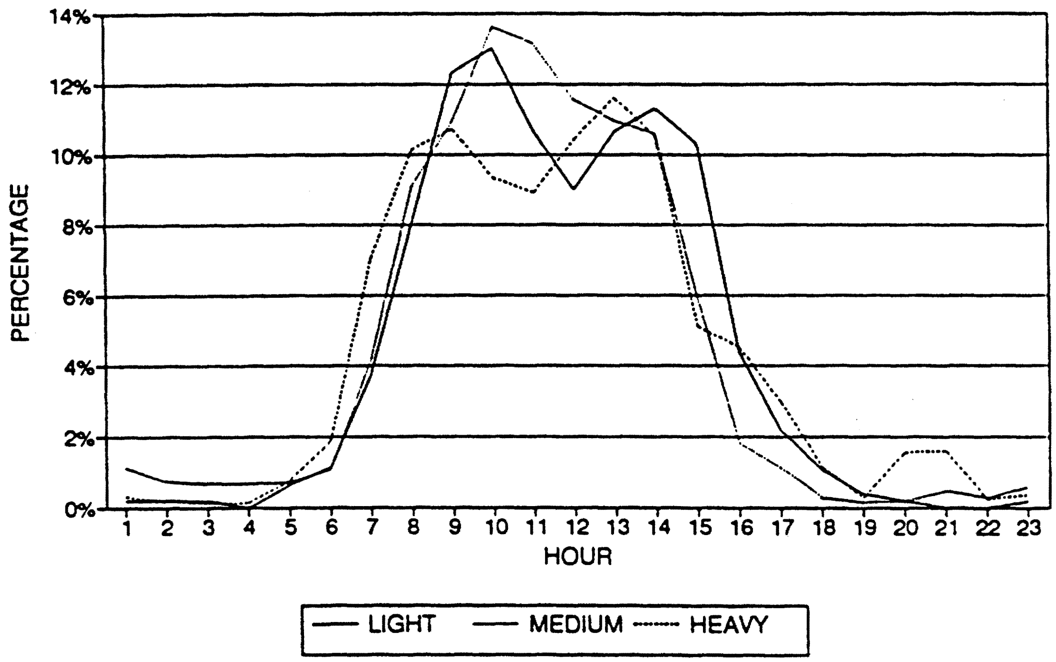
Source: Ruiter, Earl R. ***Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area***, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992,, Table 3.9, p. 3-9.

Figure 30. Truck Trip Time of Day Distribution for All Trucks in Maricopa County (Phoenix), Arizona.



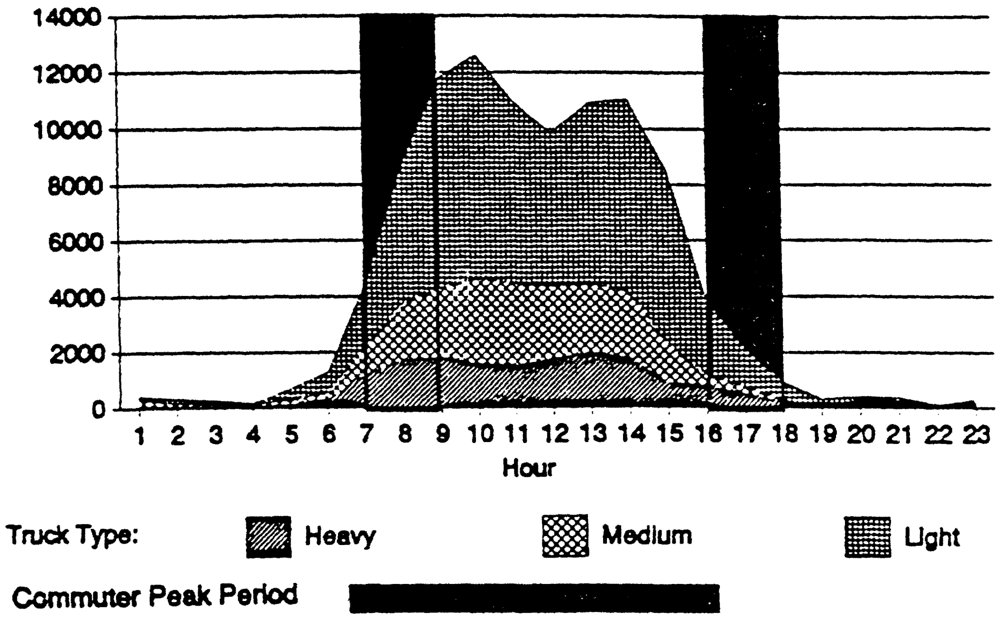
Source: Schlappi, Mark L., Roger D. Marshall, and Irene T. Itamura. "Truck Travel in the San Francisco Bay Area," Paper No. 930477. Paper presented at 72nd annual meeting of the Transportation Research Roard, January 10-14, 1993, Figure 5, p. 8.

Figure 31. Hourly Traffic Distribution as a Percentage of the 24-Hour Total, San Francisco Bay Area.



Source: Delcan Corporation and Goss, Gilroy and Associates, Ltd. *National Capital Region Goods Movement Study, Technical Report.* TRANS — A Joint Technical Committee on Transportation Systems Planning, Ottawa, Canada, Figure 15, p. 37.

Figure 32. 24-Hour Trip Percentage Distribution, Ottawa, Canada.



Source: Delcan Corporation and Goss, Gilroy and Associates, Ltd. *National Capital Region Goods Movement Study, Technical Report*. TRANS — A Joint Technical Committee on Transportation Systems Planning, Ottawa, Canada, Figure 16, p. 37.

Figure 33. 24-Hour Trip Distribution, Ottawa, Canada.

Table 29. Land Uses at Truck Trip Ends.

Land Use	Maricopa Co., Arizona (Phoenix)	Chicago	Vancouver Light Trucks	Vancouver Heavy Trucks	Houston
Residential	22.9	18.1	-	-	20.3
Household	-	-	11	1	-
Retail	19.5	23.3	17	11	15.8
Garaging	11.5	-	-	-	-
Meal, Fuel, Base	-	-	12	17	-
Manufacturing, Warehousing	20.8	-	-	-	-
Manufacturing	-	14.3	-	-	-
Industrial	-	-	-	-	42.6
Factory	-	-	8	6	-
Terminal/Warehouse	-	21.0	-	-	-
Warehouse	-	-	20	23	-
Intermodal	-	-	4	14	-
Transportation, Utilities, Communications	2.2	-	-	-	-
Educational	-	-	-	-	1.9
School, Hospital	-	-	6	1	-
Medical	-	-	-	-	1.7
Medical, Government	3.4	-	-	-	-
Government	-	-	-	-	0.6
Public/Government	-	4.9	-	-	-
Office	-	-	-	-	7.7
Office/Services	9.0	12.0	-	-	-
Office, Medical, Rest	-	-	11	3	-
Construction	-	1.7	-	-	-
Construction Site	-	-	9	15	-
Landfill	-	0.6	-	-	-
Quarry, Pit	-	-	3	8	-
Agriculture	-	1.1	-	-	-
In Transit	-	1.2	-	-	-
Other	10.7	1.8	-	-	10.1

Sources: John P. Reilly, Arnold Rosenbluh, and F. Gerald Rawlings. "Factoring and Analysis of the Commercial Vehicle Survey Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 29-46; Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.12, p. 3-12; Vancouver City Engineering Department. *Truck Study*. Greater Vancouver Regional District, Vancouver, BC, August 1990, Figures 31 and 32; Wilbur Smith Associates, Sylva Engineering Corp., and Epsilon Engineering, Inc. *Commercial Vehicle Survey*. Prepared for Houston-Galveston Area Council. Wilbur Smith Associates, Houston, TX, July 5, 1995, Figure 13, p. 4-19.

Table 30. Trip End Land Use by Truck Weight.

	0-8,000 lb		8,000-28,000 lb.		28,000-64,000 lb.		>64,000 lb.	
Land Use[1]	Phoenix	Chicago	Phoenix	Chicago	Phoenix	Chicago	Phoenix	Chicago
Residential	19.5	21.5	35.8	16.1	18.6	6.5	26.7	2.8
Retail	20.0	21.7	18.5	29.7	22.9	31.7	7.4	9.9
Manufacturing/Terminal/Warehouse/Garaging	31.5	32.2	34.2	31.1	36.7	46.5	35.6	65.2
Office/Service	11.2	14.5	3.2	10.8	1.8	4.1	1.2	0.7
Public/Government	4.0	4.6	0.4	8.3	4.0	2.9	6.4	1.4

[1]Definitions of land use vary slightly between the studies.

Sources: John P. Reilly, Arnold Rosenbluh, and F. Gerald Rawlings. "Factoring and Analysis of the Commercial Vehicle Survey Issues." *CATS Research News*, Chicago Area Transportation Study, 26(1), February 1987, pp. 29-46; Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.12, p. 3-12..

3. The largest percentage of truck trips are made by pickup trucks which make half of trips and represent 54 percent of commercial vehicles (see Table 31) (5).

4. Large trucks are used exclusively either for the pickup or dropoff of cargo, while smaller vehicles are involved in both loading and unloading at the trip end. Vehicles under 8,000 lbs. tend to have a large percentage of service calls and to a lesser extent personal business (Table 32) (5).

5. Almost 40 percent of all commercial vehicle stops are on-street. Lighter vehicles make a larger percentage of stops on-street than heavy vehicles. For trucks 8,000-28,000 lbs, half of stops are on-street (5).

Vehicle Weight (lbs)	Percentage of Vehicle Trips Stopping On-Street
0-8,000	36.8
8,000-28,000	50.2
28,000-64,000	10.9
64,000+	17.5
All Trucks	38.3

I. Urban Cordon Line Crossing

1. Truck trips have increased for the average weekday at the external cordon in Southeastern Wisconsin, where truck trips have increased in number and as a percentage of all vehicle trips (Table 33) (16).

2. The greatest increase in external truck trips in Southeastern Wisconsin are related to trucks returning to their base of operation and work connected business which together represent almost twice the trips made for the pickup and delivery of goods (Table 34) (16).

3. The level of growth in commercial vehicle activity is closely tied to degree of economic expansion. Table 35 presents an example from Toronto (18). However, growth, defined as number of trips crossing cordon lines, is not uniform across all geographic areas of the region. In Toronto, truck travel in the urban core and suburban areas did not expand as rapidly as truck travel in the overall metro area (Table 36).

4. In the Ottawa-Hull area of Canada for the period of 1986 to 1990, the number of trucks crossing the Ottawa River Crossings increased in excess of 5 percent annually, compared to a 3 percent annual growth for all traffic (14).

5. In Milwaukee, the number of truck trips crossing the CBD cordon line as a percentage of all truck trips continually decreased for 1963 to 1991, but the absolute number of trucks crossing the CBD cordon line remained stable (16).

Table 31. Trips by Vehicle Type, Maricopa County (Phoenix), Arizona.

Vehicle Type	Vehicle Weight (lbs.) 0-8,000 (%)[1]	8,000-28,000 (%)[1]	28,000-64,000 (%)[1]	>64,000 (%)[1]	Total (%)[1]
Autos and Vans	13.1	0.4	0.0	0.0	8.2
Campers	2.4	0.0	0.0	0.0	1.8
Buses	0.0	0.7	1.1	0.0	0.2
Pickup Trucks	61.3	9.8	1.1	0.0	48.5
Panel Trucks	16.0	26.8	0.0	0.0	17.3
Single Trucks	9.6	60.1	89.1	51.1	22.5
Tractor/Semitrailer	0.0	0.5	7.6	9.5	0.5
Truck/Trailer	0.0	1.7	1.1	39.3	1.1

[1]Percentage of total vehicle trips by class.

Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.8, p. 3-8.

Table 32. Activities at Trip Ends, Maricopa County (Phoenix), Arizona and Houston, Texas.

	Maricopa County (Phoenix)					
	Vehicle Weight (lbs.)					
Activity at Trip End	0-8,000 (%)[1]	8,000-28,000 (%)[1]	28,000-64,000 (%)[1]	>64,000 (%)[1]	Total (%)[1]	Houston (%)
Loading, Cargo Pickup	14.4	14.2	30.6	21.4	15.1	-
Pickup	-	-	-	-	-	15.7
Unloading, Cargo Dropoff	27.6	23.7	39.4	51.4	27.7	-
Delivery	-	-	-	-	-	46.4
Loading and Unloading	21.0	32.7	5.3	5.6	22.4	-
Service Calls	16.1	9.4	9.3	0.5	14.2	-
Vehicle Maintenance	1.3	2.2	1.2	0.8	1.5	0.9
Personal Business	11.8	1.6	1.2	2.1	9.2	-
Driver Needs	-	-	-	-	-	1.3
To/From Garaging Location	7.8	16.3	13.1	18.2	9.9	-
Base Location	-	-	-	-	-	26.5
Other	-	-	-	-	-	9.2

[1]Percentage of all commercial vehicle trips.

Sources: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.11, p. 3-11; Wilbur Smith Associates, Sylva Engineering Corp., and Epsilon Engineering, Inc. *Commercial Vehicle Survey*. Prepared for Houston-Galveston Area Council. Wilbur Smith Associates, Houston, TX, July 5, 1995, Figure 12, p. 4-18.

Table 33. Increase in Truck Trips, Southeastern Wisconsin.

Year	Truck Driver Trips: Through	Inbound	Outbound	Truck Vehicle Trips	Percentage Increase	Percent of Vehicle Trips
1963	1,700	7,100	7,200	15,300	-	15.1
1972	3,300	10,900	10,700	22,500	47%	17.9
1991	5,000	19,300	19,800	44,100	96%	16.1

Source: Unpublished draft manuscript identified as Chapter V, Travel Habits and Patterns, from *A Regional Transportation System Plan for Southeastern Wisconsin*, SEWRPC Planning Report No. 41, June 8, 1994.

Table 34. Distribution of Average External Commercial Truck Trips in Southeastern Wisconsin by Destination Purpose.

Trip Purpose	1963 (%)	1972 (%)	1991 (%)	Change 1963-1972 (%)	Change 1972-1991 (%)
Base of Operations	27.5	41.8	39.9	123.8	87.2
Work Connected Business	4.6	14.2	22.0	357.1	203.1
Pick-Up/Deliver Goods	66.0	43.6	34.7	-3.0	56.1
Customer Service	2.0	0.4	3.4	-66.7	1,400.0
Total				47.1	96.0

Source: Unpublished draft manuscript identified as Chapter V, Travel Habits and Patterns, from *A Regional Transportation System Plan for Southeastern Wisconsin*, SEWRPC Planning Report No. 41, June 8, 1994, Table 85, pp. 34A.

Table 35. Growth in Economy and Commercial Vehicle Movements, Toronto Area, 1975-1985.

Year	Economic Growth[1] GDP	Economic Growth[1] % Change from 1975	Commercial Vehicle Movements[2] Crossings	Commercial Vehicle Movements[2] % Change from 1975
1975	219,067	0.00	306,894	0.00
1977	251,288	14.71	317,102	3.33
1979	297,215	35.67	319,423	4.08
1981	352,039	60.70	335,867	9.44
1983	379,325	73.15	370,155	20.61
1985	393,265[3]	79.52	394,078	28.41

[1]Ontario GDP (millions in 1981 price).

[2]Two-way goods vehicle trips across three major cordons (central, suburban, metro), 7:00 a.m.-7:00 p.m.

[3]1984 value.

Source: *Metropolitan Toronto Goods Movement Study.* Metropolitan Toronto Roads and Traffic Department, Municipality of Metropolitan Toronto, Toronto, Ont., Table 4-26, pp. 4-21.

Table 36. Commercial Vehicle Volume Growth Rates of Three Major Cordons in the Greater Toronto Area.

Year	Metro % Change from 1975	Suburban % Change from 1975	Central Area % Change from 1975	Total % Change from 1975
1975	0.00	0.00	0.00	0.00
1977	11.83	-3.6	3.03	3.33
1979	7.65	-4.75	14.50	4.08
1981	20.28	-2.48	14.56	9.44
1983	36.38	11.81	12.88	20.61
1985	48.57	15.92	20.72	28.41

Source: *Metropolitan Toronto Goods Movement Study.* Metropolitan Toronto Roads and Traffic Department, Municipality of Metropolitan Toronto, Toronto, Ont., Table 4-26, pp. 4-21.

	CBD Cordon Line Counts Average Weekday Trip Destinations		
	1963	1972	1991
Internal Commercial Truck Trips	11,600	10,900	12,000
Portion of All Vehicle Trips	14.6%	12.3%	10.4%

6. The number of trucks entering the New York region by crossing the external cordon varied with economic conditions, but remained at 7% of all vehicles traveling into the area between 1974 and 1986 (1). "The increasing/decreasing trends between eastbound truck traffic at . . . crossings and the growth of regional . . . employment are very closely related. For instance, during the energy crisis period (1974-1976), both truck traffic and regional employment dropped sharply. When the regional economy recovered (1976 and afterward), truck traffic and regional employment steadily increased. The recent strong regional employment growth (1982-[1986]) showed truck traffic at the . . . crossings growing continuously [Figure 34]. . . . The service industry also presents different freight needs. The relationship between truck size (small and large) and the structure of the . . . economy is clearly shown in [Figure 35]. The percentage of small trucks . . . has grown at a similar pace to the increasing proportion of employment in the service industries. . . . The percentage of large trucks . . . has declined in a similar manner to the proportion of employment in . . . the manufacturing industries" (1, p. 6).

J. Urban Truck Operation Characteristics

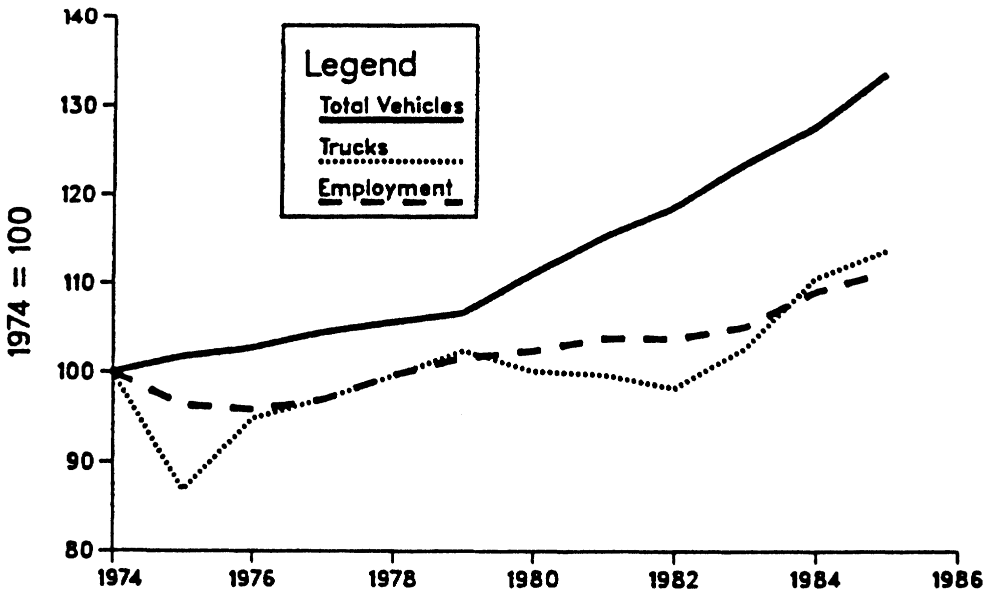
1. A study in Maricopa County (Phoenix), Arizona, found that truck speeds (including stopped time) are highest for vehicles less than 8,000 pounds and that vehicles in 8,000-28,000 pounds class make more short trips (Table 37).

2. Percentages of truck trips by time categories are presented in Appendix A.

3. In the Ottawa-Hull area in Canada, heavy vehicles are more active in interurban travel and have longer trip lengths and travel times and corresponding lower daily trip rates (Table 38) (14).

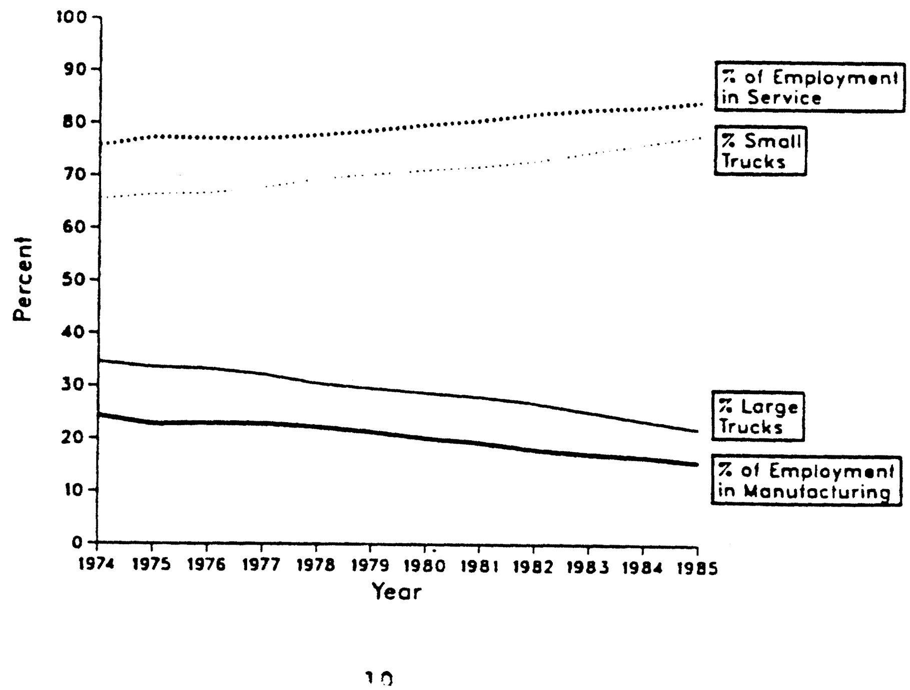
4. Heavy vehicles tend to be fully loaded or empty because they are more likely to carry indivisible or bulk loads (Figure 36) (14).

5. Houston has developed a list of commodity movements by truck on weekdays and weekends. Significantly, 18 percent of the trucks were operating empty (Table 39) (23).



Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary.* Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, Chart II-B, p. 10.

Figure 34. Growth of Eastbound Total Vehicles and Trucks at Port Authority Crossings Versus Employment in the NY/NJ Area.



Source: Anne Strauss-Wieder, Kyungwoo Kang, Mike Yokel, Brian Babo, and Gerry Pferrer. *Truck Commodity Survey, Eastbound: Overall Analysis and Summary.* Freight Research Section, Freight Planning Division, Planning and Development Department, The Port Authority of New York and New Jersey, October 1987, Chart II-C, p. 10.

Figure 35. Relationship of Truck Size at Holland and Lincoln Tunnels to Manhattan Employment Base.

Table 37. Truck Trips in Maricopa County (Phoenix), Arizona.

Trip Characteristic	Vehicle Weight (lbs.) 0-8,000 (%)[1]	8,000-28,000 (%)[1]	28,000-64,000 (%)[1]	>64,000 (%)[1]	Total (%)[1]
Distance (miles)	14.1	8.5	13.3	27.1	13.3
Average Duration/Time per Trip (minutes)[2]	23.9	18.8	30.1	57.6	28.1
Average Speed (miles/hour)[2]	35.4	27.2	26.5	28.2	28.4
Average Time Spent Traveling per Trip (minute)	16.4	11.9	16.2	23.1	15.6

[1]Percentage of all commercial vehicle trips.

[2]Includes time for loading/unloading at each stop.

Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.15, p. 3-15; Table 3.16, p. 3-17; Table 4.6, p. 4-9.

Table 38. Travel Performance by Vehicle Type, Ottawa-Hull, Canada.[1]

Characteristic	Truck Origin[2]	Light[3]	Medium[4]	Heavy/ Tractor[5]	Overall
Distance (miles)	Internal	5.9	6.7	12.5	6.5
	External	35.7	18.1	78.3	46.2
	Overall	7.5	8.5	46.9	11.7
Trip Time (minutes)	Internal	14.0	17.6	26.6	15.5
	External	61.2	40.4	113.6	74.6
	Overall	16.5	21.3	72.0	23.4
Average Speed (mph)	Internal	25.3	22.8	28.1	25.1
	External	35.0	26.9	41.4	37.1
	Overall	27.1	24.0	39.1	30.0
Average Stop Time (minutes)	Internal	29.0	23.4	28.0	27.9
	External	30.8	28.6	54.4	32.6
	Overall	62.8	56.1	78.7	62.9

[1]Includes trips made within, to, from and through the study area.

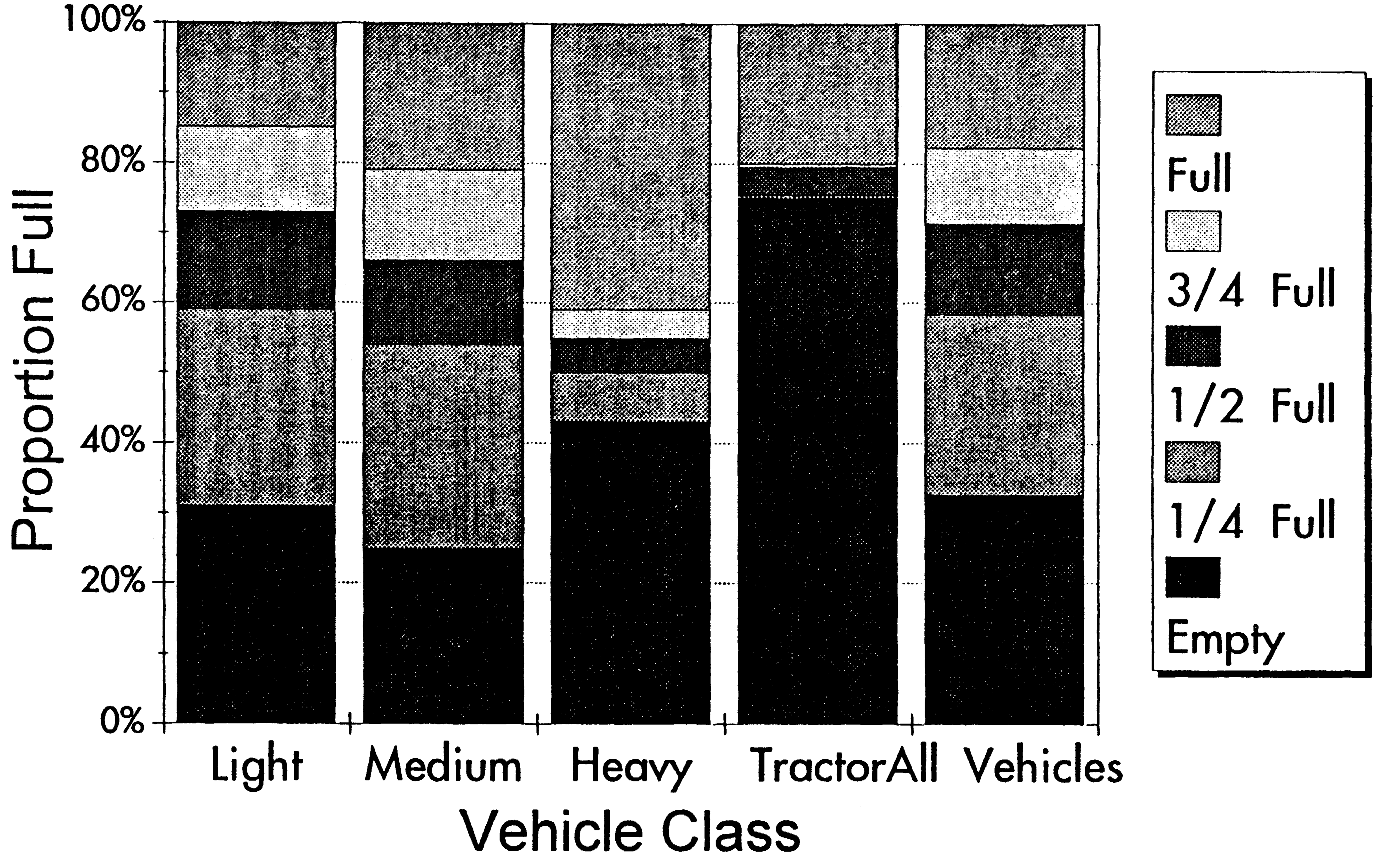
[2]"Internal" reflects trips recorded for vehicles registered in area. "External" reflects trip characteristics of vehicles based externally to area, but active in area or observed crossing an external cordon.

[3]Light = 2 axles, 4 wheels, net weight less than 2.000 kg (4,400 lbs.)

[4]Medium = 2 axles, 6 wheels, net weight 2,000-7,000 kg (4,400-15,400 lbs.).

[5]Heavy = 3 or more axles, net weight greater than 7,000 kg (15,400 lbs.). Tractor = single power unit with 2 or more axles.

Source: Delcan Corporation and Goss, Gilroy and Associates, Ltd. *National Capital Region Goods Movement Study, Technical Report*. TRANS — A Joint Technical Committee on Transportation Systems Planning, Ottawa, Canada, Tables 7 and 8, p. 31.



Notes: Light = 2 axles, 4 wheels, net weight less than 2.000 kg (4,400 lbs.). Medium = 2 axles, 6 wheels, net weight 2,000-7,000 kg (4,400-15,400 lbs.). Heavy = 3 or more axles, net weight greater than 7,000 kg (15,400 lbs.). Tractor = single power unit with 2 or more axles.

Source: Delcan Corporation and Goss, Gilroy and Associates, Ltd. *National Capital Region Goods Movement Study, Technical Report*. TRANS — A Joint Technical Committee on Transportation Systems Planning, Ottawa, Canada, Tables 7 and 8, p. 31.

Figure 36. Size of Truck Loads, Ottawa-Hull, Canada.

Table 39. Commodity/Freight Movements in Houston.

	Weekday Movement		Weekend Movement	
Commodity/Freight Description	Number	Perecent	Number	Percent
Farm Products	33	0.8	0	0.0
Forest Products	27	0.6	0	0.0
Marine Products	9	0.2	0	0.0
Metals and Minerals	234	5.3	0	0.0
Foods, Health, Beauty Products	538	12.2	24	13.7
Tobacco Products	0	0.0	0	0.0
Textiles	161	3.7	6	3.4
Wood Products	90	2.0	21	12.0
Printed Matter	33	0.8	3	1.7
Chemical Products	451	10.2	8	4.6
Refined Petro or Coal Products	138	3.1	0	0.0
Rubbers, Plastics and Styrofoam	72	1.6	0	0.0
Clay, Concrete, Glass and Stone	551	12.5	0	0.0
Manufactured Products/Equipment	569	12.9	49	28.0
Wastes	129	2.9	14	8.0
Misc. Shipments	232	3.3	0	0.0
Hazardous Materials	88	2.0	4	2.5
Unclassified	240	5.4	14	8.0
Unknown to Driver	23	0.5	0	0.0
Empty	792	18.0	32	18.3
Total	4,410		175	

Source: Wilbur Smith Associates, Sylva Engineering Corp., and Epsilon Engineering, Inc. *Commercial Vehicle Survey*. Prepared for Houston-Galveston Area Council. Wilbur Smith Associates, Houston, TX, July 5, 1995, Table 10, p. 4-21.

IV. TRUCK PERCENTAGES ON ROADWAYS

A. Overview

1. This section presents a 24-hour comparison of percent trucks in the traffic stream for different urban functional classified roadways.

2. A review of 294 sites indicates the weekday percentage of two-axle, six-tire single unit semitrailer and multiunit trailers exceeds 11 percent of vehicles on urban freeways and comprise 4-7 percent of vehicles on roads of other functional classifications (Table 40) (24). Weekend truck percentages tend to be about half of the weekday percentages.

B. Detailed Information

1. Appendix B contains detailed information about truck percentages by functional classification, vehicle type, and time of day.

Table 40. Distribution of Daily Highway Volumes.[1]

Classification	Passenger Cars and Motorcycles	Buses	2-Axle 4- and 6-Tire Single Unit Trucks	3 or More Axle Single Unit Trucks	4-Axle and Up Semitrailer and Multiunit Trailer Trucks	Number of Sites
Urban Interstate						
Weekday	75.2	0.2	14.7	2.2	7.7	91
Weekend	82.3	0.2	14.2	0.2	3.1	
Urban Freeway						
Weekday	76.8	0.3	14.8	0.8	7.2	38
Weekend	89.2	0.2	8.4	0.2	2.0	
Urban Prinicpal Arterial						
Weekday	77.6	0.2	18.6	0.7	2.9	106
Weekend	81.3	0.1	17.3	0.3	1.0	
Urban Minor Arterial						
Weekday	82.2	0.2	15.5	0.9	1.1	48
Weekend	85.3	0.3	11.3	0.9	2.2	
Urban Collector						
Weekday	77.7	0.2	16.1	3.6	2.4	11
Weekend	86.0	0.0	12.1	1.3	0.5	

[1]Based on at least one full 24-hour period at number of sites identified.

Source: Data from Federal Highway Administration Truck Weight Study, 1993, supplied by Science Applications International Corp., Oak Ridge, TN.

V. LOADING ZONE USE CHARACTERISTICS

A. Introduction

1. Urban freight delivery requires the use of loading facilities; either on-street or off-street. The urban planning may be concerned with adequacy of facilities available in a downtown area.

2. This section presents the characteristics associated with the use of loading facilities such as type of loading zone use (personal use, pickup-delivery of goods, etc.), type of vehicle use, typical dwell times, and arrival times.

B. General Use of Loading Zones

1. Studies in Toronto (24) and Washington, D.C. (25) reveal that most use of truck spaces at the curb are related to personal use and not the pickup and delivery of goods (Table 41).

2. In Toronto, automobiles represent over 70 percent of vehicles parked in curbside truck spaces, but only 30 percent of these automobiles are involved in commercial activities (Table 42) (24).

3. In Toronto, a higher percentage of vehicles occupying off-street truck loading bays are used for goods movement (Table 41) (24).

4. In Toronto, almost a third of all vehicles parked at off street loading spaces are automobiles, but most are involved in goods movement functions (Table 42) (24).

C. Dwell Times

1. On-street dwell times are considerably shorter than off-street dwell times (24).

2. Distributions off-street dwell times for courier vehicles and cartage vehicles were similar throughout the day. Figure 37 shows the distribution of off-street dwell time for courier vehicles and Figure 38 shows the distribution of off-street dwell time for cartage vehicles.

3. Figures 39 and 40 show the distribution of on-street dwell times for courier and cartage vehicles when off-street goods movement facilities are provided.

4. The distributions of on-street dwell times with and without off-street goods movement facilities available were similar (Figure 41).

5. Figure 42 compares on-street dwell times of courier and cartage vehicles when off-street goods movement facilities are not available.

Table 41. Truck Parking User Profile, Toronto and Washington.

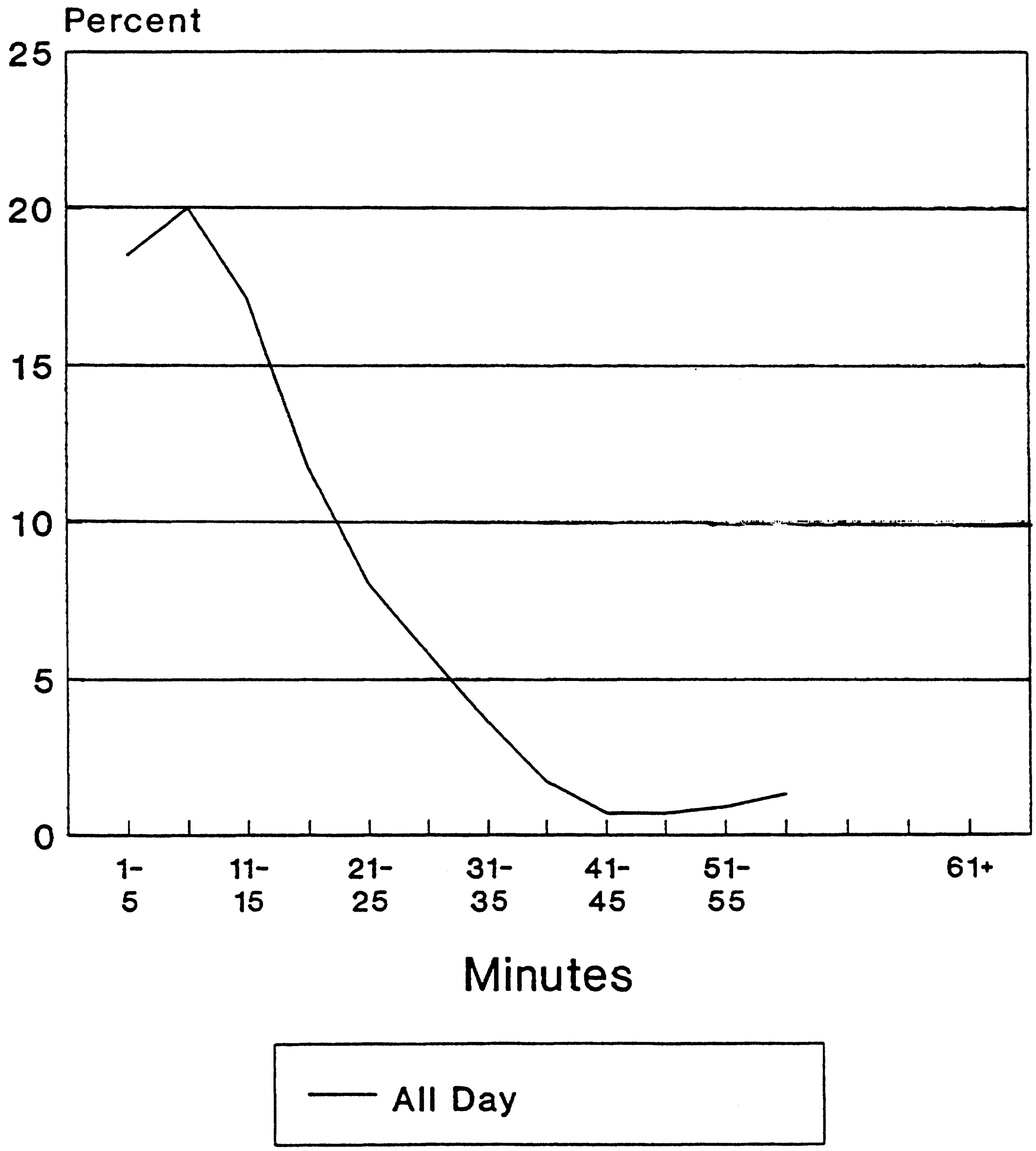
User	Toronto 1991	Washington, DC 1993
Curb Parking		
Goods Movement	28.5%	31.6%
Courier	60.0%	
Cartage	40.0%	
Service	4.4%	5.8%
Personal Use	67.1%	62.6%
Observations	1,645	209
Off-Street Truck Bays		
Goods Movement	78.5%	
Courier	47.3%	
Cartage	52.7%	
Service	9.7%	
Personal Use	11.9%	
Observations	891	

Sources: Devin Patrick Doyle. *Loading Zone Occupancy Study for the Washington, D.C. Business District*. Independent research study supported by United Parcel Service, February 16, 1994; *Retrofit Strategies for Loading/Delivery Facilities in the Central Area*. Planning and Development Department, City of Toronto, March 1993.

Table 42. Profile of Vehicles Using Truck Parking in Toronto.

	Curbside		Off-Street	
Vehicle Type	All	Involved in Goods Movement	All	Involved in Goods Movement
Automobile	72.6%	31.6%	29.3%	24.8%
Van	16.5%	34.2%	42.4%	40.3%
Straight-Truck	10.6%	33.1%	27.2%	33.5%
Tractor Trailer	0.3%	1.1%	1.1%	1.4%
n =	1,645	468	891	699

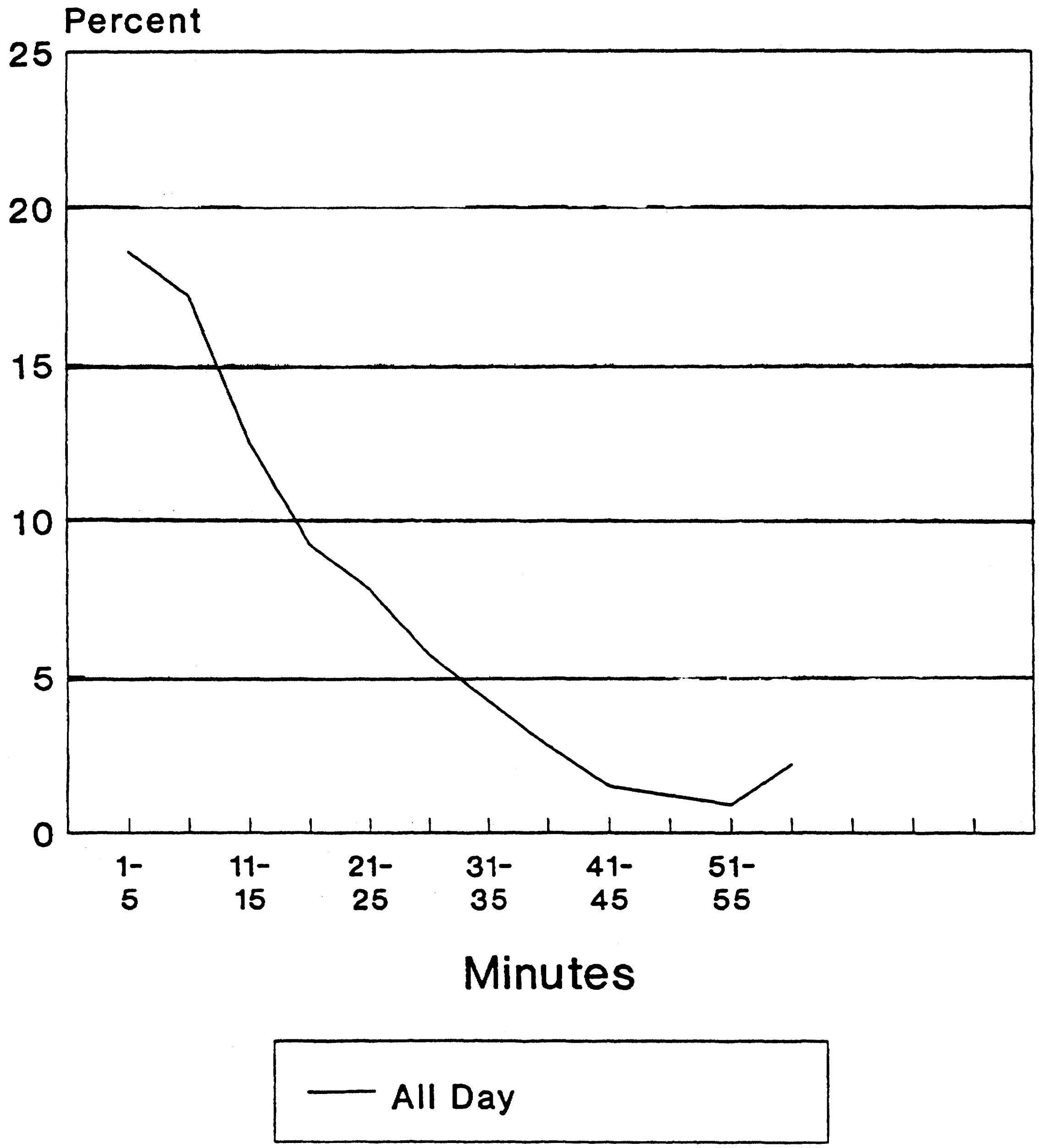
Source: *Retrofit Strategies for Loading/ Delivery Facilities in the Central Area.* Planning and Development Department, City of Toronto, March 1993.



Note: n = 304.

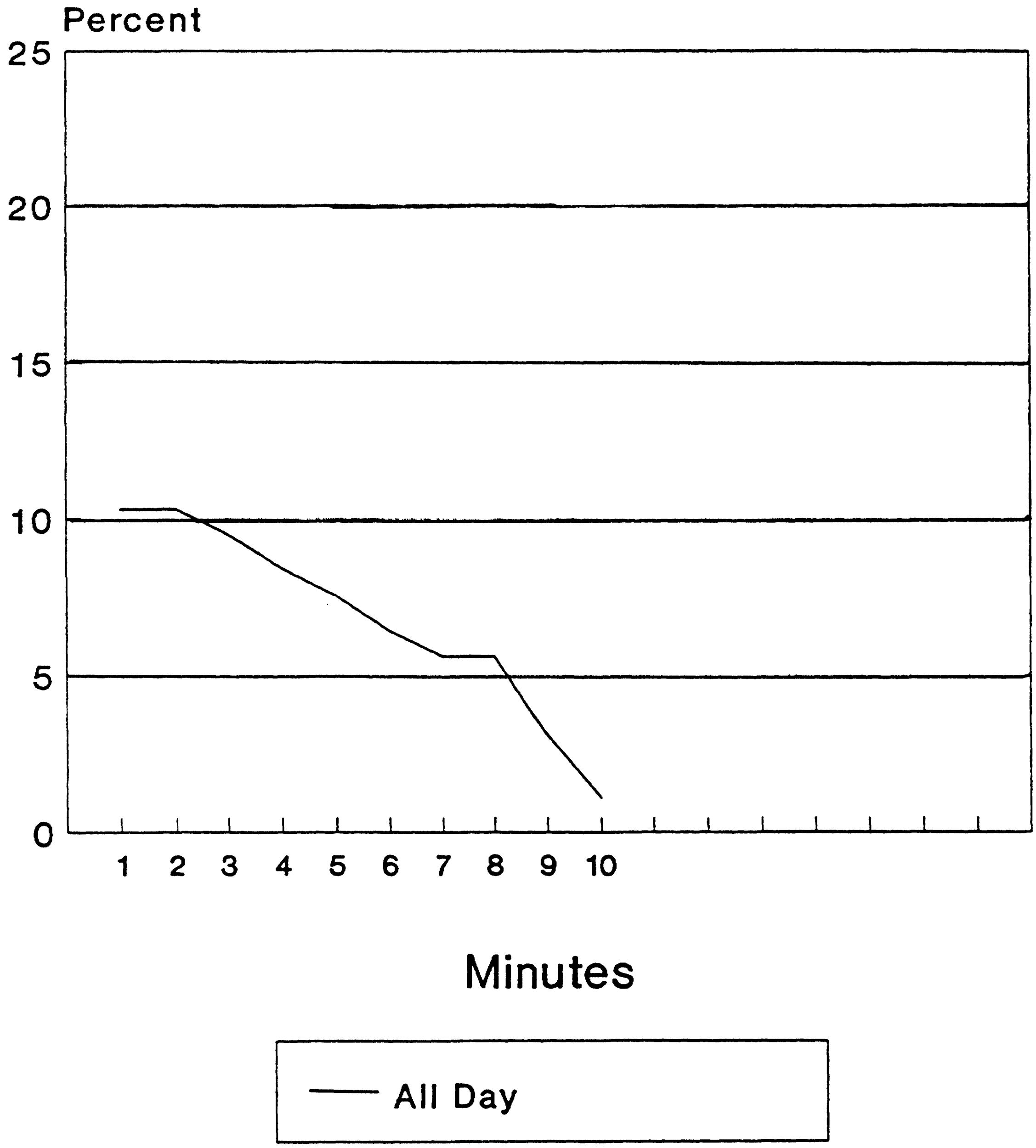
Source: *Retrofit Strategies for Loading/Delivery Facilities in the Central Area.* Planning and Development Department, City of Toronto, March 1993, Exhibit 3.4.2.

Figure 37. Off-Street Courier Vehicle Dwell Time Distribution.



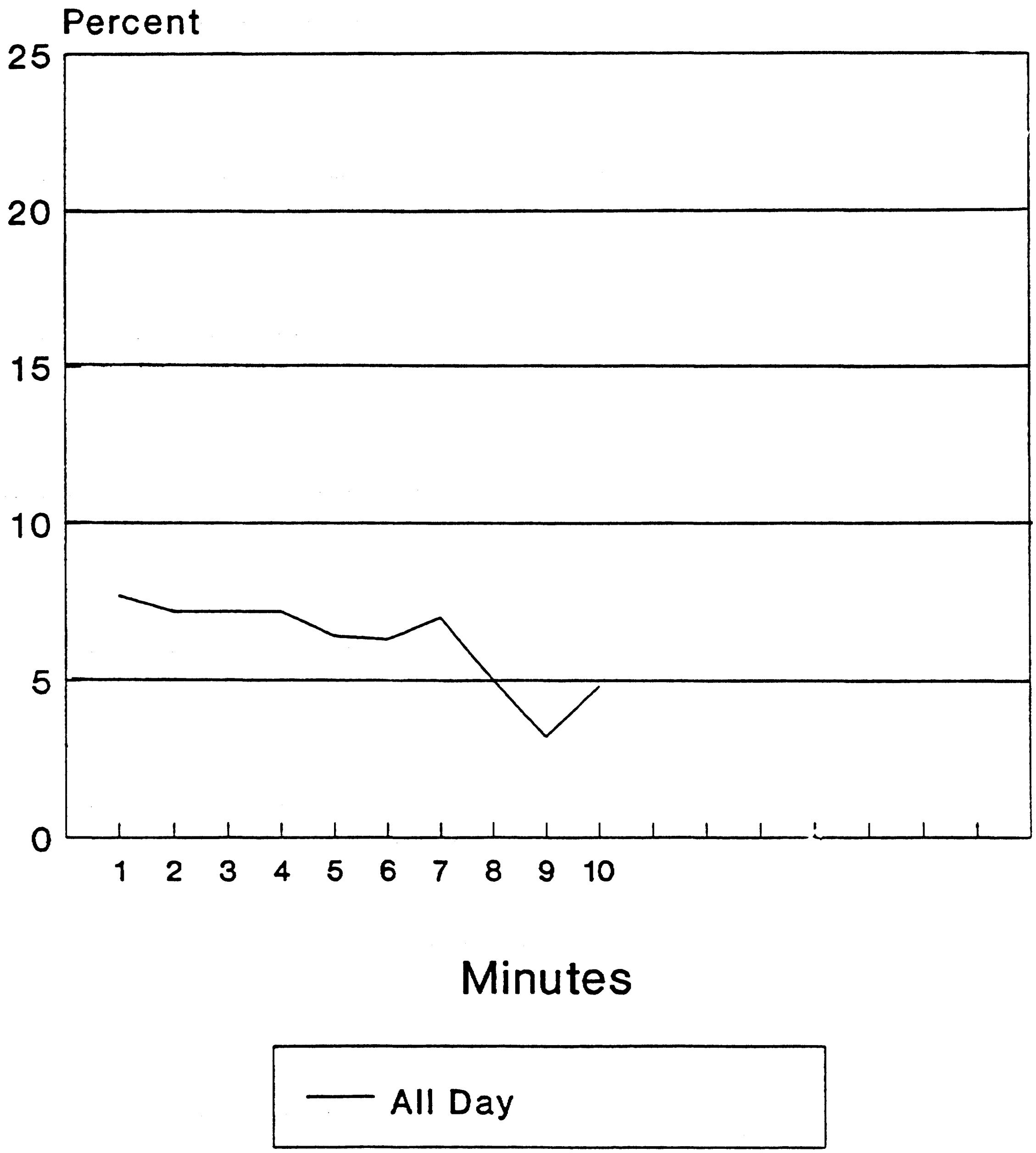
Source: *Retrofit Strategies for Loading/Delivery Facilities in the Central Area.* **Planning and Development Department, City of Toronto, March 1993, Exhibit 3.4.4.**

Figure 38. Off-Street Cartage Vehicle Dwell Time Distribution.



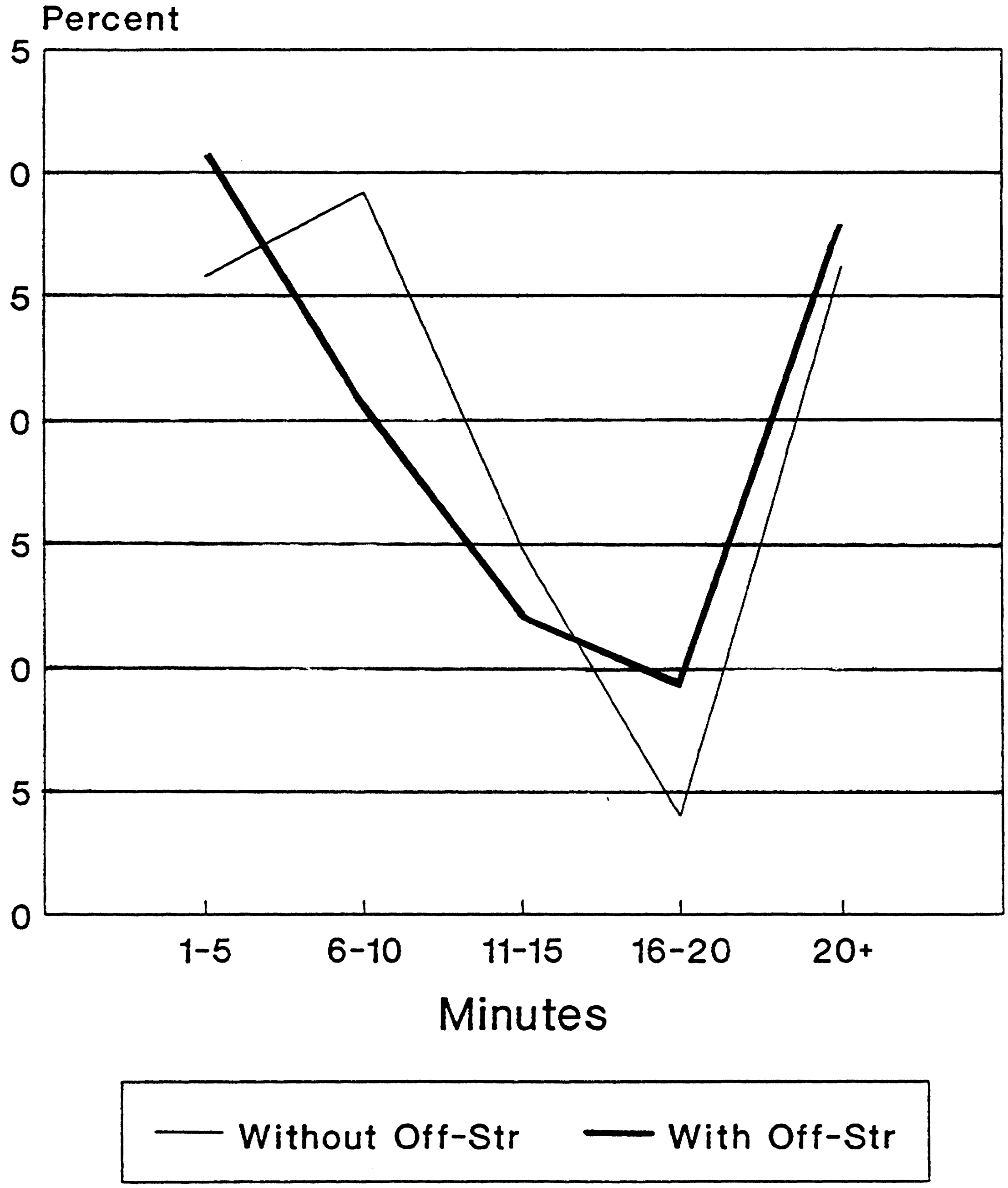
Source: *Retrofit Strategies for Loading/Delivery Facilities in the Central Area.* **Planning and Development Department, City of Toronto, March 1993, Exhibit 3.4.7.**

Figure 39. Off-Street Courier Vehicle Dwell Time Distribution with Off-Street Goods Movement Facilities Available.



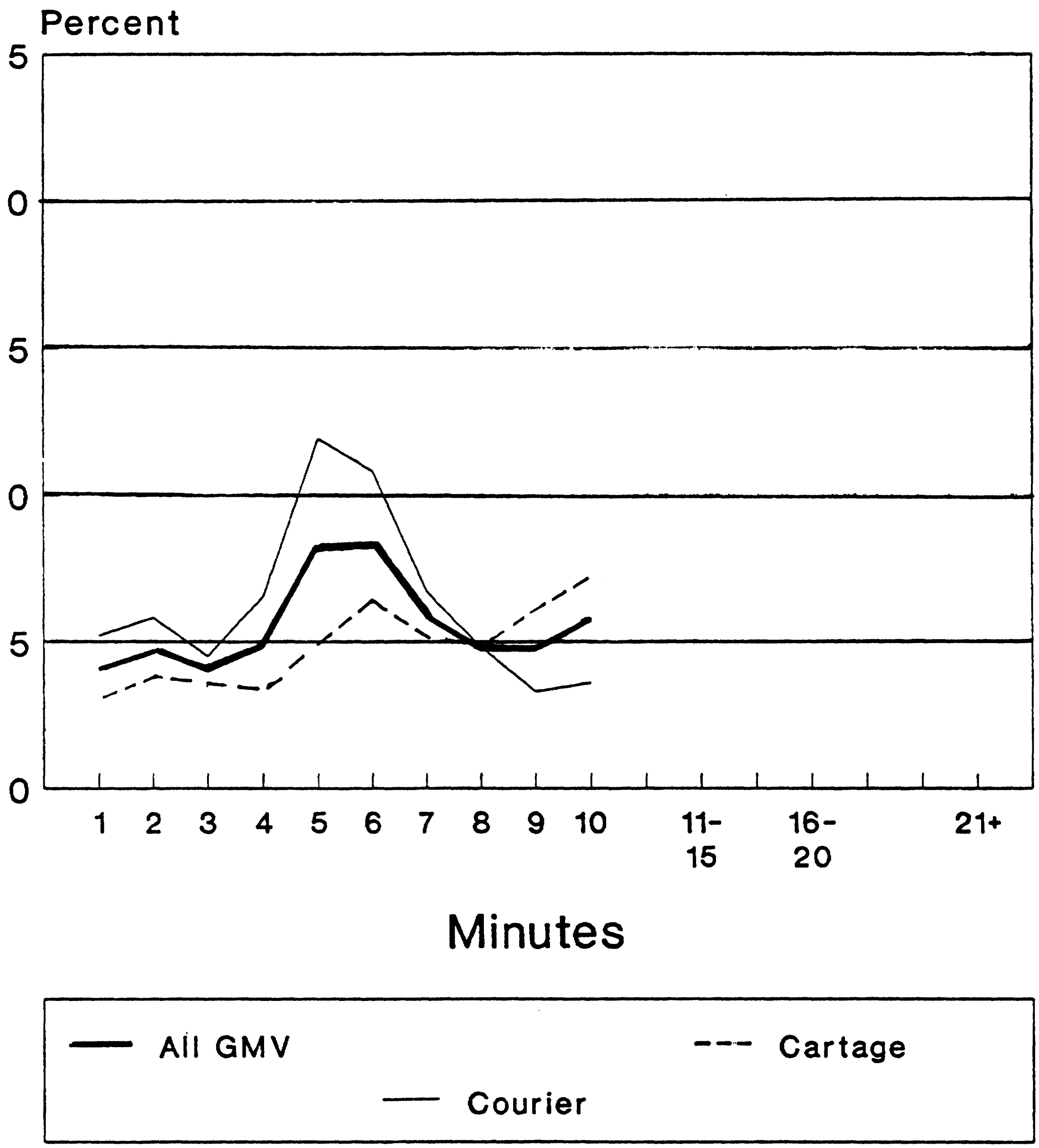
Source: *Retrofit Strategies for Loading/Delivery Facilities in the Central Area.* **Planning and Development Department, City of Toronto, March 1993, Exhibit 3.4.8.**

Figure 40. Off-Street Cartage Vehicle Dwell Time Distribution with Off-Street Goods Movement Facilities Available.



Source: *Retrofit Strategies for Loading/Delivery Facilities in the Central Area.* Planning and Development Department, City of Toronto, March 1993, Exhibit 3.4.11.

Figure 41. Vehicle Dwell Time Distribution for All Vehicles with and Without Off-Street Goods Movement Facilities Available.



Source: *Retrofit Strategies for Loading/Delivery Facilities in the Central Area.* Planning and Development Department, City of Toronto, March 1993, Exhibit 3.4.10.

Figure 42. On-Street Vehicle Dwell Time Distribution for All Vehicles Without Off-Street Goods Movement Facilities Available.

6. Figures 43-45 show arrival times for courier and cartage vehicles under various conditions of goods movement facility availability.

D. Vehicle Characteristics

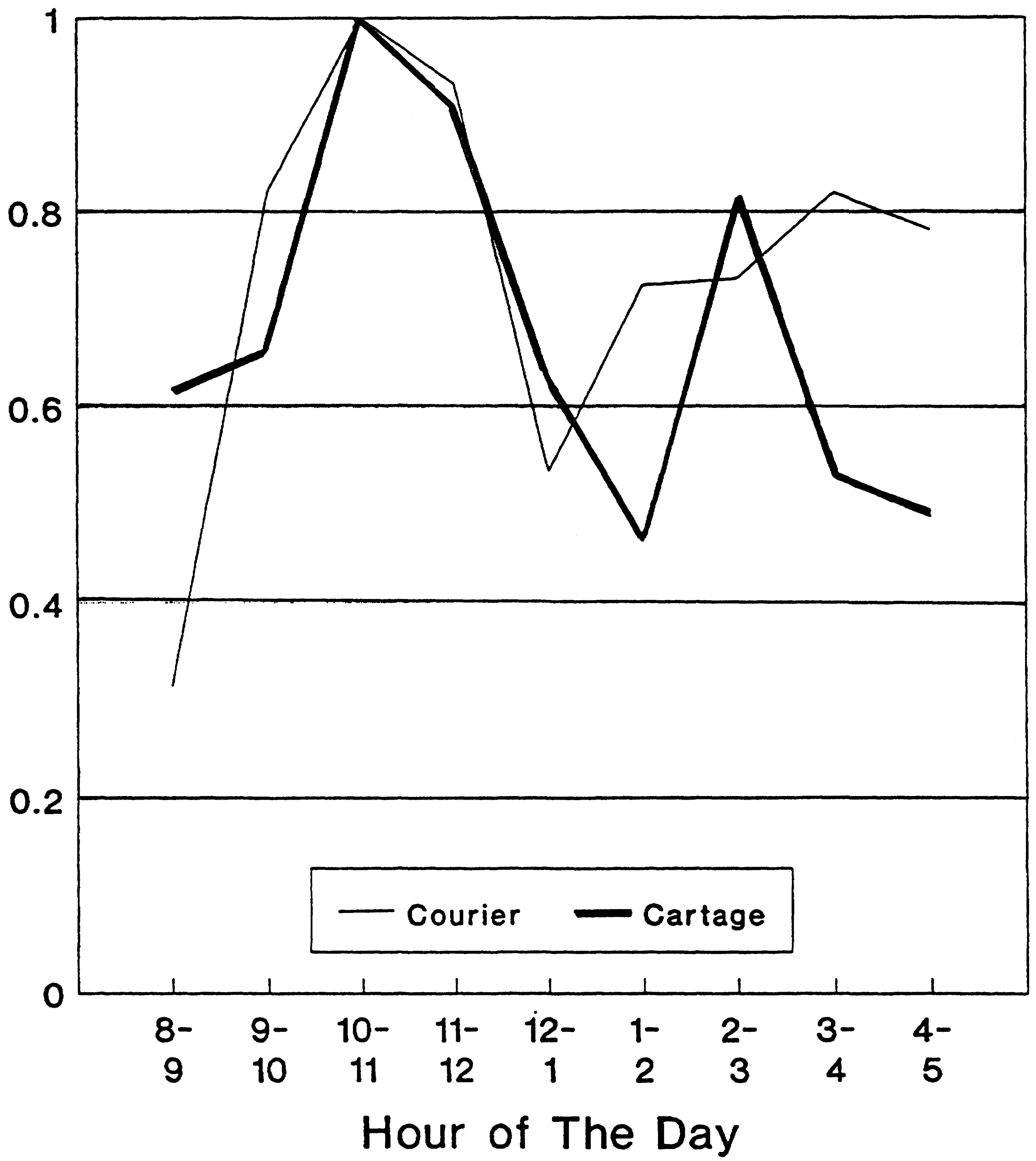
1. The characteristics of vehicles stopped on the street will depend on the availability of off-street spaces.

   - In Toronto, if an alley system was available, 38 percent of trucks parked in the alley and 62 percent of trucks parked on the block face (24).

   - If no alley system was available, 52 percent trucks parked legally at curbside, 22 percent of trucks parked illegally at curbside, 17 percent of trucks double parked illegally in a moving lane, and 9 percent of trucks parked curbside in a moving lane (24).

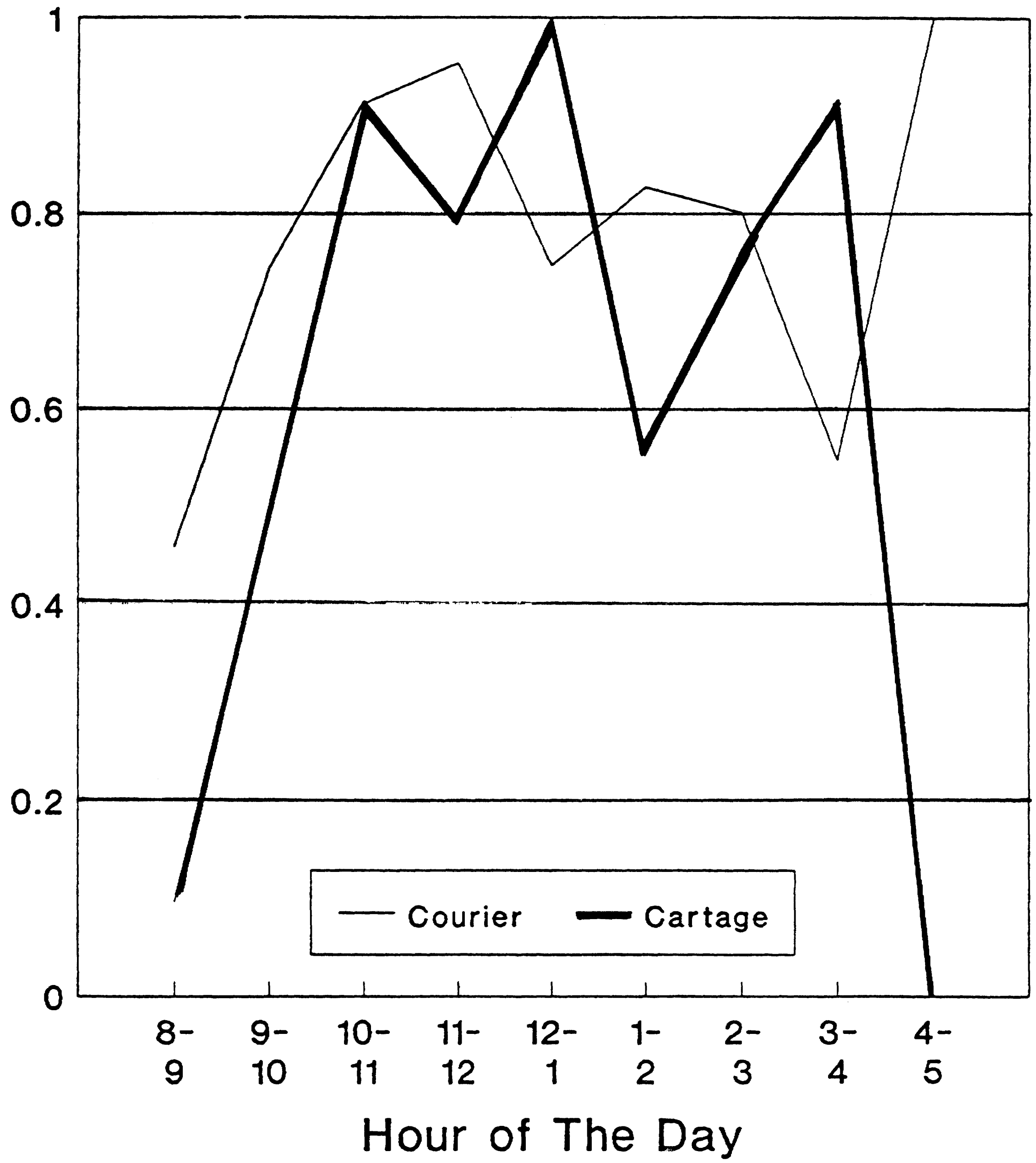
2. Table 43 shows dwell time by parking mode (26).

3. There is no appreciable differences between double parked and legally curbside parked vehicles in terms of shipment weights (Table 44) (26).



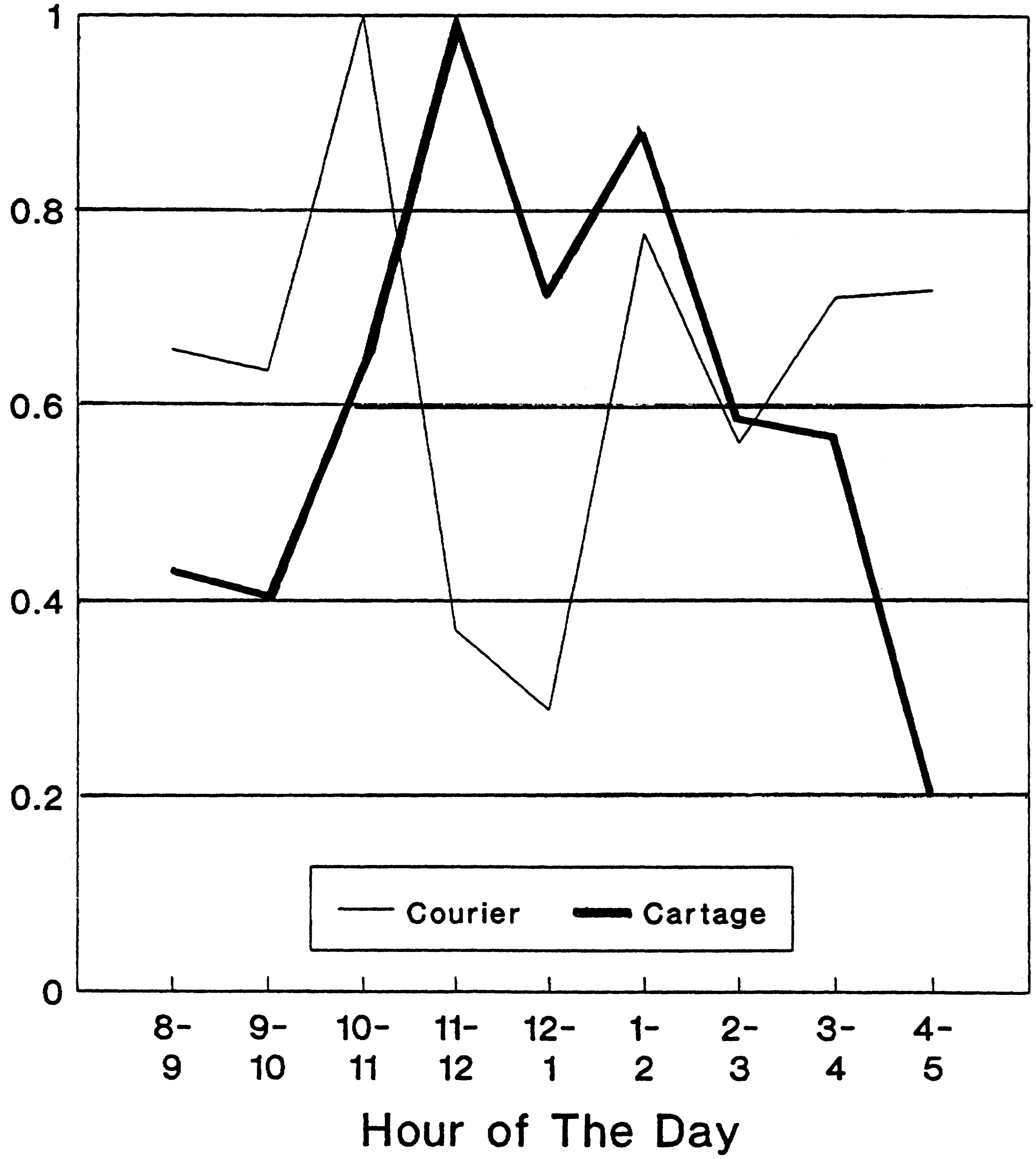
Source: *Retrofit Strategies for Loading/Delivery Facilities in the Central Area.* **Planning and Development Department, City of Toronto, March 1993, Exhibit 3.5.1.**

Figure 43. Off-Street Facility Vehicle Arrival Times.



Source: *Retrofit Strategies for Loading/Delivery Facilities in the Central Area.* **Planning and Development Department,** City of Toronto, March 1993, Exhibit 3.5.2.

Figure 44. On-Street Vehicle Arrival Times with Off-Street Goods Movement Facilities Available.



Source: *Retrofit Strategies for Loading/Delivery Facilities in the Central Area.* Planning and Development Department, City of Toronto, March 1993, Exhibit 3.5.3.

Figure 45. On-Street Vehicle Arrival Times Without Off-Street Goods Movement Facilities Available.

Table 43. Dwell Time Distribution by Parking Mode.

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

Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Table 13, p. 36.

Table 44. Shipment Weight by Parking Mode.

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

Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Table 15, p. 38.

VI. URBAN TRUCK ACCIDENTS AND INCIDENTS

A. Introduction

1. This section reviews the characteristics of truck accidents. The relationships between truck accident involvement rate by type of roadway and type of truck are shown. The characteristics of truck related freeway accidents for three metropolitan areas in Texas are presented. Finally the section discusses the impact of truck accidents and incidents on urban freeway operations.

B. Urban Traffic Accidents

1. The total accident involvement rate for large trucks (three or more axles, gross vehicle weight $\geq$26,000 lb.) is greater for urban highways than rural highways, while the involvement rate is lower for urban freeways than for other urban highways (Table 45).

2. While the total accident rate is greater on urban highways, the death rate and casualty accident rate are not as great as on rural highways (Table 46).

C. Freeway Accidents in Texas

1. Tables 47 and 48 show truck accident rates in three metropolitan areas in Texas.[1]

2. On Texas freeways (in a three metropolitan area sample), over two thirds of fatalities and almost 80 percent truck related accidents involve trucks other than 18 wheelers (heavy trucks) (Table 49) (11).

3. Based on data provided for freeways in three Texas metropolitan areas, 37 percent of truck related accidents occurred in the outside lane of the freeway and 56 percent of truck related accidents occurred on the outside lane, ramp, and shoulder areas (Table 50) (11).

4. A survey of 12 Houston freeways indicated that trucks were involved in 18.5 percent of all accidents while they represented only 5.9 percent of traffic. Based on vehicle-miles of travel, this suggests that the accident rate for trucks is about 40 percent higher than the rate for nontrucks (Table 51) (11).

5. Truck accidents on Houston freeways increase toward late afternoon while total traffic volumes increase (Figures 46 and 47) (11).

---

[1]Dallas-Fort Worth, Houston, and San Antonio.

Table 45. Accident Rates per 100 Million VMT by Vehicle Type and Roadway Type.

Vehicle Type	Rural Freeway	Rural Nonfreeway	Urban Freeway	Urban Nonfreeway
Total Traffic	90	261	359	492
Nontrucks	87	269	365	507
Total Large Trucks	112	234	273	302

Note: Based on California and Michigan data only.

Source: Perkins, David B. *Urban Freeway Gridlock Study: Technical Memorandum 1-4*. Prepared for California Department of Transportation. Cambridge Systematics, Inc., Cambridge, Massachusetts, November 1988, Table 2.

Table 46. Accident Involvement Rates for Single-Trailer and Multitrailer Combination Trucks and Other Vehicles.

Vehicle Type	Rural Interstate	Other Rural	Urban Interstate	Other Urban
Vehicle-Miles of Travel (x 10^6)				
Single-Trailer Combination	2,433	1,112	683	125
Multitrailer Combination	233	115	49	7
Other Vehicle	10,863	12,220	12,459	4,808
Fatal and Injury Involvements				
Single-Trailer Combination	596	461	389	96
Multitrailer Combination	24	25	17	3
Other Vehicle	4,200	8,889	9,736	7,777
Involvement Rate (per 10^8 miles)				
Single-Trailer Combination	24.5	41.5	56.9	76.6
Multitrailer Combination	10.3	21.8	34.8	40.8
Other Vehicle	38.7	72.7	78.1	161.7

Note: Based on Transportation Research Board *Special Report 211*, unpublished 1983-1985 accident and travel data for the federally designated network reported by seven states to the Federal Highway Administration.

Source: Perkins, David B. *Urban Freeway Gridlock Study: Technical Memorandum 1-4*. Prepared for California Department of Transportation. Cambridge Systematics, Inc., Cambridge, Massachusetts, November 1988, Table 3.

Table 47. Truck Related Accidents for Three Metropolitan Areas in Texas by Accident Severity.

Area Noninjury	Possible Injury	Nonincapa-citating	Incapa-citating	Fatal	Total	
Dallas/Fort Worth	1,659 28.67%	374 6.46%	325 5.62%	93 1.61%	25 0.43%	2,476 42.79%
Houston	2,306 39.85%	413 7.14%	389 6.72%	86 1.49%	26 0.45%	3,220 55.65%
San Antonio	59 1.02%	18 0.31%	12 0.21%	1 0.02%	0 0.00%	90 1.56%
Total	4,024 69.55%	805 13.91%	726 12.55%	180 3.11%	51 0.88%	5,786

Source: McCasland, William R., and Robert W. Stokes. *Truck Operations and Regulations on Urban Freeways*, Research Report 338-1F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1984, Table 12, p. 20.

Table 48. Freeway Vehicle-Miles of Travel and Truck Accidents for Three Metropolitan Areas in Texas.

	1983 Truck Accidents		Truck Accidents 100 Million VMT (annual)	
Area	Fatal Accidents	Total Accidents	Fatal Accidents	Total Accidents
Dallas/Fort Worth	25	2,476	0.44	43.9
Houston	26	3,220	0.57	70.0
San Antonio	0	90	-	5.1

Source: McCasland, William R., and Robert W. Stokes. *Truck Operations and Regulations on Urban Freeways*, Research Report 338-1F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1984, Table 13, p. 20.

Table 49. Summary of Truck-Related Accidents for Three Metropolitan Areas in Texas by Truck Type and Accident Severity.

Accident Severity	Eighteen Wheelers	Other Trucks	Total
Non-Injury	823 14.22%	3,201 55.32%	4,024 69.55%
Possible Injury	146 2.52%	659 11.39%	805 13.91%
Non-Incapacitating	161 2.78%	565 9.76%	726 12.55%
Incapacitating	33 0.57%	147 2.54%	180 3.11%
Fatal	16 0.28%	35 0.60%	51 0.88%
Total	1,179 20.38%	4,607 79.62%	5,786

Source: McCasland, William R., and Robert W. Stokes. *Truck Operations and Regulations on Urban Freeways*, Research Report 338-1F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1984, Table 14, p. 22.

Table 50. Summary of Truck-Related Accidents for Three Metropolitan Areas in Texas by Accident Severity and Location.

Accident Severity	Inside Lane	Middle Lane(s)	Outside Lane	Ramps and Shoulders	Total
Non-Injury	48 7.54%	127 19.94%	166 26.06%	70 10.99%	411 64.52%
Possible Injury	14 2.20%	29 4.55%	32 5.02%	19 2.98%	94 14.76%
Non-Incapacitating	13 2.04%	33 5.18%	31 4.87%	16 2.51%	93 14.60%
Incapacitating	3 0.47%	7 1.10%	7 1.10%	11 1.73%	28 4.40%
Fatal	0 0.00%	7 1.10%	1 0.16%	3 0.47%	11 1.73%
Total	78 12.24%	203 31.87%	237 37.21%	119 18.68%	637

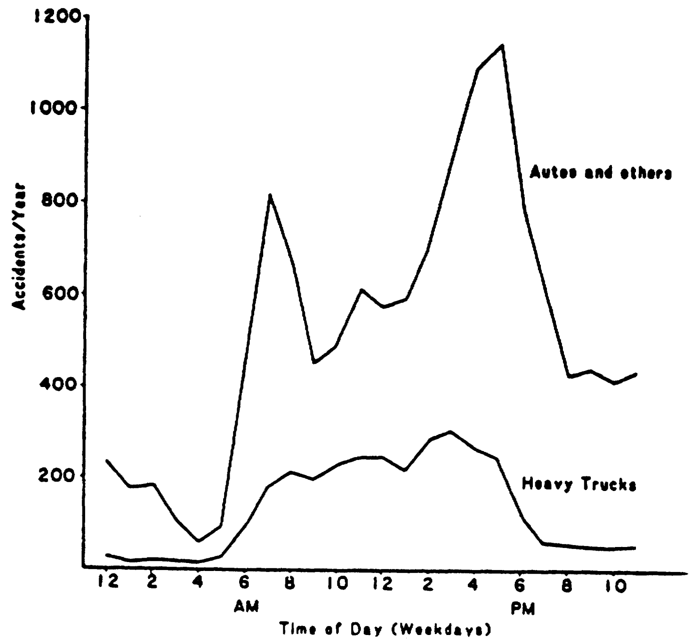
Note: Data are for those accidents where the specific location of the accident was reported.

Source: McCasland, William R., and Robert W. Stokes. *Truck Operations and Regulations on Urban Freeways*, Research Report 338-1F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1984, Table 15, p. 23.

Table 51. Truck Accident Experience on Houston Freeways.

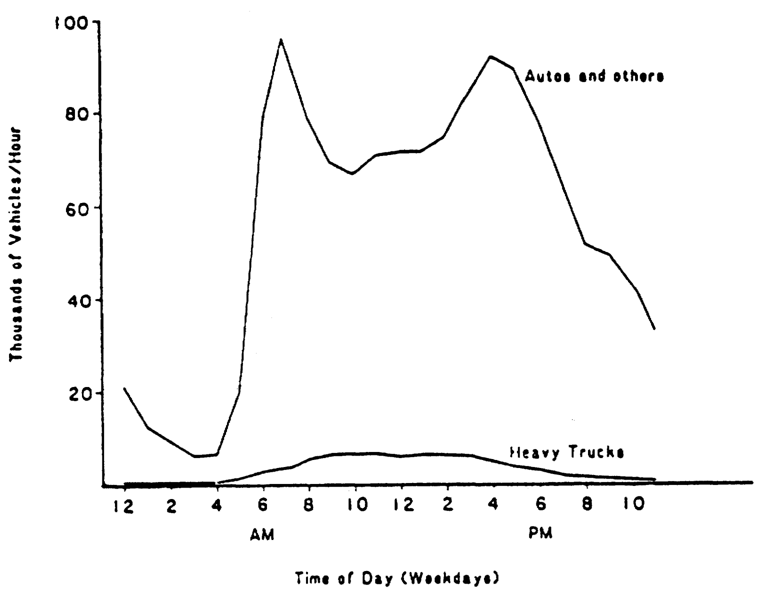
Freeway	Volume (1978) AADT	Volume (1978) Percent Trucks	Accidents (1979) Number Involving Trucks	Accidents (1979) Percent of Total Accidents
Katy I-10	163,090	5.6	435	19.5
North I-45	128,750	5.1	492	19.5
Gulf I-45	155,340	4.6	395	14.2
Southwest U.S. 59	214,720	4.7	437	13.2
North Loop I-610	159,360	6.6	407	22.7
East Loop I-610	110,970	11.7	496	30.8
South Loop I-610	136,370	4.8	265	15.1
West Loop I-610	215,620	4.0	216	13.0
Unweighted Average		5.9		18.5

Source: McCasland, William R., and Robert W. Stokes. *Truck Operations and Regulations on Urban Freeways*, Research Report 338-1F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1984, Table 17, p. 26.



Source: McCasland, William R., and Robert W. Stokes. *Truck Operations and Regulations on Urban Freeways*, Research Report 338-1F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1984, Figure 6, p. 28.

Figure 46. Vehicle Accidents for Nine Houston Freeways (1979).



Source: McCasland, William R., and Robert W. Stokes. *Truck Operations and Regulations on Urban Freeways*, Research Report 338-1F. Texas Transportation Institute, Texas A&M University, College Station, TX, August 1984, Figure 5, p. 27.

Figure 47. Vehicle Distribution for Nine Houston Freeways (1979).

D. Impact of Trucks on Traffic Flow

1. Large trucks (three or more axles, ≥26,000 lb.) have an adverse impact on traffic flow. They are larger and occupy more roadway space. They have poor operating characteristics, especially acceleration, deceleration, and ability to remain speeds on grades.

2. The *Highway Capacity Manual* provides passenger vehicle equivalents for trucks on general multilane highway segments and the impact of specific gradients. Additional experiences with passenger vehicle equivalencies is summarized by Lau (27).

3. Some observations:
   - On an urban freeway with 10 percent trucks in the traffic stream and grades below 2 percent — which would be typical of the freeway segments — trucks have an impact equivalent to 1.5 to 2.0 passenger cars (4).
   - An additional 0.1 equivalent cars may be added to the 1.5 to 2.0 base to account for the "frictional" impact of trucks on passenger cars in an adjacent lane.
   - Trucks are restricted by regulation to the rightmost lane of California freeways. This increased the density of trucks in the rightmost lanes and created a perceived, if not an actual, barrier to merging traffic. This phenomenon is not well understood and documented (28, p. 1).

4. In Los Angeles, trucks involved in freeway accidents are estimated to represent 20 percent of total nonrecurrent congestion ($100 million of $500 million) (4).

5. Major incidents[2] which comprise 5-10 percent of all trucks incidents, are responsible for half of total delay caused by all truck incidents. Common incidents[3] which comprise 90-95 percent of all incidents are responsible for the other half of total delay (4).

6. Most truck incidents occur on weekdays during the mid-day period.

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[2]A major incident is an accident that will block two or more lanes of the freeway for two hours or longer.

[3]A common incident has an average duration of one hour, but triggers 1,200 vehicle-hours of delays. Half of common incidents are caused by breakdowns, stalls, broken fan belts, and flat tires, and 27 percent of common incidents are caused by accidents.

VII. TRIP RATES

A. Truck Trip Rates

1. Truck trip rates have been established for different land uses. Some relationships have been aggregated to a zonal level and are used to predict truck trips for a traffic analysis zone.

2. Typical truck trip rates and other pickup and delivery characteristics are presented for:
   - Central city areas
     - Office
     - Residential
     - Light industry and warehousing
     - Hotel
     - Retail and services
     - Food
   - Neighborhood business districts
     - Businesses
     - Retail food stores
     - Clothing stores
   - Government facilities
     - Office facilities
     - Warehouse and garage facilities
   - Suburban establishments
     - Prepared foods
     - Variety/pharmacy
     - Personal services
     - Office buildings
     - Sales and retail
     - Retail foods
   - Industrial establishments
     - Inner city industrial areas
     - Air cargo facilities
     - Industrial establishments
     - Wholesale establishments
     - Warehouse establishments
     - Truck terminals
   - Downtown retail establishments
   - Pipeline terminals
   - Miscellaneous land uses

B. Areawide Trip Rates

1. Table 52 shows areawide trip rates (5).

Table 52. Final Trip Generation Models.

	Vehicle Weight (lbs.)			
	0-8,000	8,000-28,000	28,000-64,000	>64,000
Total Households	.2505	.1113	.0109	.0096
Retail Employment	.9723	.2151	.0499	.0099
Industrial Employment	1.0401	.1618	.0530	.0289
Public Employment	.4786	.0097	.0219	.0170
Office Employment	.5019	.0343	.0037	.0015
Other Employment	1.2391	.1715	.0653	.0568

Notes: Commercial vehicle one-way trips per one unit of the independent variable. The coefficients shown here do not reflect the results of the traffic calibration/assignment phase of the project. An adjustment of 1.623 is included to reflect the final regional factors used to estimate total commercial vehicle trip generation.

Source: Based on Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ-92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 4.5, p. 4-7.

2. Trip generation relationships have been developed for light and heavy trucks[1] in Vancouver, BC (1):

$$Light_i = 0.327Wh_i + 0.0212NWh_i + 0.0103Pop_i$$

where:

$Light_i$ = 24-hour light truck trips produced by zone i
Wh_i = wholesale employment in zone i
NWh_i = nonwholesale employment in zone i
Pop_i = population in zone i

$$Heavy_i = 0.164Wh_i + 0.0665Man_i$$

where:

$Heavy_i$ = 24-hour heavy truck trips produced by zone i
Wh_i = wholesale employment in zone i
Man_i = manufacturing employment in zone i

C. Central City Areas

1. CBD land use: office.[2]

- Weekly trip generation (26):

$$WG = 0.8 \times FA + 2.0 \qquad R^2 = .93$$

where:

WG = weekly trip generation
FA = floor area (100 m^2)

See Figure 48.

- Daily trip generation (26)

$$DG = 0.16 \times FA + 0.4 \qquad R^2 = .93 \qquad n = 48$$

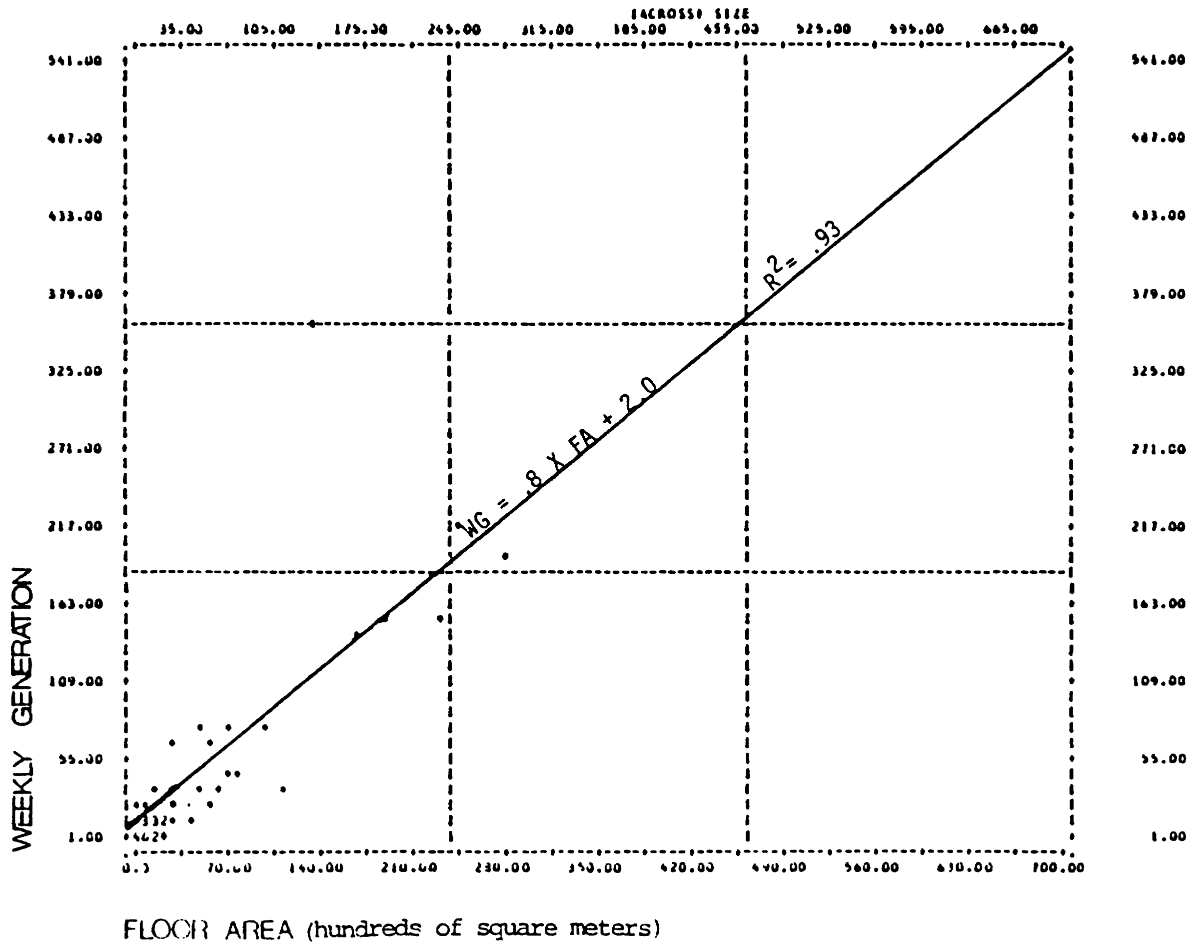
where:

DG = daily trip generation
FA = floor area (100 m^2)

[1]Light trucks are vehicles with a gross vehicle weight of 9,000-44,000 lbs. (4,500-20,000 Kg). Heavy trucks are vehicles with a gross vehicle weight of greater than 44,000 lbs. (20,000 Kg).

[2]Only considers land use clearly definable as office use — does not include other general floor uses.

OFFICE



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure 5, p. 15.

Figure 48. Plot of Weekly Pickup and Delivery Generation Versus Size for Office Land Use.

- Distribution of shipment size (number of pieces) for office land use in six cities[3] (26):

Number of Pieces	
Under 4	70%
4-5	11%
6-10	10%
10-50	8%
Over 50	1%
Mean	5.2 pieces
Average Weight/Piece	8.3 kg (18.7 lbs.)
Sample Size	2,873

- Figure 49 shows the distribution of pickup and delivery vehicle arrival times for office land use in six cities (26).

- The distribution of shipment weight for office land use in six cities (26):

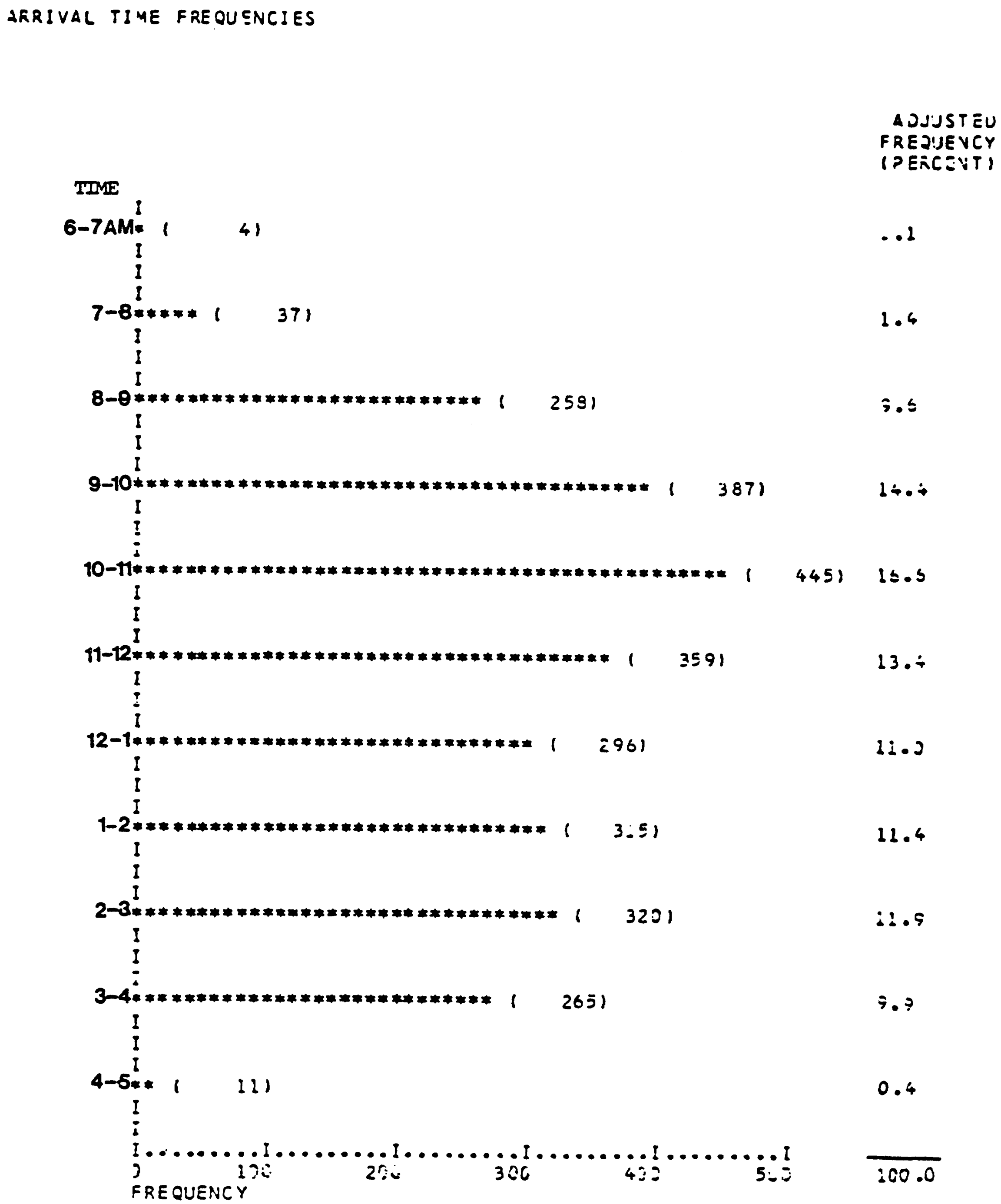
Weight	
Under 2 kg (4.4 lbs.)	29%
2-5 kg (4.4-11 lbs.)	16%
5-25 kg (11-55 lbs.)	27%
25-50 kg (55-110 lbs.)	11%
50-250 kg (110-550 lbs.)	14%
250-500 kg (550-1,100 lbs.)	2%
Over 500 kg (over 1,100 lbs.)	1%
Mean	44 kg (96.8 lbs.)

- Daily pattern for pickups and deliveries for office land use in New York City (29):

Day	
Monday	19%
Tuesday	21%
Wednesday	21%
Thursday	21%
Friday	18%
Saturday	0%

- Average vehicle dwell times for office land use pickup and delivery in New York City are (29):

[3] Boston, Dallas, Oklahoma City, Phoenix, San Francisco, St. Paul.



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure I5, p. 30.

Figure 49. Plot of Pickup and Delivery Arrival Time for Office Land Use.

	Deliveries	Pickups	All
Average Dwell Time (min.)	21	19	20
Pieces/Shipment	10	5	9
Weight/Shipment (kg)	238	165	223

- The distribution of pickup and delivery trips to office land use by vehicle type in New York City is light vehicles, 68 percent; medium vehicles, 31 percent; and heavy vehicles, 1 percent. Light vehicles include passenger cars, light pickup trucks, and walk-in panel trucks. Medium vehicles include single unit sanitation trucks. Heavy vehicles are tractor-trailer combinations (29).

- Data from the Brooklyn and Manhattan office building surveys were combined with dwell-time data collected for other large buildings in Manhattan. A plot of gross building size versus dwell time for pickup and delivery vehicles at these office buildings is shown in Figure 50 (29).

2. CBD land use: residential.[4]

- Weekly trip generation (26):

$$WG = 0.15 \times DU + 2.27 \qquad R^2 = .94$$

where:
WG = weekly trip generation
DU = dwelling units

See Figure 51.

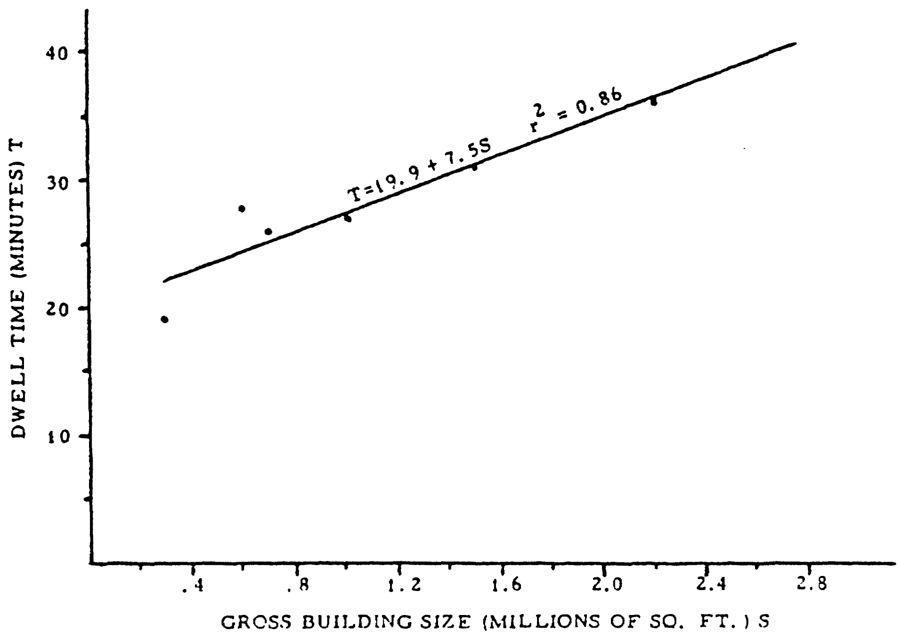
- Daily trip generation (26):

$$DG = 0.032 \times DU + 0.45 \qquad R^2 = .94, n = 87$$

where:
DG = daily trip generation
DU = dwelling unit

- Distribution of shipment size (number of pieces) for residential land use in six cities (26):

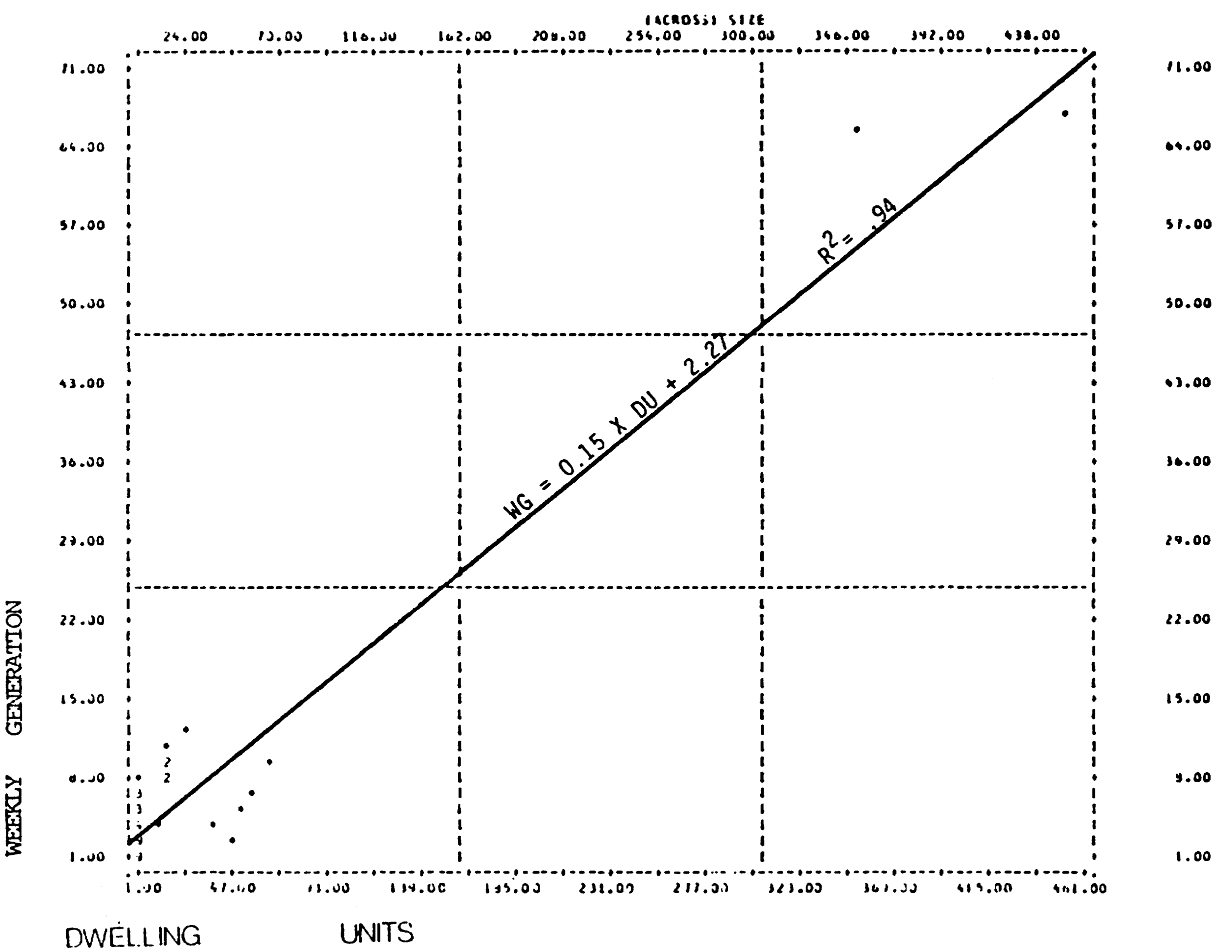
[4]Single family dwelling units were the predominant type of residence. Some small and large residential buildings also were included.



Source: Crowley, K. W., and P. A. Habib. *Mobility of People and Goods in the Urban Environment: Facilitation of Urban Goods Movement*, Report No. DOT-TST-76-90. Prepared for Office of University Research, U.S. Department of Transportation. Department of Transportation Planning and Engineering, Polytechnic Institute of New York, Brooklyn, NY, December 1975, Figure 3-1., p. 22.

Figure 50. Dwell Time Versus Size of Office Building in New York City.

RESIDENTIAL



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure 6, p. 17.

Figure 51. Plot of Weekly Pickup and Delivery Generation Versus Dwelling Unit for Residential Land Use.

Number of Pieces	
Under 4	79%
4-5	10%
6-10	7%
10-50	4%
Over 50	0%
Mean	3.8 pieces
Average Weight/Piece	10.3 kg
Sample Size	472

- Figure 52 shows the distribution of pickup and delivery vehicle arrival times for residential land use in six cities (26).

- Distribution of shipment weight for residential land use in six cities (26):

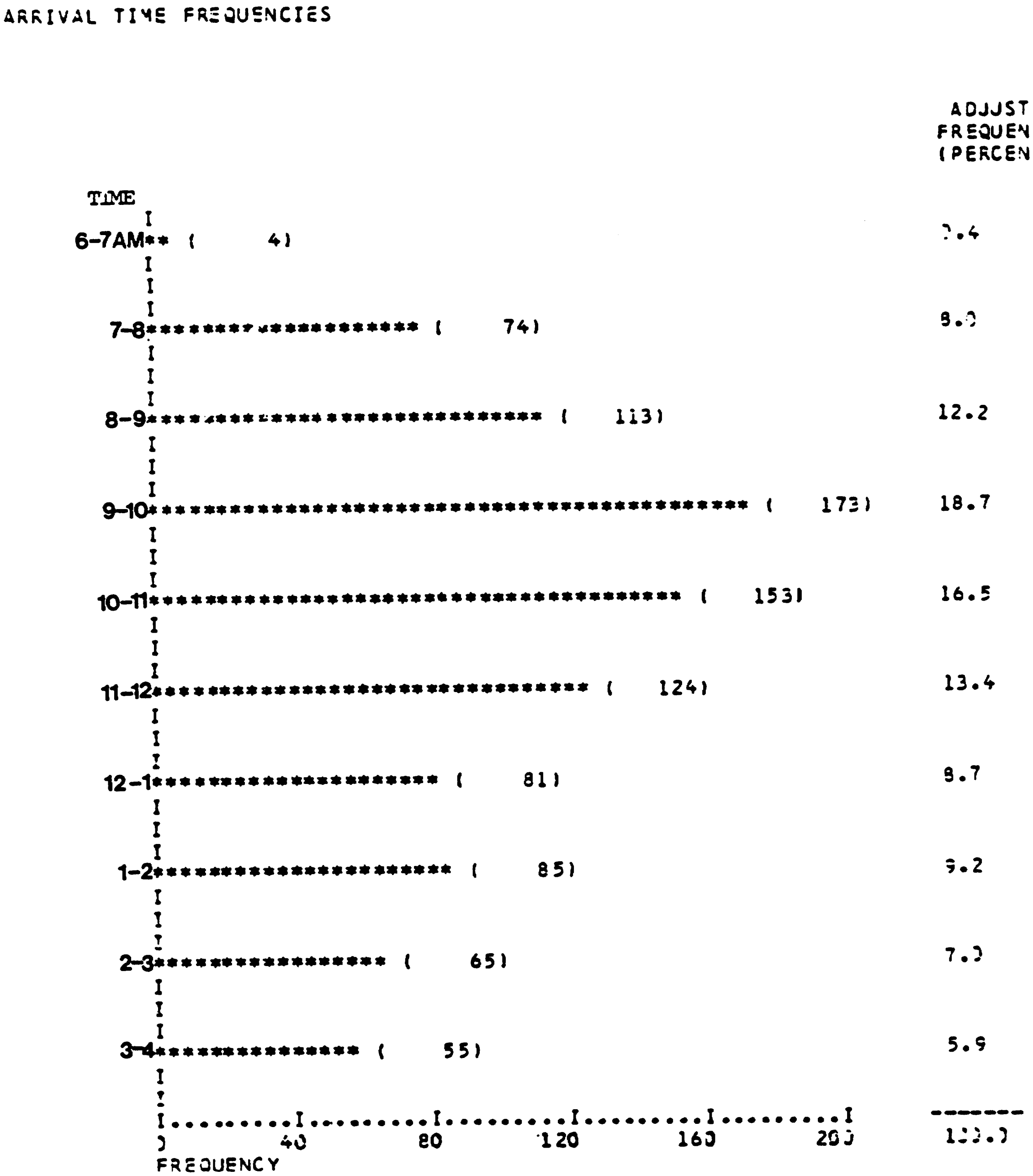
Weight	
Under 2 kg (4.4 lbs.)	34%
2-5 kg (4.4-11 lbs.)	13%
5-25 kg (11-55 lbs.)	34%
25-50 kg (55-110 lbs.)	9%
50-250 kg (110-550 lbs.)	5%
250-500 kg (550-1,100 lbs.)	2%
Over 500 kg (Over 1,100 lbs.)	3%
Mean	39 kg (86 lbs.)

- Daily pattern for pickups and deliveries for residential land use in New York City (29):

Day	
Monday	18%
Tuesday	16%
Wednesday	18%
Thursday	15%
Friday	22%
Saturday	11%

- Average vehicle dwell times for residential land use pickup and delivery in New York City are (29):

	Deliveries	Pickups	All
Average Dwell Time (min.)	9	6.5	8
Pieces/Shipment	3	6	4
Weight/Shipment (kg)	37	116	61



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure I6, p. 31.

Figure 52. Plot of Pickup and Delivery Arrival Time for Hotel and Residential Land Use.

- The distribution of pickup and delivery trips to residential land use by vehicle type in New York City is light vehicles, 81 percent; medium vehicles, 18 percent; and heavy vehicles, 1 percent. Light vehicles include passenger cars, light pickup trucks, and walk-in panel trucks. Medium vehicles include single unit and sanitation trucks. Heavy vehicles are tractor-trailer combinations.

3. CBD land use: light industry and warehousing.

- Weekly trip generation (26):

$$WG = 1.28 \times FA + 1.21 \times E + 5.2$$

where:

WG = weekly trip generation
FA = floor area (100 m^2)
E = Employment

See Figure 53.

- Weekly trip generation (26):

$$WG = 1.85 \times FA + 12.7 \qquad R^2 = .61$$

where:

WG = weekly trip generation
FA = floor area (100 m^2)

See Figure 54.

- Daily trip generation (23):

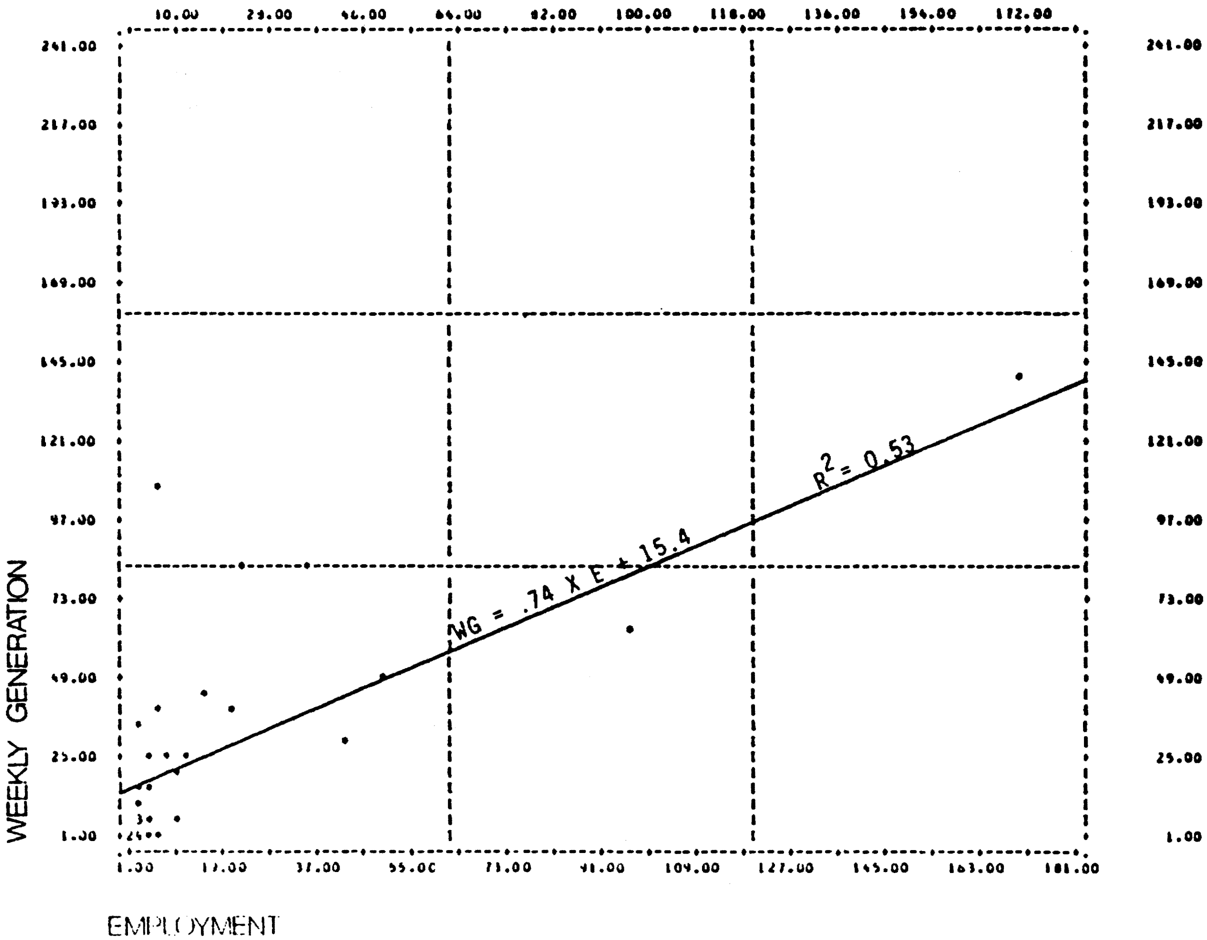
$$DG = 0.26 \times FA + 0.06 \times E + 2.4 \qquad R^2 = 0.64 \qquad n = 31$$

where:

DG = daily trip generation
FA = floor area (100 m^2)
E = employment

- Distribution of shipment size (number of pieces) for light industry and warehousing land use in six cities (26):

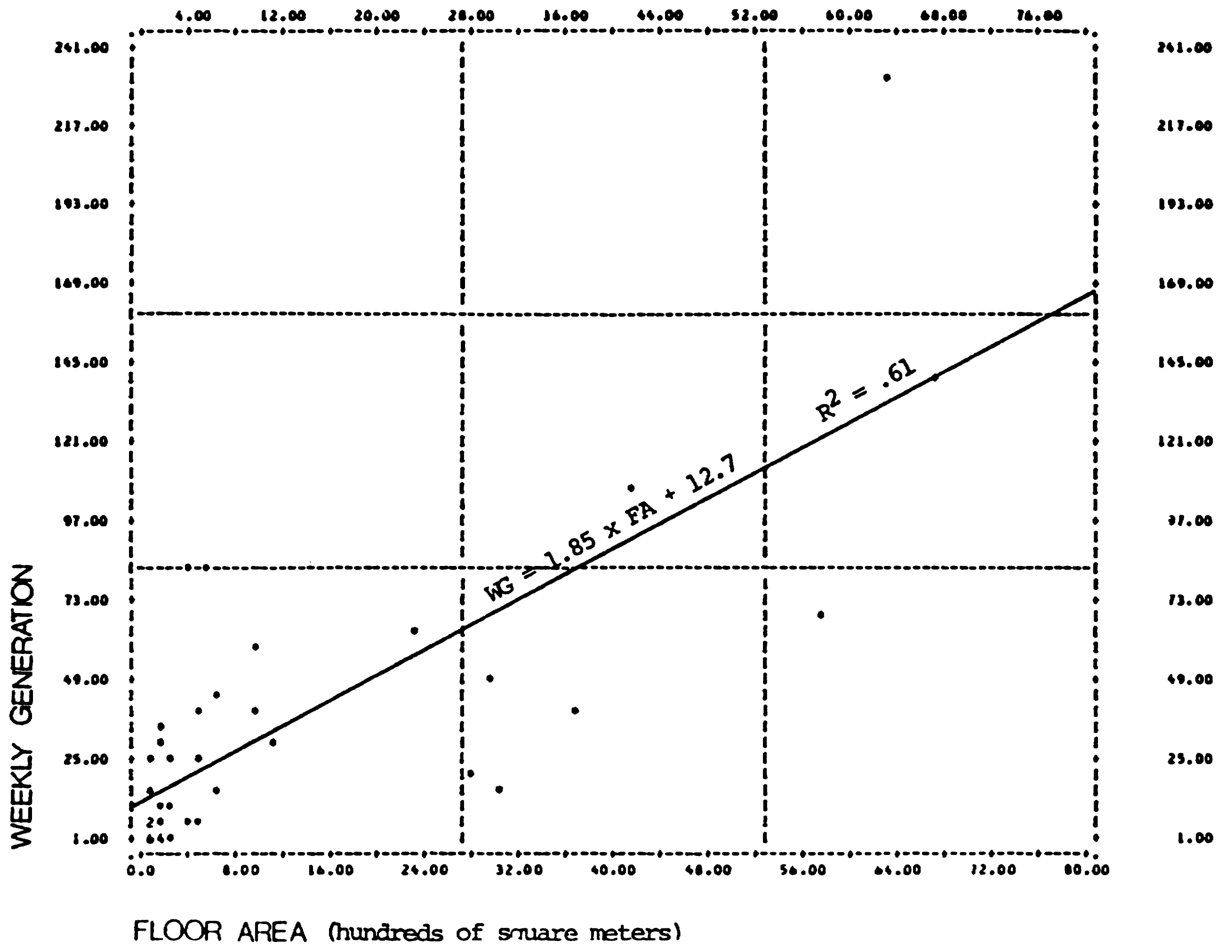
LIGHT INDUSTRIAL & WAREHOUSING



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure I0, p. 23.

Figure 53. Plot of Weekly Pickup and Delivery Generation Versus Employment for Light Industry and Warehousing Land Use.

LIGHT INDUSTRIAL & WAREHOUSING



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure II, p. 24.

Figure 54. Plot of Weekly Pickup and Delivery Arrival Generation Versus Floor Area for Light Industry and Warehousing Land Use.

Number of Pieces	
Under 4	53%
4-5	12%
6-10	13%
10-50	15%
Over 50	7%
Mean	22.6 pieces
Average Weight/Piece	11.7 kg (25.7 lbs.)
Sample Size	1,333

- Figure 55 shows the distribution of pickup and delivery vehicle arrival times for light industry and warehousing land use in six cities (26).

- Distribution of shipment weight for light industry and warehousing land use in six cities (26):

Weight	
Under 2 kg (4.4 lbs.)	16%
2-5 kg (4.4-11 lbs.)	12%
5-25 kg (11-55 lbs.)	21%
25-50 kg (55-110 lbs.)	12%
50-250 kg (110-550 lbs.)	22%
250-500 kg (550-1,100 lbs.)	7%
Over 500 kg (Over 1,100 lbs.)	10%
Mean	265 kg (583 lbs.)

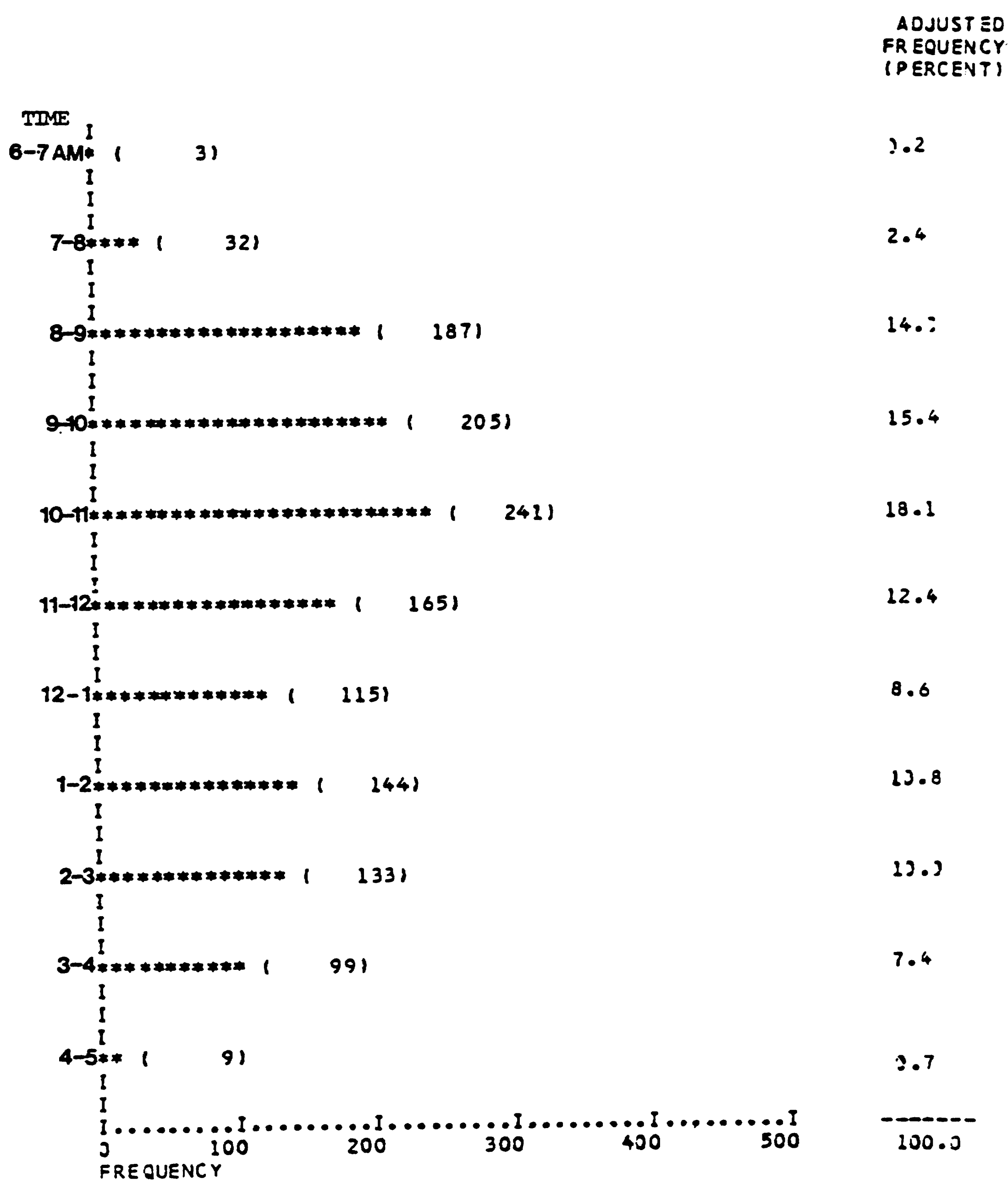
- Daily pattern for pickups and deliveries for light industry and warehousing land use in New York City (29):

Day	
Monday	25%
Tuesday	23%
Wednesday	15%
Thursday	19%
Friday	28%
Saturday	0%

- Average vehicle dwell times for light industry and warehousing land use pickup and delivery in New York City are (29):

	Deliveries	Pickups	All
Average Dwell Time (min.)	17.5	18	17.5
Pieces/Shipment	8	9	8
Weight/Shipment (kg)	302	500	363

ARRIVAL TIME FREQUENCIES



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure I8, p. 33.

Figure 55. Plot of Pickup and Delivery Arrival Time for Light Industry and Warehousing Land Use.

- The distribution of pickup and delivery trips to light industry and warehousing land use by vehicle type in New York City is light vehicles, 51 percent; medium vehicles, 47 percent; and heavy vehicles, 2 percent. Light vehicles include passenger cars, light pickup trucks, and walk-in panel trucks. Medium vehicles include single unit and sanitation trucks. Heavy vehicles are tractor-trailer combinations.

4. CBD land use: hotel.[5]

- Weekly trip generation (26):

$$WG = 0.30 \times RU - 12.0 \qquad R^2 = .96$$

where:
WG = weekly trip generation
RU = rental unit

See Figure 56.

- Daily trip generation (26):

$$DG = 0.06 \times RU - 2.4 \qquad R^2 = .96 \qquad n = 11$$

where:
DG = daily trip generation
RU = rental unit

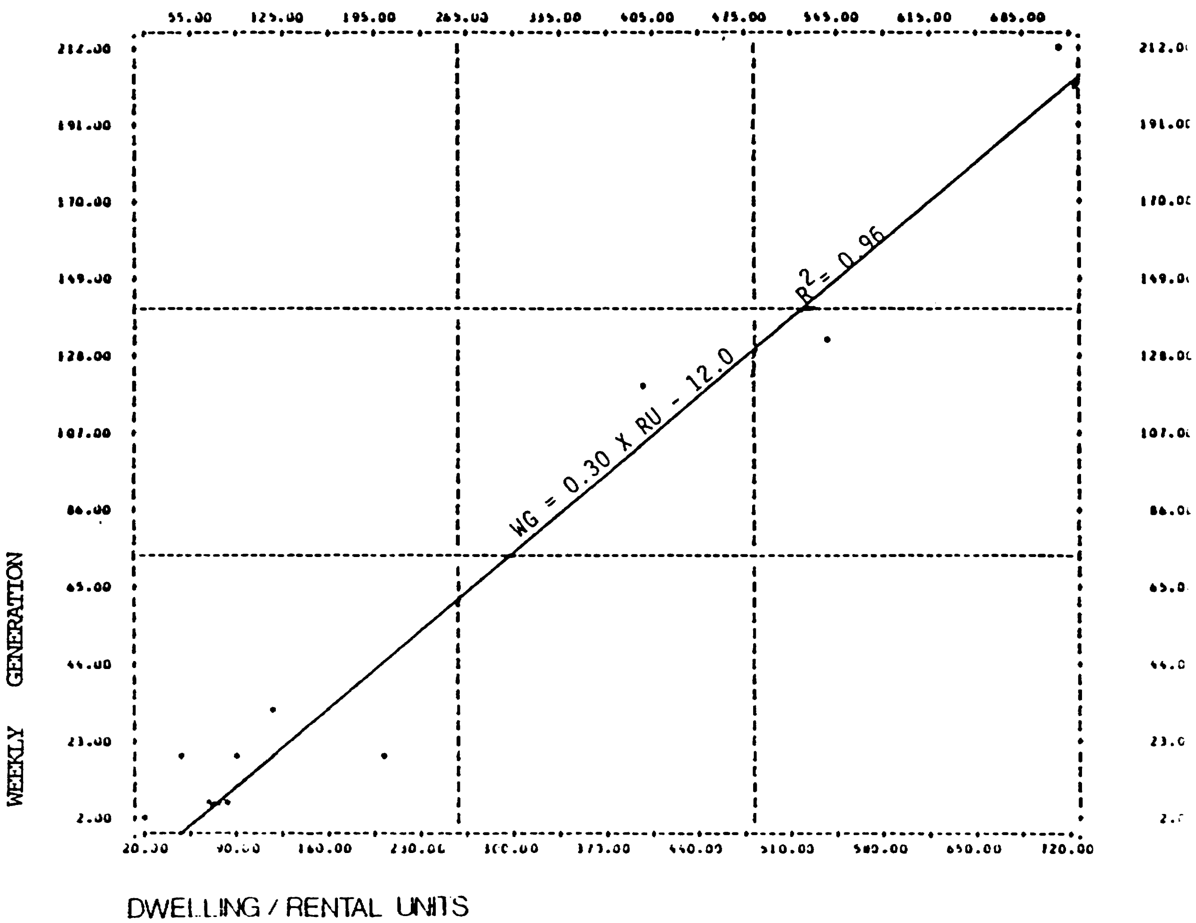
- Distribution of shipment size (number of pieces) for light hotel land use in six cities (26):

Number of Pieces	
Under 4	45%
4-5	13%
6-10	19%
10-50	20%
Over 50	3%
Mean	8.0 pieces
Average Weight/Piece	7.6 kg (16.7 lbs.)
Sample Size	535

- Figure 57 shows the distribution of pickup and delivery vehicle arrival times for hotel land use in six cities (26).

[5]Hotels with restaurants, shops, etc. Does not include boarding hotels.

HOTEL



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure 7, p. 19.

Figure 56. Plot of Weekly Pickup and Delivery Arrival Generation Versus Rental Units for Hotel Land Use.

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ARRIVAL TIME FREQUENCIES

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

ARRHR

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         FREQUENCY

VALID CASES      448        MISSING CASES       0
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HOTEL

Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, p. 102.

Figure 57. Plot of Pickup and Delivery Arrival Time for Hotel Land Use.

- Distribution of shipment weight for hotel land use in six cities (26):

Weight	
Under 2 kg (4.4 lbs.)	8%
2-5 kg (4.4-11 lbs.)	10%
5-25 kg (11-55 lbs.)	24%
25-50 kg (55-110 lbs.)	12%
50-250 kg (110-550 lbs.)	32%
250-500 kg (550-1,100 lbs.)	7%
Over 500 kg (Over 1,100 lbs.)	7%
Mean	120 kg (264 lbs.)

5. CBD land use: retail and services.[6]

- Weekly trip generation (26):

$$WG = 0.30 \times E + 8.2 \qquad R^2 = .74$$

where:
WG = weekly trip generation
E = employment

See Figure 58.

- Weekly trip generation (26):

$$WG = 0.53 \times FA + 9.5 \qquad R^2 = .57$$

where:
WG = weekly trip generation
FA = floor area (100 m^2)

See Figure 59.

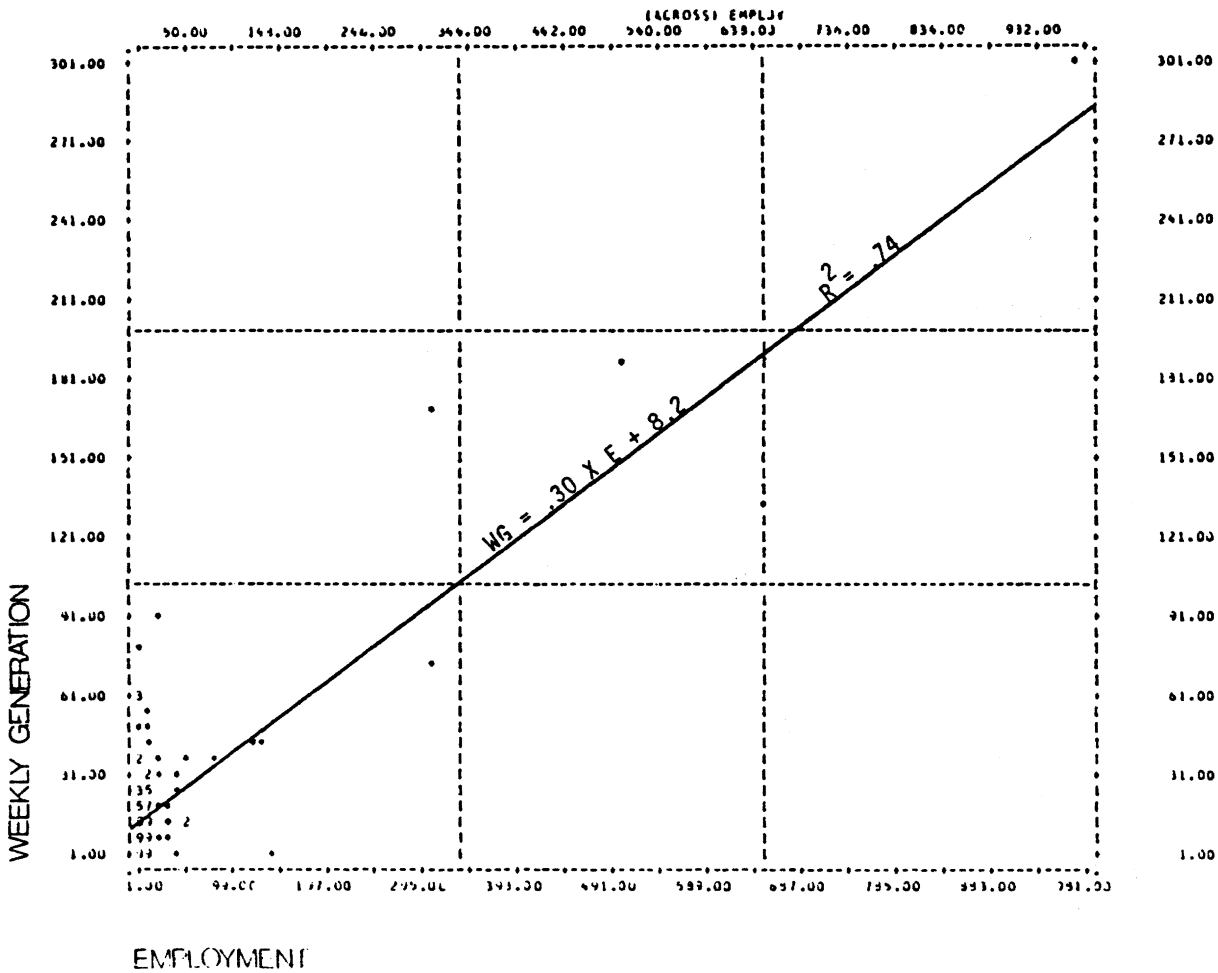
- Daily trip generation (26):

$$DG = .06 \times E + 1.6 \qquad R^2 = .74 \qquad n = 219$$

where:
DG = daily trip generation
E = employment

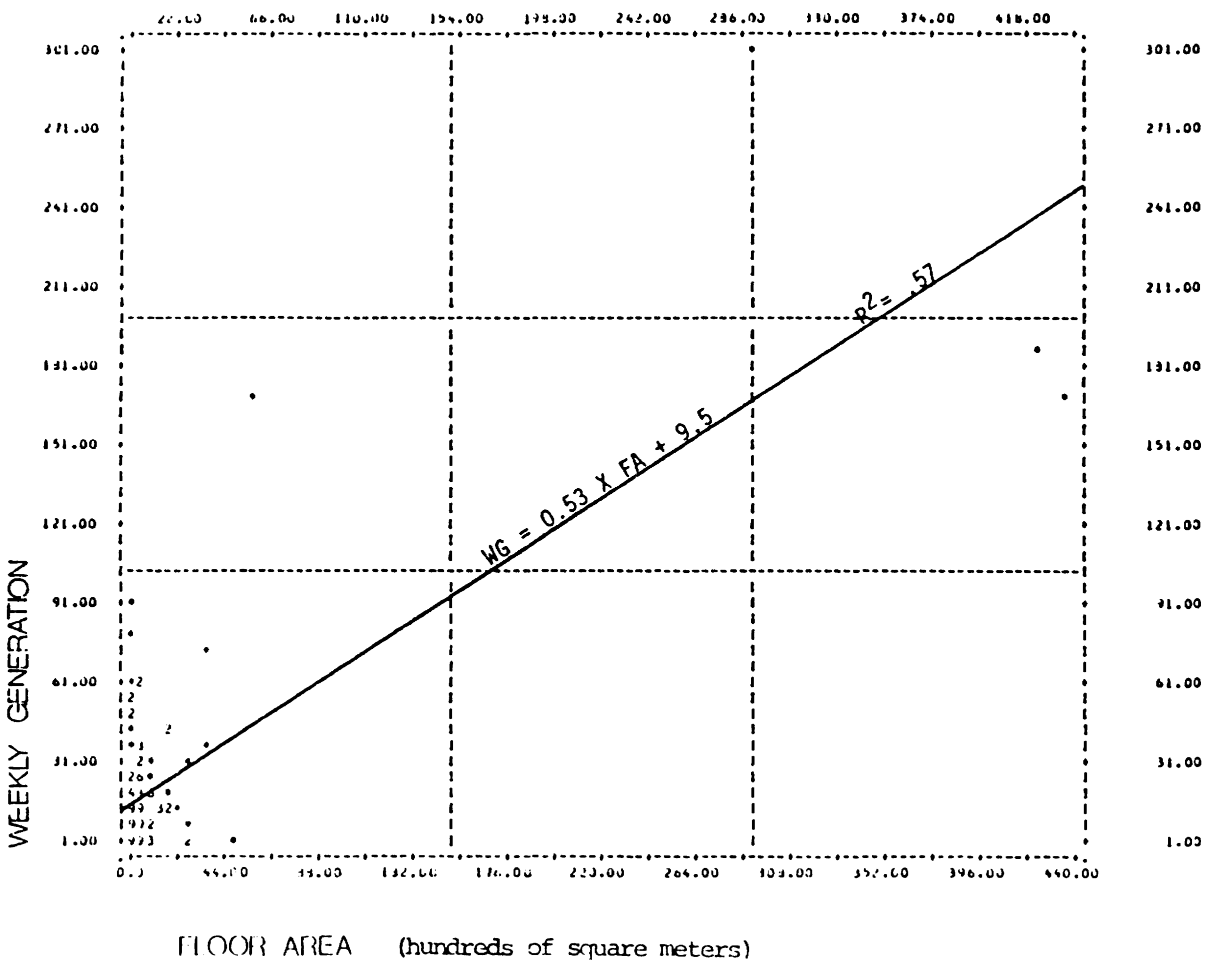
[6]Banks, stationery, clothing, department stores, drug stores, health and beauty aids, electronics, appliances, cameras, flowers, furniture, jewelry, liquor, novelties, shoes, bars, taverns, entertainment, garages, service stations, services (locksmith, shoe repair), miscellaneous.

RETAIL & SERVICES



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure I2, p. 25.

Figure 58. Plot of Weekly Pickup and Delivery Arrival Generation Versus Employment for Retail and Services Land Use.



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure I3, p. 26.

Figure 59. Plot of Weekly Pickup and Delivery Arrival Generation Versus Floor Area for Retail and Services Land Use.

- Distribution of shipment size (number of pieces) for retail and services land use in six cities (26):

Number of Pieces	
Under 4	60%
4-5	12%
6-10	13%
10-50	12%
Over 50	3%
Mean	11.8 pieces
Average Weight/Piece	8.1 kg (17.8 lbs.)
Sample Size	3,970

- Figure 60 shows the distribution of pickup and delivery vehicle arrival times for retail and services land use in six cities (26). Distributions of pickup and delivery vehicle arrival times for some specific classes of retail and service businesses are provided in Appendix C.

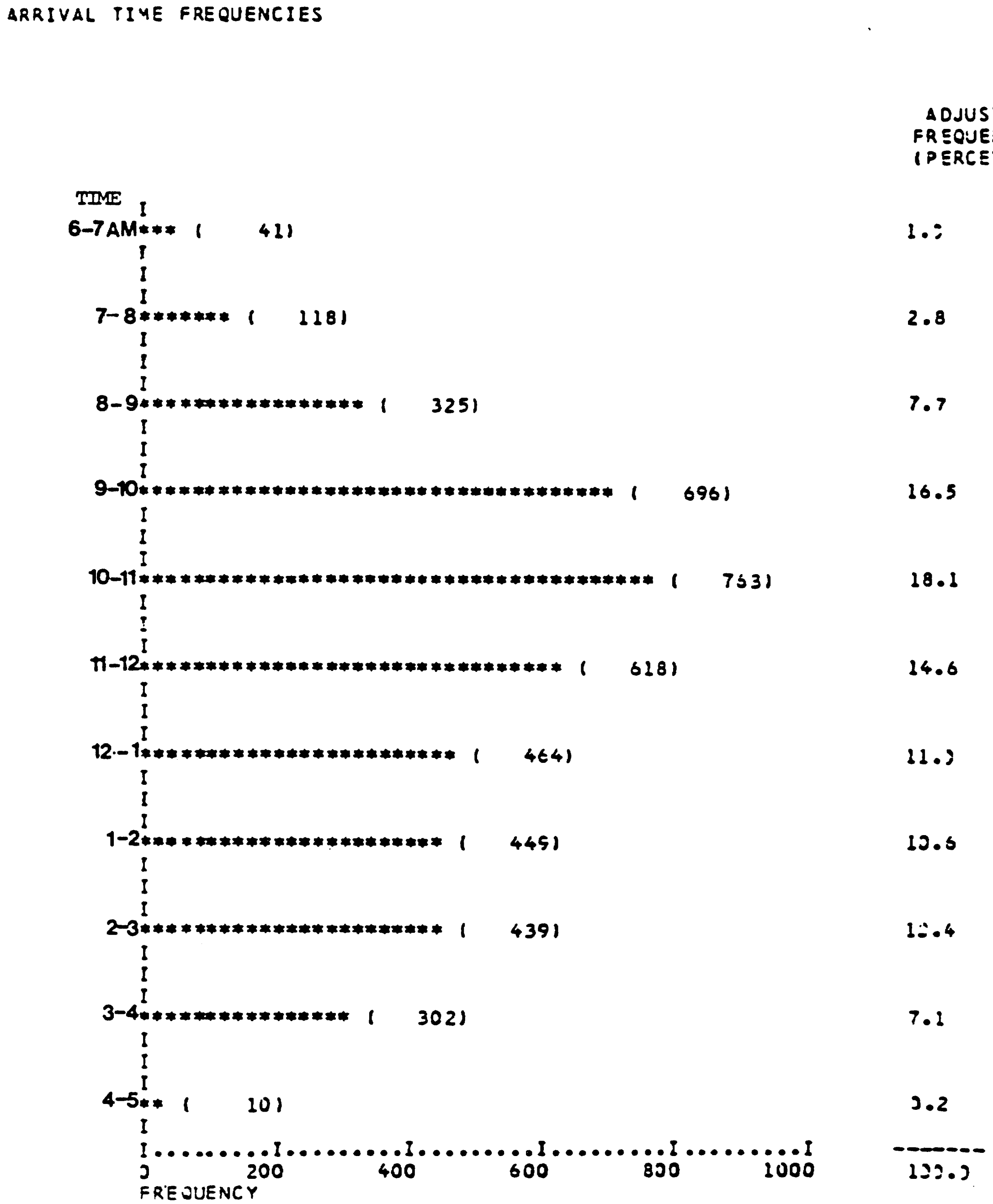
- Distribution of shipment weight for retail and services land use in six cities (26):

Weight	
Under 2 kg (4.4 lbs.)	22%
2-5 kg (4.4-11 lbs.)	14%
5-25 kg (11-55 lbs.)	26%
25-50 kg (55-110 lbs.)	13%
50-250 kg (110-550 lbs.)	18%
250-500 kg (550-1,100 lbs.)	3%
Over 500 kg (Over 1,100 lbs.)	4%
Mean	95 kg (209 lbs.)

- Daily pattern for pickups and deliveries for retail and services land use in six cities (26) and New York City (29):

Day	Six Cities	New York City
Monday	19%	19%
Tuesday	22%	17%
Wednesday	18%	19%
Thursday	21%	22%
Friday	20%	23%
Saturday	0%	0%

- Average vehicle dwell times for department store and other retail/commercial land use pickup and delivery in New York City (29) are shown in Table 53.



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure I9, p. 34.

Figure 60. Plot of Pickup and Delivery Arrival Time for Retail and Services Land Use.

Table 53. Average Dwell Time of Pickup and Delivery Vehicles at Department Store and Other Retail/Commercial Land Use in New York City.

	Deliveries	Pickups	All
Department Store (n = 3)			
Average Dwell Time (min.)	17	25.5	18
Pieces/Shipment	22	12	21
Weight/Shipment (kg)	485	799	523
Other Retail/Commercial			
Average Dwell Time (min.)	16.5	12	15.6
Soft Goods[1] (n = 17)			
Pieces/Shipment	15	17	15
Weight/Shipment (kg)	276	334	288
Hard Goods[2] (n = 29)			
Pieces/Shipment	16	6	13
Weight/Shipment (kg)	312	133	236

[1]Soft goods are shoes, men; shoes, women; shoes, all; wigs; clothes, men; clothes, women; clothes, all; miscellaneous personal services.

[2]Hard goods are furniture, jewelry, stationary, fabrics, appliances, flowers, drugstores, electronic and camera, banks, miscellaneous.

Source: Crowley, K. W., and P. A. Habib. *Mobility of People and Goods in the Urban Environment: Facilitation of Urban Goods Movement*, Report no. DOT-TST-76-90. Prepared for Office of University Research, U.S. Department of Transportation. Department of Transportation Planning and Engineering, Polytechnic Institute of New York, Brooklyn, NY, December 1975.

- The distribution of pickup and delivery trips for department store land use by vehicle type in New York City is light vehicles, 27 percent; medium vehicles, 67 percent; and heavy vehicles, 6 percent. The distribution of pickup and delivery trips for other retail/commercial land use by vehicle type in New York City is light vehicles, 43 percent; medium vehicles, 53 percent; and heavy vehicles, 4 percent. Light vehicles include passenger cars, light pickup trucks,s and walk-in panel trucks. Medium vehicles include single unit and sanitation trucks. Heavy vehicles are tractor-trailer combinations.

6. CBD land use: foods (retail and prepared).

- Weekly trip generation (26):

$$WG = 1.42 \times E + 7.2 \qquad R^2 = .22$$

where:
WG = weekly trip generation
E = employment

See Figure 61.

- Weekly trip generation (26):

$$WG = 3.09 \times FA + 10.9 \qquad R^2 = .11$$

where:
WG = weekly trip generation
FA = floor area

See Figure 62.

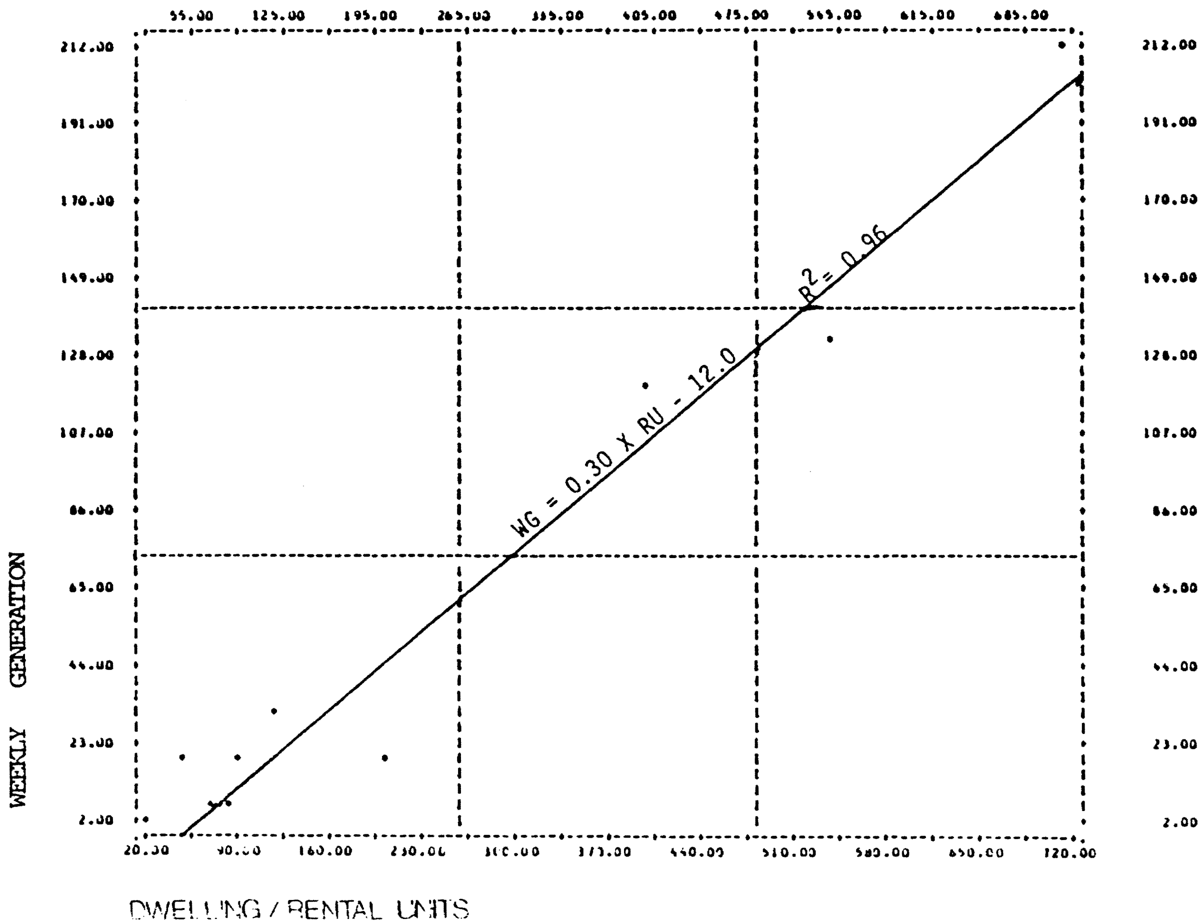
- Daily trip generation (26):

$$DG = 0.33 \times FA + 242 \times E + 1.04 \qquad R^2 = .25 \qquad n = 44$$

where:
DG = daily trip generation
E = employment
FA = floor area (100 m^2)

- Distribution of shipment size (number of pieces) for food (retail and prepared) land use in six cities (26):

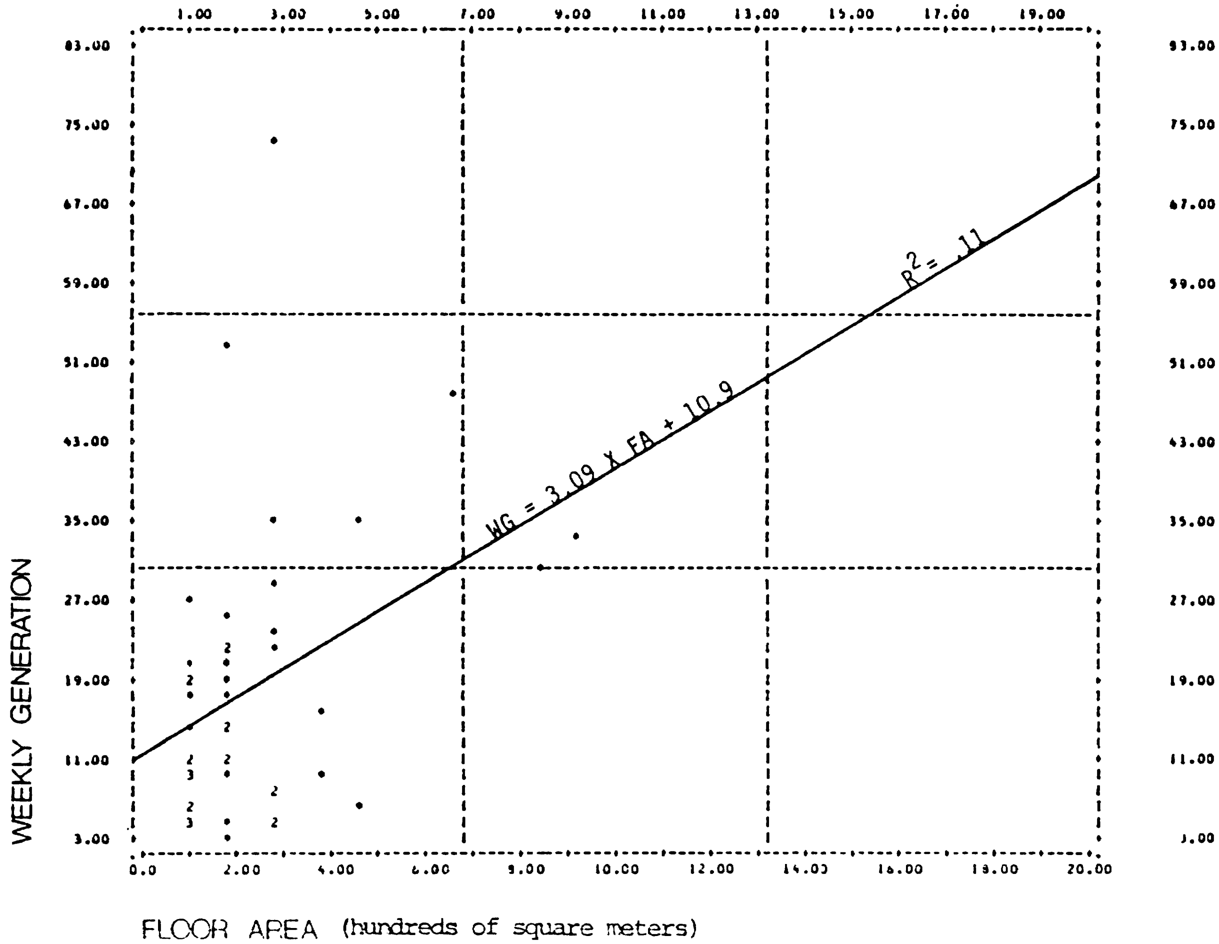
HOTEL



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure 8, p. 20.

Figure 61. Plot of Weekly Pickup and Delivery Arrival Generation Versus Employment for Foods Land Use.

FOOD ESTABLISHMENTS



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure 9, p. 21.

Figure 62. Plot of Weekly Pickup and Delivery Arrival Generation Versus Floor Area for Foods Land Use.

Number of Pieces	
Under 4	45%
4-5	13%
6-10	19%
10-50	20%
Over 50	3%
Mean	9.1 pieces
Average Weight/Piece	13.2 kg (29.0 lbs.)
Sample Size	539

- Figures 63-65 shows the distribution of pickup and delivery vehicle arrival times for food (retail and prepared) land use in six cities (26).

- Distribution of shipment weight for food (retail and prepared) land use in six cities (23):

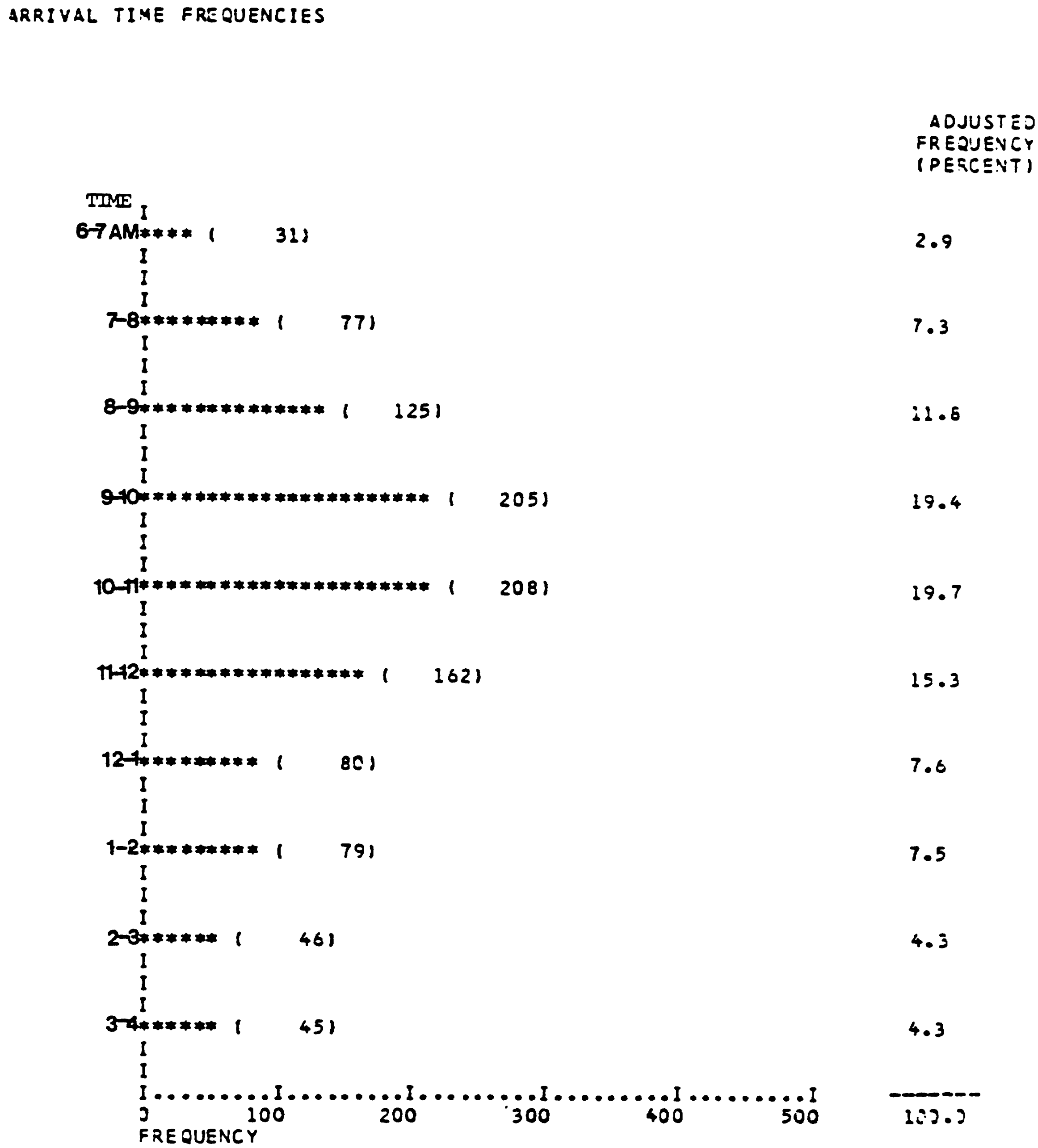
Weight	
Under 2 kg (4.4 lbs.)	8%
2-5 kg (4.4-11 lbs.)	10%
5-25 kg (11-55 lbs.)	24%
25-50 kg (55-110 lbs.)	12%
50-250 kg (110-550 lbs.)	32%
250-500 kg (550-1,100 lbs.)	7%
Over 500 kg (Over 1,100 lbs.)	7%
Mean	120 kg (264 lbs.)

- Daily pattern for pickups and deliveries for foods (retail) land use in New York City (29):

Day	
Monday	30%
Tuesday	20%
Wednesday	16%
Thursday	17%
Friday	17%
Saturday	0%

- Average vehicle dwell times for foods (retail) land use pickup and delivery in New York City are (29):

	Deliveries	Pickups	All
Average Dwell Time (min.)	21	22	21
Pieces/Shipment	19	7	18
Weight/Shipment (kg)	107	480	448



Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, Figure I7, p. 32.

Figure 63. Plot of Pickup and Delivery Arrival Time for Foods Land Use.

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ARRIVAL TIME FREQUENCIES

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VALID CASES      273      MISSING CASES      0
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FOOD (RETAIL)

Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, p. 99.

Figure 64. Plot of Pickup and Delivery Arrival Time for Foods (Retail) Land Use.

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ARRIVAL TIME FREQUENCIES

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

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          FREQUENCY

VALID CASES      785      MISSING CASES      0
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FOOD (PREPARED)

Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, p. 98.

Figure 65. Plot of Pickup and Delivery Arrival Time for Foods (Prepared) Land Use.

- The distribution of pickup and delivery trips to foods (retail) land use by vehicle type in New York City is light vehicles, 49 percent; medium vehicles, 44 percent; heavy vehicles, 7 percent. Light vehicles include passenger cars, light pickup trucks, and walk-in panel trucks. Medium vehicles include single unit and sanitation trucks. Heavy vehicles are tractor-trailer combinations.

- Daily pattern for pickups and deliveries for foods (prepared) land use in New York City (29):

Day	
Monday	22%
Tuesday	19%
Wednesday	24%
Thursday	17%
Friday	18%
Saturday	0%

- Average vehicle dwell times for foods (prepared) land use pickup and delivery in New York City are (29):

	Deliveries	Pickups	All
Average Dwell Time (min.)	12	14	12
Pieces/Shipment	6	9	6
Weight/Shipment (kg)	164	377	174

- The distribution of pickup and delivery trips to foods (prepared) land use by vehicle type in New York City is light vehicles, 55 percent; medium vehicles, 45 percent. Light vehicles include passenger cars, light pickup trucks, and walk-in panel trucks. Medium vehicles include single unit and sanitation trucks.

D. Neighborhood Business Districts

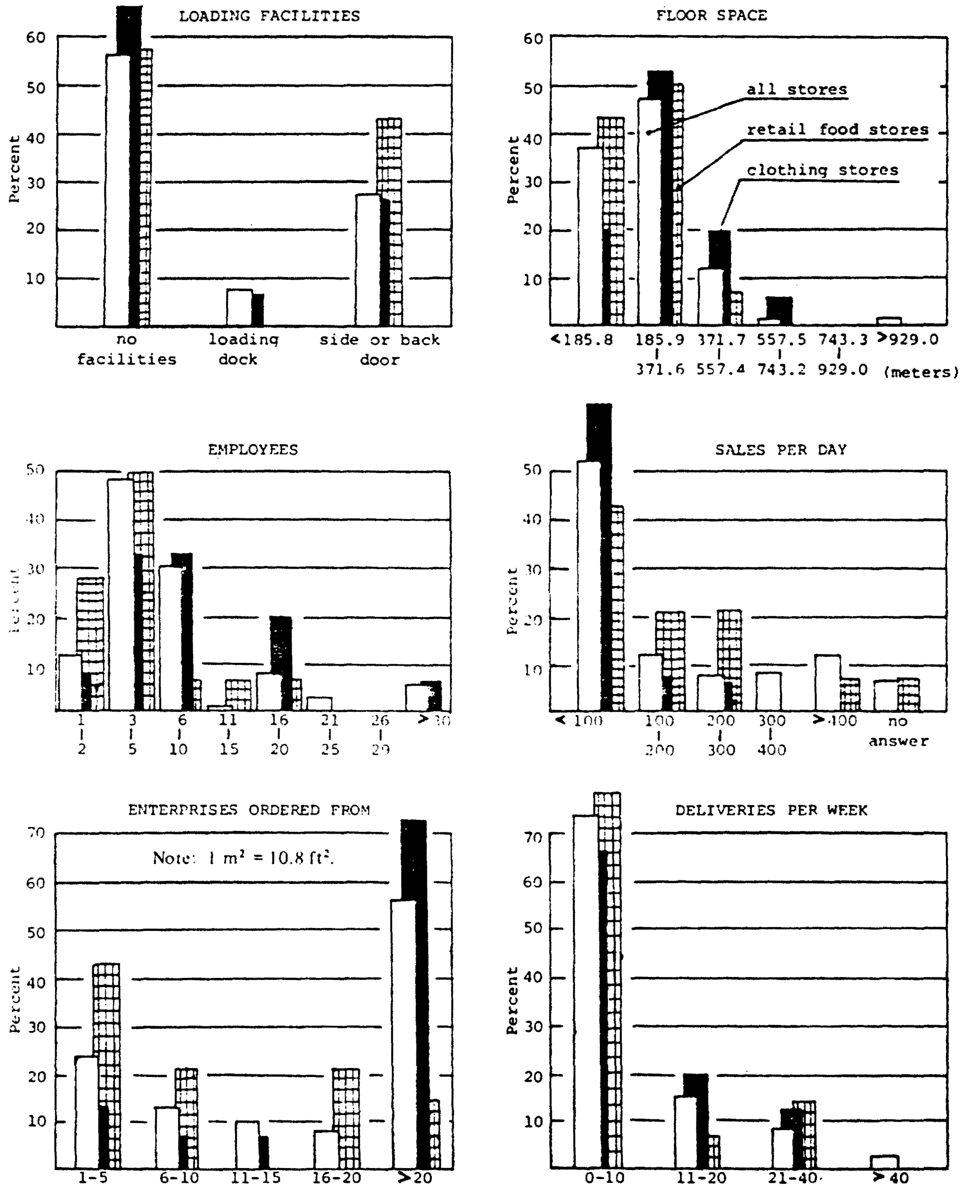
1. Weekly trip generation (30):

$$WG = 0.21 \times EN + 0.58 \times E \qquad n = 59$$

Where:
E = number of employees
EN = number of enterprises delivering

2. Figure 66 shows deliveries per week in a small commercial district[7] in Pittsburgh (30).

[7]Based on the Squirrel Hill business district on Murray Avenue and Forbes Avenue in Pittsburgh, PA.



Source: Ahrens, Gerd A., Keith W. Forstall, Raymond U. Guthrie, and Byron J. Ryan. "Analysis of Truck Deliveries in a Small Business District." *Transportation Research Record*, No. 637, 1977, Figure 1, p. 83.

Figure 66. Distribution of Business Survey Responses in Pittsburgh.

3. Table 54 lists establishment characteristics of businesses surveyed in a small commercial district in Pittsburgh (30).

4. Figure 67 shows the distribution of pickup and delivery vehicle delivery times in a small commercial district in Pittsburgh.

5. Figure 67 also shows the distribution of pickup and delivery vehicle dwell times in a small commercial district in Pittsburgh.

6. Figure 68 shows the daily pickup and delivery vehicle stops and deliveries in a small commercial district in Pittsburgh.

7. Delivery times (30):

$$T = 4.453 + 0.177 \times P + 0.007 \times W \qquad R^2 = .68 \qquad n = 167$$

where:

T = delivery time (minutes)
P = number of packages
W = Total weight

E. **Government Facilities**

1. Land use: office.

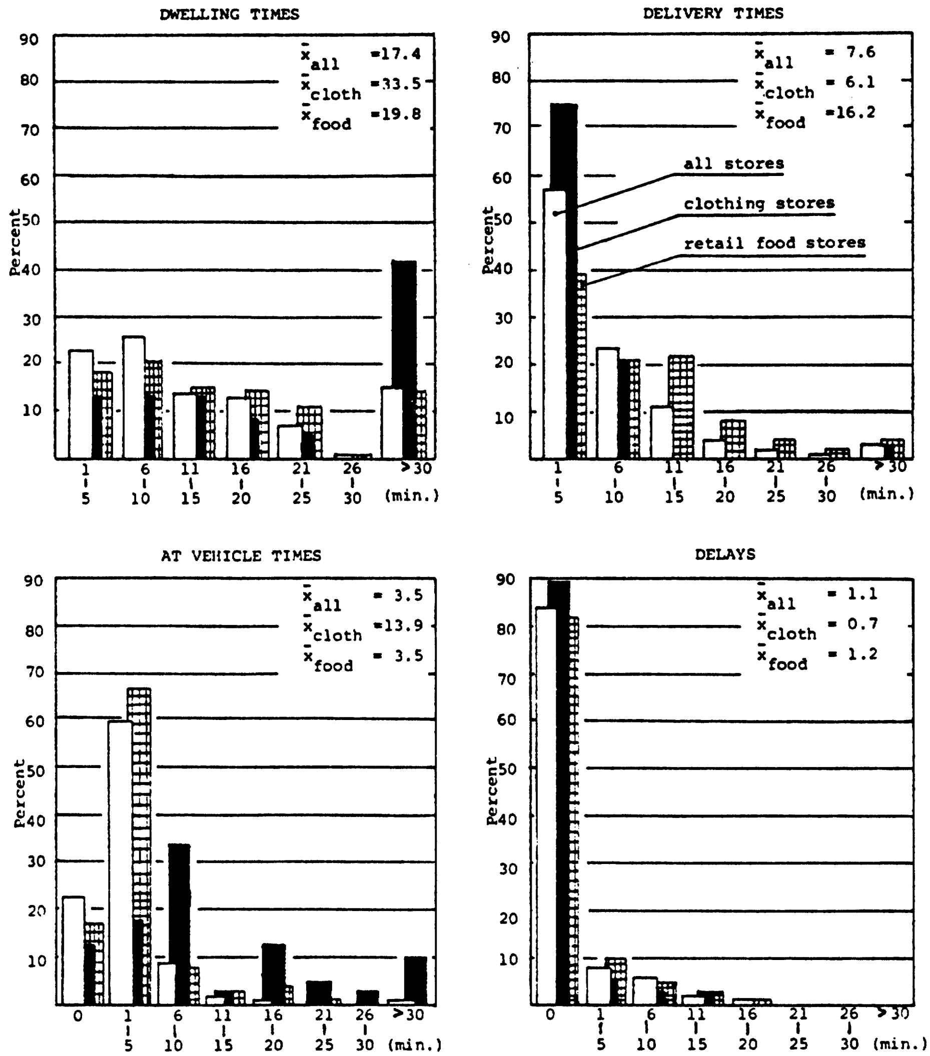
- Table 55 shows the number of service trips per employee and by floor area at six Washington, D.C., government facilities, including the Department of Commerce, Hoffman Building, National Bureau of Standards, Naval Research Laboratory, Pentagon, and Veterans Administration Hospital (31). These rates are lower than for commercial office space because of the greater consolidation of goods by government warehouses. In planning facilities the government uses a value of 0.013 service trips per employee per day.

- The distribution of arrival times is shown below:

Table 54. Establishment Characteristics of Stores in a Small Commercial District in Pittsburgh.

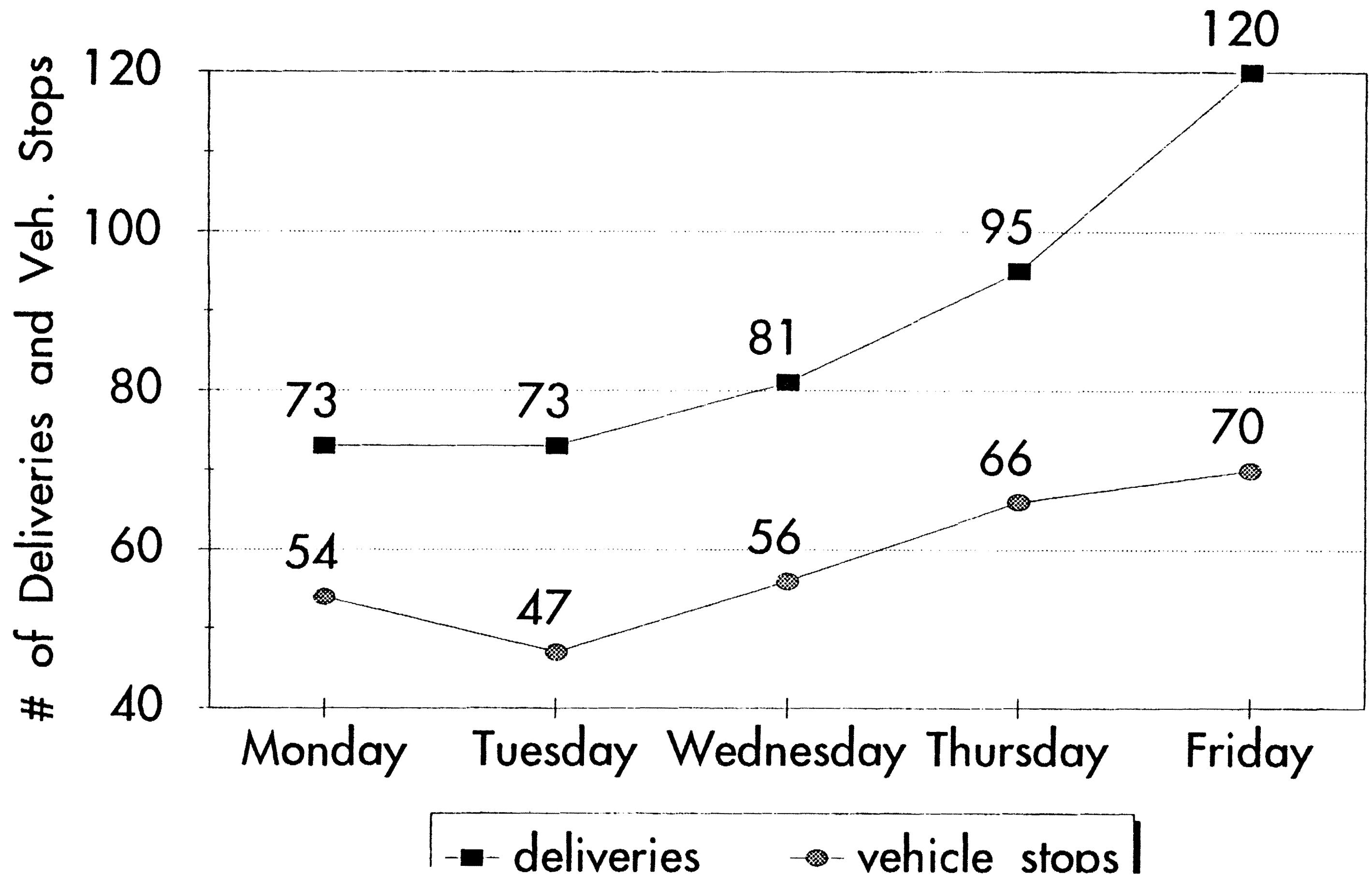
Characteristic	All Stores (n = 59) (%)	Retail Food Stores (n = 14) (%)	Clothing Stores (n = 15) (%)
Loading Facilities			
No facilities	58	57	66
Loading Dock	8	0	7
Side/back door	28	43	27
Number of Employees			
1-2	12	28	9
3-5	47	50	33
6-10	29	7	33
11-15	1	7	0
16-20	7	8	20
Over 20	4	0	7
Floor Space (sq. ft.)			
<2,000	37	43	20
2,000-4,000	47	50	53
4,000-6,000	12	7	20
6,000-8,000	1	0	7
>8,000	3	0	0

Source: Ahrens, Gerd A., Keith W. Forstall, Raymond U. Guthrie, and Byron J. Ryan. "Analysis of Truck Deliveries in a Small Business District." *Transportation Research Record*, No. 637, 1977, pp. 81-86.



Source: Ahrens, Gerd A., Keith W. Forstall, Raymond U. Guthrie, and Byron J. Ryan. "Analysis of Truck Deliveries in a Small Business District." *Transportation Research Record*, No. 637, 1977, Figure 3, p. 84.

Figure 67. Comparison of Delivery Characteristics in a Small Business District in Pittsburgh.



Source: Ahrens, Gerd A., Keith W. Forstall, Raymond U. Guthrie, and Byron J. Ryan. "Analysis of Truck Deliveries in a Small Business District." *Transportation Research Record*, No. 637, 1977, estimated numbers based on Figure 2, p. 84.

Figure 68. Daily Vehicle Stops and Deliveries in a Small Business District in Pittsburgh.

Table 55. Service Trip Rates for Government Office Facilities, Washington, D.C.

Location	Truck Trips per Employee	All Service and Supply Vehicle Trips per Employee	Truck Trips per 1,000 sq. ft. of Office Space
Department of Commerce	0.014	0.019	0.065
National Bureau of Standards	0.017	0.021	—
Naval Research Laboratory	0.013	0.014	0.036
Pentagon	0.008	0.009	0.046
Hoffman Building	0.007	0.007	0.041
Veterans Administration Hospital	0.007	0.015	0.028

Source: Spielberg, Frank, and Steven A. Smith. "Service and Supply Trips at Federal Institutions in Washington, D.C., Area." *Transportation Research Record*, No. 834, 1977, Tables 2 and 3, p. 17.

Arrival Time	Percent of Daily Arrivals[8]
7:00-8:00 a.m.	6.7
8:00-9:00 a.m.	8.0
9:00-10:00 a.m.	17.7
10:00-11:00 a.m.	19.3
11:00-12:00 a.m.	12.7
12:00-1:00 p.m.	3.7
1:00-2:00 p.m.	9.0
2:00-3:00 p.m.	12.0
3:00-4:00 p.m.	8.3
4:00-5:00 p.m.	1.7

The peak arrival activity at all sites occurred between 9:30 and 10:30 a.m. (31).

- Approximately 52 percent of all deliveries are more than 100 pounds and 48 percent of all deliveries are under 100 pounds. (31).[9]

- The distribution of vehicle types making deliveries to government facilities in Washington, D.C., is automobile/pickup truck/van, 48.8 percent; single unit truck, 37.7 percent; and semitrailer, 13.5 percent (31).[9]

- The mean duration of stay for vehicles making deliveries is 38.8 minutes (31).[9]

- The distribution of trip purposes is shown below:

Trip Purpose	Percent of Trips
Pickup	25.3
Delivery	63.6
Pickup and Delivery	8.0
Service Call	2.3
Service Call and Pickup and Delivery	0.8

- The distribution of types of commodities and services is shown below (31)[9]:

[8]Average of the individual averages for the National Bureau of Standards, Naval Research Laboratory, and Pentagon.

[9]Average of the individual averages for the Department of Commerce, Hoffman Building, National Bureau of Standards, Naval Research Laboratory, Pentagon, and Veterans Administration Hospital.

Commodity/Service	Percent of Trips
Commodity	
Mail and trash	13.5
Food and beverages	15.2
Hard goods	39.7
Paper	12.8
Other	3.3
Service	
Utilities	3.2
Office equipment	6.2
Vending machine	1.3
Other	4.3

2. Land use: warehouse and garage facilities.

- Table 56 shows the number of service trips per employee and by floor area at six Washington, D.C., government facilities, including Cameron Station, Government Printing Office (GPO) North Capitol Street, GPO Franconia, GPO Eisenhower, and National Park Service Maintenance Depot (31). These rates are lower than for commercial office space because of the greater consolidation of goods by government warehouses. In planning facilities the government uses a value of 0.15 service trips per employee per day.

- The distribution of arrival times is shown below:

Arrival Time	Percent of Daily Arrivals[10]
7:00-8:00 a.m.	6.0
8:00-9:00 a.m.	12.0
9:00-10:00 a.m.	18.5
10:00-11:00 a.m.	17.5
11:00-12:00 a.m.	14.0
12:00-1:00 p.m.	6.5
1:00-2:00 p.m.	9.5
2:00-3:00 p.m.	8.0
3:00-4:00 p.m.	8.0
4:00-5:00 p.m.	0.0

[10]Average of the individual averages for Cameron Station and GPO North Capitol.

Table 56. Service Trip Rates for Government Warehouse and Garage Facilities, Washington, D.C.

Location	Truck Trips per Employee	All Service and Supply Vehicle Trips per Employee	Truck Trips per 1,000 sq. ft. of Office Space
Cameron Station	0.038	0.037	0.149
GPO, North Capital	0.019	0.033	0.148
GPO, Franconia	1.235	1.235	0.115
GPO, Eisenhower	0.107	0.107	0.137
National Park Service	0.889	—	—

Source: Spielberg, Frank, and Steven A. Smith. "Service and Supply Trips at Federal Institutions in Washington, D.C., Area." *Transportation Research Record*, No 834, 1977, Tables 2 and 3, p. 17.

- Approximately 38 percent of all deliveries are < 100 lbs. and 62 percent of all deliveries are > 100 lbs. (31).[11]

- The distribution of vehicle types making deliveries to government facilities in Washington, D.C., is automobile/pickup truck/van, 32.2 percent; single unit truck, 31.3 percent; and semitrailer, 36.5 percent (31).[11]

- The mean duration of stay for vehicles making deliveries is 55 minutes (31).[11]

- The distribution of trip purposes is shown below:

Trip Purpose	Percent of Trips
Pickup	14.0
Delivery	60.8
Pickup and Delivery	13.7
Service Call	8.7
Service Call and Pickup and Delivery	2.8

- The distribution of types of commodities and services is shown below (31):[11]

Commodity/Service	Percent of Trips
Commodity	
Mail and trash	10.8
Food and beverages	9.8
Hard goods	13.5
Paper	55.5
Other	6.0
Service	
Utilities	1.5
Office equipment	0.8
Vending machine	1.0
Other	1.1

F. Suburban Establishments

1. Table 57 presents a distribution of truck stops by land use observed in a suburban area of Baltimore (32).

2. Table 58 presents a distribution of truck stop trip rates by land use observed in a suburban area of Baltimore (32).

[11]Average of the individual averages Cameron Station, GPO North Capitol, GPO Franconia, and GPO Eisenhower.

Table 57. Distribution of Truck Stops by Land Use
in a Suburban Area of Baltimore.

Land Use	Number of Observations	Average Truck Stops		
		Total	Delivery	Customer
Prepared Foods	24	12.4	7.6	4.3
Carry Out/Deli	10	15.9	7.8	7.6
Restaurant/Chain	9	9.8	5.3	2.9
Variety/Pharmacy	8	8.0	7.4	0.1
Personal Services	22	4.2	3.3	0.1
Office Buildings	9	13.8	11.1	0.6
Soft Retail	14	4.9	4.7	0.0
Retail Food	18	32.4	-	-
Miscellaneous	9	8.8	4.6	1.7

Source: Larry Reich, Warren Anderson, and Peggy Drake. *Baltimore Truck Trip Attraction Study*. Department of Planning, City of Baltimore, MD, August 1987.

Table 58. Distribution of Truck Stops per 1,000 Square Feet of Floor Space by Land Use in a Suburban Area of Baltimore.

Land Use	Number of Observations	Truck Stops per 1,000 Sq. Ft.		
		Total	Delivery	Customer
Prepared Foods				
Average	24	3.9	2.4	1.3
High		61.4	9.6	52.5
Low		0.7	0.4	0.0
Carry Out/Deli	10	8.0	3.9	3.8
Restaurant/Chain	9	2.3	1.3	0.7
Variety/Pharmacy				
Average	8	0.6	0.5	0.1
High		10.9	10.0	0.4
Low		0.1	0.1	0.0
Personal Services				
Average	22	2.3	1.8	0.05
High		5.7	5.7	1.4
Low		0.5	0.5	0.0
Office Buildings				
Average	9	0.2	0.2	0.01
High		4.0	4.0	0.02
Low		0.1	0.1	0.0
Soft Retail				
Average	14	2.0	2.0	0.0
High		16.7	16.7	0.0
Low		0.4	0.3	0.0
Retail Food				
Average	18	5.2	-	-

Source: Larry Reich, Warren Anderson, and Peggy Drake. *Baltimore Truck Trip Attraction Study*. Department of Planning, City of Baltimore, MD, August 1987.

3. Table 59 presents a distribution of truck peak accumulation rates by land use observed in a suburban area of Baltimore (32).

4. Table 60 presents truck trip rates for suburban commercial and office land uses in Tampa, FL (33).

G. Industrial Establishments

1. Truck trip rates by type of firm at nonresidential inner city industrial areas. Table 61 shows truck trip rates for the Sunset Park Industrial Area in Brooklyn, NY (34).

2. Truck trip rates for air cargo facilities. Table 62 shows truck trip rates for air cargo facilities at JFK International Airport in New York (34).

3. Truck trip rates for pickup and delivery at industrial establishments.

    - Table 63 shows truck trip rates for industrial establishments in Fontana, CA (35).

    - Table 60 shows truck trip rates for industrial sites in Tampa, FL (33).

4. Truck trip rates for wholesale establishments.

    - Table 64 shows truck trip end rates for wholesale establishments in four cities — Knoxville, TN; Modesto, CA; Rochester, NY; and Saginaw, MI (36).

    - Table 65 shows truck trip end rates for wholesale establishments by vehicle class in four cities (36).

    - The distribution of truck trip ends for wholesale establishments by day of week in four cities are shown below (n = 22) (36):

Day	
Monday	21.6%
Tuesday	21.9%
Wednesday	19.2%
Thursday	20.0%
Friday	17.3%

    - Figure 69 shows the hourly distribution of truck trip ends by truck type for wholesale establishments in four cities (36).

    - Table 66 shows truck trip end rates for wholesale establishments by trip purpose in four cities (36).

Table 59. Peak Truck Accumulation Rates by Land Use in a Suburban Area of Baltimore.

Land Use	% Large Vehicles[1]	Peak Accumulation		
		% of Total Daily Stops	Peak Hour	Rate per 1000 Sq. Ft. Floor Space
Prepared Foods				
Average	30.6			
High	82.4			
Low	0.0			
Carry Out/Deli		0.17	9:00 a.m.	1.3
Restaurant/Chain		0.22	9:00 a.m.	0.5
Variety/Pharmacy				
Average	26.6	0.10	11:00 a.m.	0.1
High	60.0			
Low	8.3			
Personal Services				
Average	9.7	0.23	10:00 a.m.	0.5
High	50.0			
Low	0.0			
Office Buildings				
Average	12.9	0.27	10:00 a.m.	0.1
High	37.5			
Low	0.0			
Soft Retail				
Average	7.4	0.32	10:00 a.m.	0.6
High	25.0			
Low	0.0			
Retail Food				
Average	35.4	0.31	9:00 a.m.	0.5
High	73.9			
Low	0.0			

[1]Large vehicles are trucks other than delivery vans and pickup trucks.

Source: Larry Reich, Warren Anderson, and Peggy Drake. *Baltimore Truck Trip Attraction Study*. Department of Planning, City of Baltimore, MD, August 1987.

Table 60. Truck Trip Rates per Employee by Land Use in Tampa.

		Truck Trips per Employee[1]		
Land Use		Light Trucks	Heavy Trucks	Peak Hour
Commercial (5 sites)	Average	0.178	0.047	9:15 a.m.-10:15 a.m.
	High	0.432	0.075	
	Low	0.071	0.009	
Office (5 sites)	Average	0.038	0.009	11:00 a.m.-12:00 p.m.
	High	0.075	0.015	
	Low	0.019	0.003	
Industrial (5 sites)	Average	0.285	0.164	8:30 a.m.-9:30 a.m.
	High	0.718	0.335	
	Low	0.077	0.039	

[1]based on a 12-hour count (6:00 a.m.-6:00 p.m.) of vehicles entering and exiting. Employess include all workers classified as commercial, service, and industrial employment at each site regardless of site type.

Source: Gannett Fleming, Inc., Tindale-Oliver snd Associates, Inc., and Resources Systems Group. *Technical Memorandum No. 2, Truck/Taxi Travel Survey.* Gannett Fleming, Inc., Tampa, FL, July 1993, Tables 2, A-1, A-2, and A-3.

Table 61. Truck Trip Rates for the Sunset Park Industrial Area of Brooklyn, NY.

Type of Firm	n	Number of Workers per Firm	Truck Trips per Day per Firm	Truck Trips per Day per Employee
Manufacturer	17	92	18	0.19
Manufacturer and/or Distributor	7	159	21	0.13
Food Preparation	1	100	150	1.50
Trucking	1	200	400	2.0
Retail	1	50	50	1.0
Other	8	55	11	.20

Source: Table 3, Sunset Park Industrial Area Case Study, data from Transportation Issues Survey Summary, furnished by New York Metropolitan Transportation Council., New York, NY.

Table 62. Truck Trip Rates for the Air Cargo Operations at JFK International Airport.

Type of Firm	n	Number of Workers per Firm	Truck/Van Trips per Day per Firm	Truck/Van Trips per Day per Employee
Courier	3	35	26	0.75
Forwarder	9	39	27	0.67
Broker	5	20	22	0.91
Trucking	1	20	10	0.5
Total/Average	18	33	25	0.73

Source: Table 6, JFK Air Cargo Area, data from Transportation Issues Survey Summary, furnished by New York Metropolitan Transportation Council., New York, NY.

Table 63. Trips Rates for Industrial Establishments, Fontana, CA.

Time Period/Land Use	Independent Variable	Auto	2 & 3 Axle Trucks	4, 5, & 6+ Axle Trucks	All Trucks	Total
Weekdays						
Light Industry	TSF[1]	3.02	0.33	0.27	0.60	3.60
Heavy Industry[2]	TSF	2.51	0.19	0.38	0.56	3.07
	Acre	67.11	11.90	8.63	20.53	87.66
Industrial Park	TSF	1.90	0.21	0.15	0.36	2.23
Morning Peak Hour						
Light Industry	TSF	0.57	0.03	0.02	0.05	0.62
Heavy Industry	TSF	0.22	0	0.02	0.02	0.23
	Acre	17.33	0	0.03	0.03	17.39
Industrial Park	TSF	0.28	0.01	0	0.01	0.29
Afternoon Peak Hour						
Light Industry	TSF	0.22	0.01	0	0.01	0.24
Heavy Industry	TSF	0.19	0.03	0.03	0.06	0.24
	Acre[3]	1.10	0.58	0.08	0.66	1.76
Industrial Park	TSF	0.24	0.02	0.02	0.04	0.28
Site Peak Hour, Weekdays						
Light Industry	TSF	0.59	0.03	0.02	0.05	0.64
Heavy Industry	TSF	0.27	0.02	0.03	0.05	0.31
	Acre	17.39	0.08	0.08	0.16	17.55
Industrial Park	TSF	0.31	0.01	0	0.01	0.33

[1]Building area in thousand square feet.

[2]Results based on two sites only.

[3]Use caution as manual counts encompass only up to 4:30 p.m.

Source: Tadi, Ramakrishna R., and Paul Balbach. "Truck Trip Generation Characteristics of Nonresidential Land Uses." *ITE Journal*, 64(7), July 1994, Tables 2-5, pp. 45-46.

Table 64. Truck Trip End Rates for Wholesale Establishments in Four Cities.[1]

Establishment Type	Truck Trip Ends per day	Truck Trip Ends per Day per 10,000 Sq. Ft. Floor Area	Truck Trip Ends per Day per Employee
Grocery	42.4 (n = 11)	6.8 (n = 11)	0.56 (n = 10)
Hardware	19.2 (n = 3)	2.4 (n = 3)	0.32 (n = 3)
Other	7.2 (n = 8)	4.8 (n = 8)	0.48 (n = 8)
Total	26.5 (n = 22)	5.5 (n = 22)	0.50 (n = 21)

[1]Knoxville, TN; Modesto, CA; Rochester, NY; and Saginaw, MI.

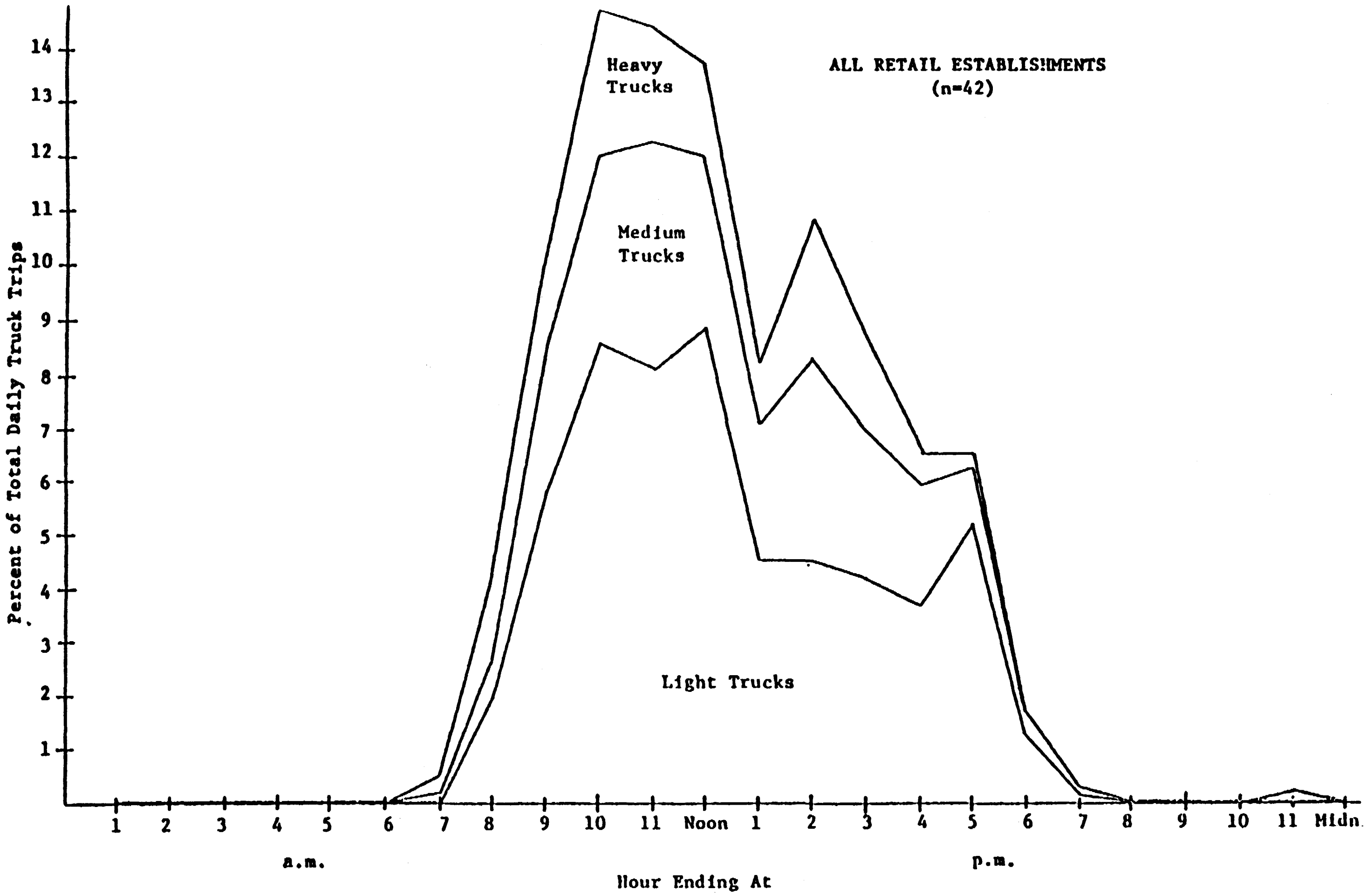
Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements*. Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Table 6-6, p. 157.

Table 65. Truck Trip End Rates by Vehicle Class for Wholesale Establishments in Four Cities.[1]

Vehicle Class	Wholesale Establishments Grocery (n = 11)	Hardware (n = 3)	Other (n = 8)	Total (n = 11)
Panel-Pickup	3.6 (8.5%)	5.7 (29.7%)	2.3 (31.5%)	3.4 (12.8%)
Single Unit, Single Rear Tire	0.5 (1.2%)	1.4 (7.3%)	0.2 (2.7%)	0.5 (1.9%)
Single Unit, Dual Rear Tire	11.5 (27.1%)	8.3 (43.2%)	2.8 (38.4%)	7.9 (29.8%)
Single Unit, 3 and 4 Axle	0.8 (1.9%)	0.1 (0.5%)	0.0 (0.0%)	0.4 (1.5%)
Small Combination Unit	1.3 (3.1%)	0.5 (2.6%)	0.4 (5.5%)	0.9 (3.4%)
Over-the-Road Combination	24.6 (58.0%)	3.1 (16.1%)	1.6 (21.9%)	13.3 (50.2%)
All Trucks	42.4	19.2	7.3	26.5

[1]Knoxville, TN; Modesto, CA; Rochester, NY; and Saginaw, MI.

Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements*. Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Table 6-6, p. 157.



Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements.* Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Figure 6-1, p. 142.

Figure 69. Hourly Distribution of Truck trip Ends by Truck Type for Wholesale Establishments.

Table 66. Truck Trip End Rates by Trip Purpose for Wholesale Establishments in Four Cities.[1]

Trip Purpose	Wholesale Establishments			
	Grocery (n = 11)	Hardware (n = 3)	Other (n = 8)	Total (n = 11)
Pickup Goods	1.8 (4.2%)	4.9 (25.5%)	0.8 (11.0%)	1.9 (7.2%)
Deliver Goods	32.6 (76.9%)	12.3 (64.1%)	5.4 (74.0%)	19.9 (75.1%)
Pickup and Deliver Goods	0.4 (0.9%)	0.8 (4.2%)	0.1 (1.4%)	0.4 (1.5%)
Service Call	0.2 (0.5%)	0.1 (0.5%)	0.2 (2.7%)	0.1 (0.4%)
Personal Business	0.1 (0.2%)	0.0 (0.0%)	0.0 (0.0%)	0.1 (0.4%)
Base of Operations	7.3 (17.2%)	1.1 (5.7%)	0.8 (11.0%)	4.1 (15.5%)
Other	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)	0.0 (0.0%)
All Trucks	42.4	19.2	7.3	26.5

[1]Knoxville, TN; Modesto, CA; Rochester, NY; and Saginaw, MI.

Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements.* Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Table 6-4, pp. 151-152.

5. Truck trip rates for warehouse establishments. Table 67 shows truck trip rates for warehouse establishments in Fontana, CA (35).

6. Truck trip rates for truck terminal establishments.

   - Table 68 shows truck trip rates for truck terminal establishments in Fontana, CA (35).

   - The distribution of truck trip ends for terminals by vehicle class in four cities is shown in Table 69 (36):

   - The distribution of truck trip ends for terminals by day of week in four cities is shown below (36):

Day	
Monday	18.9%
Tuesday	20.6%
Wednesday	20.5%
Thursday	20.4%
Friday	19.6%

   - Figure 70 shows the hourly distribution of truck trip ends by truck type for terminals in four cities (36).

   - Table 70 shows truck trip end rates for terminals by trip purpose in four cities (36).

H. Downtown Retail Establishments

1. Table 71 shows truck trip end rates for downtown retail establishments in four cities (36).

2. Table 72 shows truck trip end rates for downtown retail establishments by vehicle class in four cities (36).

3. The distribution of truck trip ends for downtown retail establishments by day of week in four cities are shown below (n = 42) (36):

Day	
Monday	19.5%
Tuesday	20.4%
Wednesday	19.5%
Thursday	21.1%
Friday	19.5%

Table 67. Trips Rates for Industrial Establishments, Fontana, CA.

Time Period/Land Use	Independent Variable	Auto	2 & 3 Axle Trucks	4, 5, & 6+ Axle Trucks	All Trucks	Total
Weekday						
Light	TSF[1]	0.79	0.17	0.21	0.37	1.17
Heavy	TSF	1.20	0.10	0.27	0.37	1.60
Morning Peak Hour						
Light	TSF	0.11	0.01	0.02	0.03	0.15
Heavy	TSF	0.07	0.01	0.01	0.02	0.10
Afternoon Peak Hour						
Light	TSF	0.06	0.01	0.02	0.03	0.09
Heavy	TSF	0.13	0	0.01	0.01	0.15
Site Peak Hour, Weekday						
Light	TSF	0.12	0.03	0.03	0.06	0.17
Heavy	TSF	0.30	0.01	0.03	0.04	0.32

[1]Building area in thousand square feet.

Source: Tadi, Ramakrishna R., and Paul Balbach. "Truck Trip Generation Characteristics of Nonresidential Land Uses." *ITE Journal*, 64(7), July 1994, Tables 2-5, pp. 45-46.

Table 68. Trips Rates for Truck Terminal Establishments, Fontana, CA.

Time Period/Land Use	Independent Variable	Auto	2 & 3 Axle Trucks	4, 5, & 6+ Axle Trucks	All Trucks	Total
Weekday						
Truck Terminal	Acre	22.38	7.34	28.47	35.81	54.76
Truck Sales and Leasing	TSF[1]	27.80	6.95	1.79	8.74	36.60
	Acre	500.20	-	-	-	651.00
Morning Peak Hour						
Truck Sales and Leasing	TSF	2.41	0.64	0.11	0.75	3.16
	Acre	8.26	1.16	0.35	1.51	9.90
Afternoon Peak Hour						
Truck Terminal	Acre	0.95	0.36	1.66	2.02	3.17
Truck Sales and Leasing	TSF	2.32	0.52	0.08	0.60	2.96
	Acre	9.32	1.91	0.80	2.71	12.03
Site Peak Hour, Weekday						
Truck Terminal	Acre	2.34	0.67	1.73	2.40	4.74
Truck Sales and Leasing	TSF	2.35	1.22	0.25	1.47	3.99
	Acre	10.92	3.41	1.58	4.99	15.90

[1]Building area in thousand square feet.

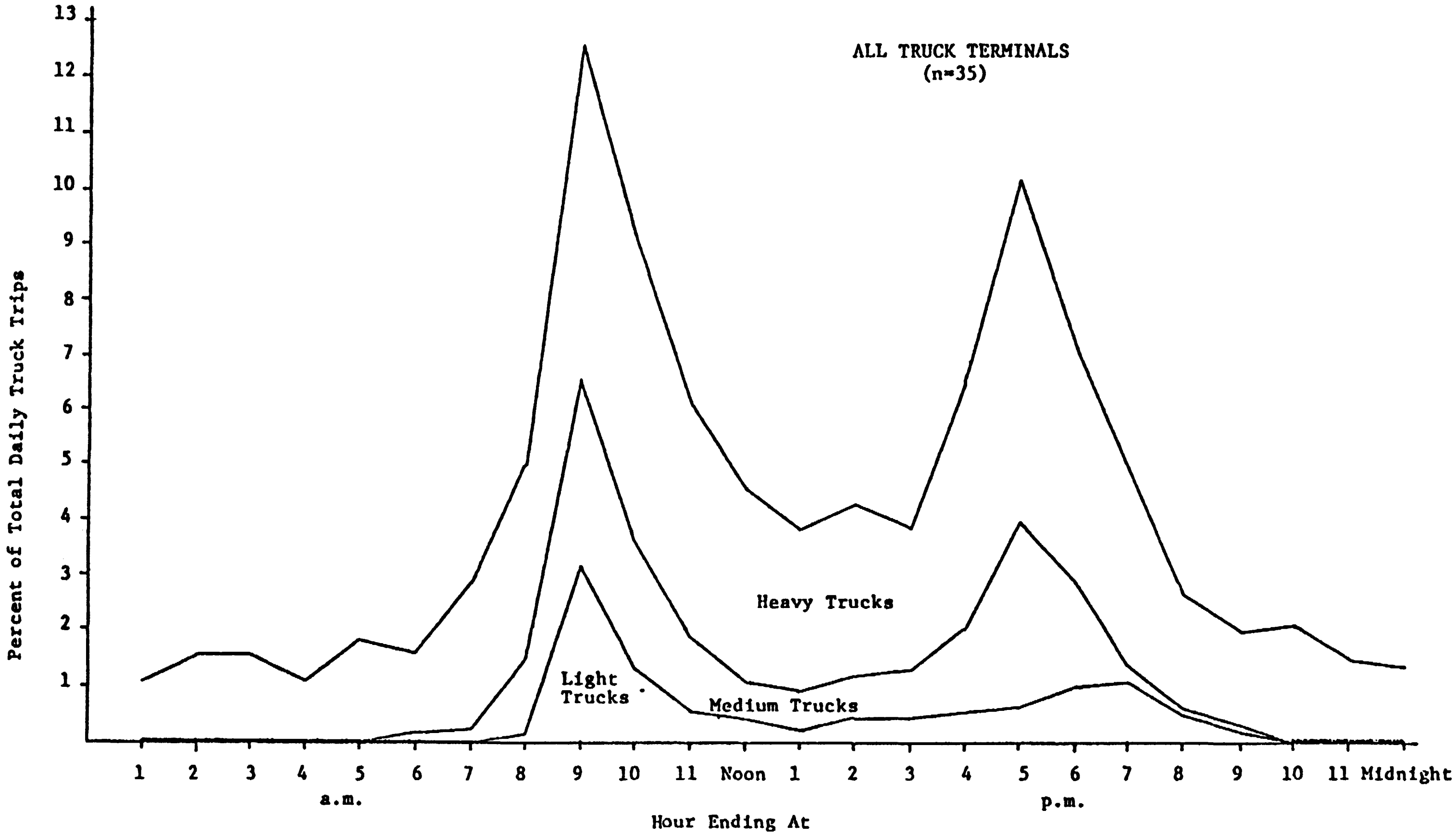
Source: Tadi, Ramakrishna R., and Paul Balbach. "Truck Trip Generation Characteristics of Nonresidential Land Uses." *ITE Journal*, 64(7), July 1994, Tables 2-5, pp. 45-46.

Table 69. Truck Trip End Rates by Vehicle Class for Truck Terminal Establishments in Four Cities.[1]

Truck Type	Total (n = 34)
Panel-Pickup	4.0 (9.1%)
Single Unit-Single Rear Tire	0.6 (1.4%)
Single Unit-Dual Rear Tire	8.0 (18.3%)
Single Unit-3 and 4 Axle	0.5 (1.1%)
Small Combination Unit	4.0 (9.1%)
Over-the-Road Combination	26.7 (61.0%)
All Trucks	43.8

[1]Knoxville, TN; Modesto, CA; Rochester, NY; and Saginaw, MI.

Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements.* Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Table 6-3, pp. 147-148.



Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements.* Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Figure 6-2, p. 143.

Figure 70. Hourly Distribution of Truck Trip Ends by Truck Type for Truck Terminal Establishments.

Table 70. Truck Trip End Rates by Trip Purpose for Truck Terminal Establishments in Four Cities.[1]

	Truck Terminals			
Trip Purpose	Common Carrier (n = 29)	Local Cartage (n = 4)	Other (n = 1)	Total (n = 34)
Pickup Goods	4.4 (9.3%)	2.6 (12.1%)	2.6 (7.5%)	4.1 (9.4%)
Deliver Goods	17.0 (36.0%)	6.8 (31.6%)	3.0 (8.6%)	15.4 (35.2%)
Pickup and Deliver Goods	9.7 (20.6%)	2.1 (9.8%)	0.6 (1.7%)	8.5 (19.4%)
Service Call	0.6 (1.3%)	0.3 (1.4%)	10.2 (29.3%)	0.9 (2.1%)
Personal Business	0.2 (0.4%)	0.2 (0.9%)	7.2 (20.7%)	0.4 (0.9%)
Base of Operations	10.1 (21.4%)	7.0 (32.6%)	11.0 (31.6%)	9.7 (22.1%)
Other	5.3 (11.2%)	2.5 (11.6%)	0.2 (0.6%)	4.8 (11.0%)
All Trucks	47.2	21.5	34.8	43.8

[1]Knoxville, TN; Modesto, CA; Rochester, NY; and Saginaw, MI.

Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements.* Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Table 6-4, pp. 150-151.

Table 71. Truck Trip End Rates for Downtown Retail Establishments in Four Cities.[1]

Establishment Type	Truck Trip Ends per day	Truck Trip Ends per Day per 10,000 Sq. Ft. Floor Area	Truck Trip Ends per Day per Employee
General Merchandise	17.7 (n = 16)	6.0 (n = 13)	0.18 (n = 13)
Apparel and Accessories	2.5 (n = 12)	2.3 (n = 11)	0.15 (n = 10)
Furniture	7.2 (n = 5)	2.0 (n = 5)	0.48 (n = 5)
Other	16.4 (n = 9)	13.9 (n = 9)	0.98 (n = 9)
Total	11.8 (n = 42)	6.3 (n = 38)	0.40 (n = 37)

[1]Knoxville, TN; Modesto, CA; Rochester, NY; and Saginaw, MI.

Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements*. Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Table 6-6, p. 157.

Table 72. Truck Trip Ends for Downtown Retail Establishments in Four Cities.[1]

	Truck Type	Average Trip Rate
Truck Trip Ends per Day	Light	6.7 (n = 42)
	Medium	3.1 (n = 42)
	Heavy	1.9 (n = 42)
	Total	11.8 (n = 42)
Truck Trip Ends per Day per 10,000 Square Feet of Floor Area	Light	4.6 (n = 38)
	Medium	1.3 (n = 38)
	Heavy	0.3 (n = 38)
	Total	6.3 (n = 38)
Truck Trip Ends per Day per Employee	Light	0.26 (n = 37)
	Medium	0.11 (n = 37)
	Heavy	0.03 (n = 37)
	Total	0.40 (n = 37)

[1]Knoxville, TN; Modesto, CA; Rochester, NY; and Saginaw, MI.

Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements.* Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Table 6-12, p. 181.

4. Figure 71 shows the hourly distribution of truck trip ends by truck type for downtown retail establishments in four cities (36).

5. Table 73 shows truck trip end rates for downtown retail establishments by trip purpose in four cities (34).

I. Pipeline Terminals

1. The pipeline system accounts for more than 20 percent of the total intercity ton-miles shipped within the United States. It is limited to a specific range of products that are suitable for such transport — liquid and gaseous fuels, water, coal slurry, and chemicals. However, pipelines only move a small amount of these products to the final users of the products (37).

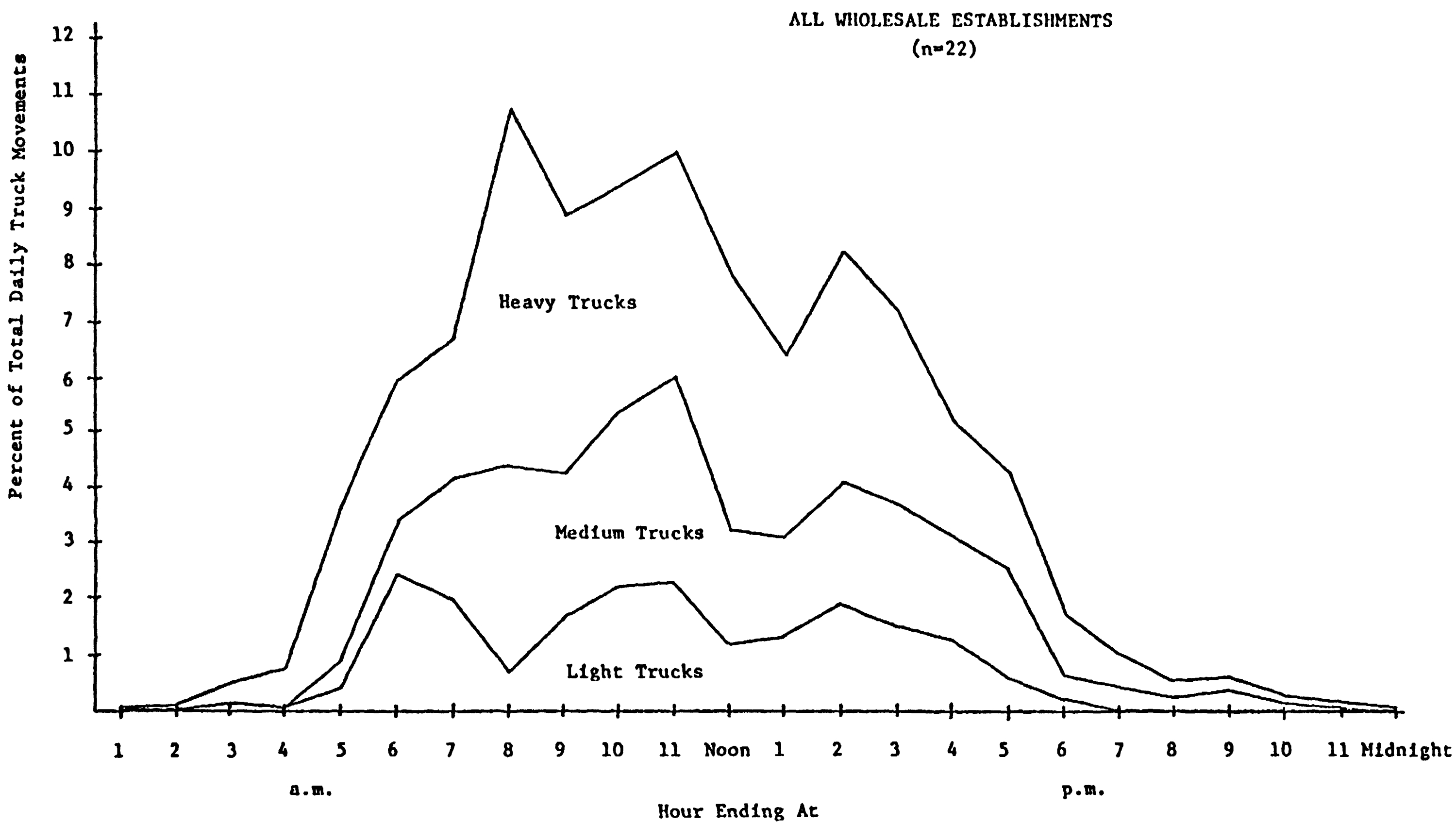
2. Since pipelines are generally underground and not visible to the community, they can have very little impact upon the communities through which they pass. However, where they interface at the surface with other modes at distribution terminals or production facilities, they can have a major impact. Pipelines deliver a large volume of product at one time, so distribution terminals maintain large amounts of storage capacity. The product is then distributed over a period of time, generally by truck, drawing down the stored supply of the product.

3. Because there is little direct pipeline competition and most terminals are centered over a pipeline's route, terminals are generally highly concentrated and produce extremely large and constant truck volumes where they exist Data for Knoxville, TN, suggest than approximately 2 billion gallons of products are handled by eight pipeline terminal operators, generating 1,500 daily truck trips (Table 74) (38).

J. Miscellaneous Truck Users

1. A crushed limestone operator near Wilmington, OH, averages 600 truck trips of crushed stone daily during the June-October construction season. Trucks arrive and depart between 7:00 a.m. and 4:30 p.m., with the greatest concentration of traffic occurring between 7:00 a.m. and 8:30 a.m. Dump trucks haul 75 percent of the loads and tractor trailers haul the remainder.

2. Agribusinesses such as elevator operators and fertilizer/farm chemical dealers also have large seasonal fluctuations influenced by planting (April-June) and harvest (October-December). During the harvest, an elevator in Wilmington, OH, averages 200 truckloads of inbound grain a day. About 70 percent of the inbound grain is transported by farmers with tractor trailers. The remaining 30 percent is hauled by single unit trucks or wagons. Approximately 70 percent of the grain is shipped out by rail (1,200 cars in 1992). The remaining 30 percent is transported throughout the year by tractor trailers south to ports along the Ohio River. The pattern is reversed during the planting season. Fertilizers and other farm chemicals are shipped in by rail and are hauled to area farms by truck or wagon (39).



Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements*. Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Figure 6-3, p. 144.

Figure 71. Hourly Distribution of Truck Trip Ends by Truck Type for Downtown Retail Establishments.

Table 73. Truck Trip End Rates by Vehicle Class for Downtown Retail Establishments in Four Cities.[1]

Truck Type	Total (n = 42)
Pickup Goods	1.1 (9.3%)
Deliver Goods	6.5 (55.1%)
Pickup and Deliver Goods	1.5 (12.7%)
Service Call	0.7 (5.9%)
Personal Business	0.2 (1.7%)
Base of Operations	1.7 (14.4%)
Other	0.1 (0.8%)
All Trucks	11.8

[1]Knoxville, TN; Modesto, CA; Rochester, NY; and Saginaw, MI.

Source: Brogan, James Denis. *An Analysis of Truck Travel Demand Forecasting Techniques and Data Requirements.* Unpublished doctoral dissertation, The University of Tennessee, Knoxville, June 1977, Table 6-4, pp. 151-152.

Table 74. Pipeline Terminal Movements in Knoxville, TN.

Terminal	Annual Volume (million gallons)	Storage (million gallons)	Racks[1]	Hours of Operation	Peak Hours of Truck Movements	Maximum Haul (hours)	Estimated Daily Truck Trips
Amoco	140	4.6	5/5	24	5:30 a.m.-10:00 a.m.	4	100
BP	300	12.8	5/5	24	early a.m.	4-5	210
Citgo	146	3.6	3/4	24	4:30 a.m.-7:00 a.m. 8:30 a.m.-11:00 a.m. 12:30 p.m.-3:00 p.m.	4	100
Cummings 1&2	378[2]	21.8	8/9	24 3:00 p.m.	7:00 a.m.	4	265
Exxon	400[2]	18	7/7	24	5:00 a.m.-11:00 a.m.	4-5	285
Marathon	300	13.9	5/5	24	5:00 a.m.-11:00 a.m.	3-4	210
Shell	250	9.5	3/4	24 1:00 p.m.-4:00 p.m.	4:00 a.m.-noon	4	175
Southern	250[2]	12.6	5/6	varies	6:00 p.m.-7:00 p.m.	4	175
Total	2,165						1,520

[1]First value is product inventories. Second number is products distributed. Several terminals blend medium octane unleaded gasoline as needed for each truck load.

[2]Estimate. Value not provided by terminal; some rail movements.

Source: Jennings, Barton Edward. *An Investigation of Transload: The Use of Non-Containerized Multimodal Bulk Shipments Within the U.S. Freight Carrier Industry*. Unpublished Ph.D. dissertation, The University of Tennessee, Knoxville, TN, December 1994.

VIII. TRUCK TERMINALS

A. Introduction

1. Truck terminals are an integral part of the urban freight system. They deserve the attention of both land use planners and traffic engineers, but unfortunately, in many cases, truck terminals do not receive adequate attention in the long-range land use and transportation planning process.

2. In very large cities such as New York, Chicago, and Los Angeles, there may be nearly 100 truck terminals. In a city of the size of St. Louis and Atlanta, there may be 40 to 50 truck terminals.

3. The nature and size of truck terminals vary depending on the characteristics of trucking companies they belong to. Truck terminals should not be confused with truck stops. Truck terminals belong to specific trucking companies which use them for the handling/sorting of freight, storage and maintenance of trucks, and administrative and operational functions such as order processing and dispatching of vehicles.

B. Truck Facilities

1. Truck stops are facilities used by trucks of different companies that are already enroute for pickup or delivery of freight. Truck stops are used by truck drivers for rest and meals, truck refueling, and light truck maintenance, if needed. Truck stops are owned by companies other than trucking firms.

2. Generally, there are two broad categories of trucking companies/carriers — truckload (TL) carriers and less-than-truckload (LTL) carriers.

3. TL companies serve large customers who have sufficient amount of cargo to make up a full truck load. TL carriers do not need to mix shipments of different customers, and their loading and unloading of cargo take place at the docks of shippers and receivers. A TL company's terminal is primarily for storage and service of its trucks but may also include office space in some cases. The number of truck trips generated by a terminal of a TL company usually is not large. However, its vehicles usually are large combination trucks with 48-foot and 53-foot trailers. These large trucks need well designed access roads to and from freeways. Examples of TL companies are J.B. Hunt, Schneider National, and Werner Enterprise.

C. Less-Than-Truckload Companies and Break-Bulk Terminals

1. Terminals of LTL companies generate a large number of truck trips and involve the sorting of shipments. These terminals are called break-bulk terminals.

2. Examples of LTL carriers include Roadway Express, Consolidated Freightways, Carolina Freight Carriers, and United Parcel Service.

3. Most LTL companies use a system or hierarchy of terminals. One common system of terminals is known as the hub-and-spoke system, which is also known as the cluster concept. A hub terminal is a major facility located in a large city, and it serves as a gateway to other major terminals or hubs. Each hub serves a number of smaller terminals called satellites, which are located in smaller communities. Shipments collected by a satellite terminal are sent through its designated hub for long distance destinations. This concept is graphically illustrated in Figure 72a.

4. It should be pointed out that although the hub-and-spoke system of terminals is popular, many trucking companies use hybrid systems which combine the concept of a strict hierarchy with certain exceptions. A hybrid system is illustrated in Figure 72b. With regard to truck trips generated at a terminal, a hub terminal would generate more trips than a satellite terminal and its proportion of large trucks also would be higher.

5. Both hub and satellite terminals accommodate break-bulk or sorting functions, although the majority of sorting is done at the hubs. (It may be noted that some companies use the term break-bulk for their hub terminals only.)

6. A typical layout of a break-bulk terminal of a LTL carrier is shown in Figure 73. The dock of a break-bulk terminal accommodates sorting activities. Typically on one side of a dock are parking spaces, i.e., doors, for over-the-road trucks, which are large in size. These are combination trucks with trailers of varying lengths of 45, 48, and 53 feet. On the other side of the dock are doors for smaller trucks used for city pickup and delivery. These trucks are either single-unit straight trucks or single 28-foot trailers (referred to as "pups").

7. There are two types of flows of shipments through a break-bulk dock.

    - The first flow involves the transfer of shipments brought by over-the-road (long distance) trucks for delivery in the city where the terminal is located. These shipments are unloaded and sorted on the dock and reloaded on small delivery trucks assigned to specific zones within the city. The delivery usually occurs in the morning period.

    - The second flow involves shipments picked up by city trucks mostly in the afternoon period. These are unloaded on the dock, sorted, and then loaded on over-the-road trucks assigned to other cities and hubs. In the case of major hubs, the majority of interchange of shipments takes place between large over-the-road trucks.

7\. Sorting procedures and times vary according to specific needs of individual terminals. In many cases, most of the sorting is performed at night.

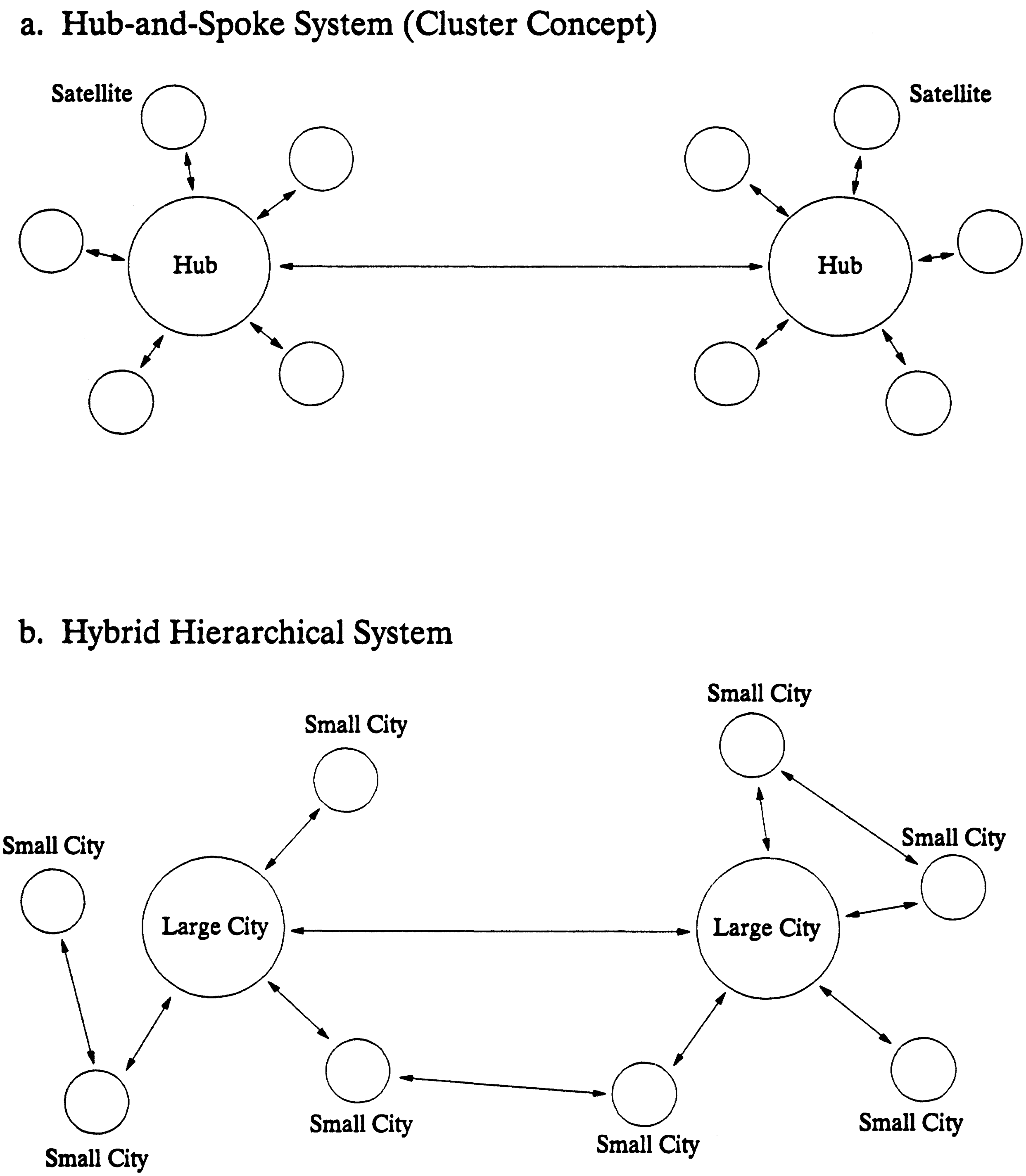


Figure 72. System Hierarchy of Terminals.

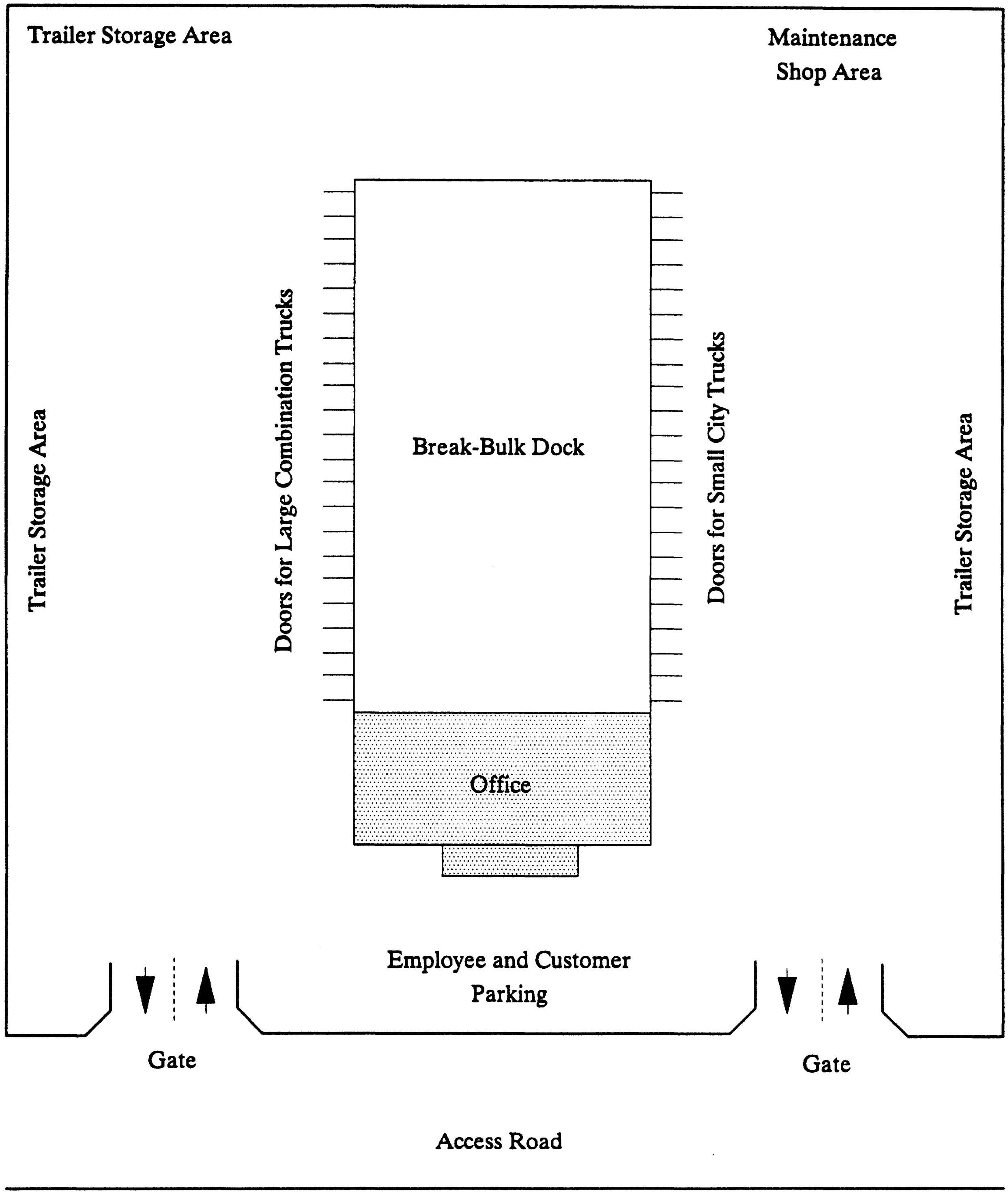


Figure 73. Typical Layout of a Break-Bulk Terminal.

8. The design and operation of some of the break-bulk terminals is quite sophisticated. For example, UPS utilizes an intricate conveyor belt network for sorting at their terminals.

D. **Truck Trip Generation**

1. The size and nature of a terminal influence the number of truck trips, size of trucks, and the distribution of trips by time of day.

2. Terminals that are responsible for city delivery and pickup usually experience a peak in early morning when city delivery trucks leave and another peak in late afternoon or early evening when these vehicles return with shipments to be taken to other cities.

3. Hub terminals that serve primarily large over-the-road trucks have a different pattern of truck trips. These usually generate a large proportion of trips at night.

4. The volume of a terminal's business activities can be measured in terms of the number of doors, i.e., parking stalls for trucks provided at the dock.

5. Data on truck trip generation at LTL truck terminals were obtained for six different terminals operated by four different companies (Table 75). The terminals are arranged according to size using the number of doors as the criterion. These data were collected in 1975.

6. It should be noted that more data on truck trips generated by truck terminals, which were collected in the late 1970s, are presented in Section VII (Table 70).

Table 75. Truck Trips Generated at LTL Terminals.

Type of Terminal	Number of Doors	Truck Trips per Day	Peak Periods	Truck Size
Hub	162	200	3:00-4:00 a.m.; 7:30-8:30 a.m.; 5:00-6:00 p.m.	80% Large, 20% Small
Satellite	39	150	7:00-8:00 a.m. 6:00-7:00 p.m.	30% Large, 70% Small
Hub	36	120	2:30-3:30 a.m.; 5:30-6:30 p.m.	80% Large, 20% Small
Satellite	26	54	8:30-9:30 a.m.; 5:30-6:30 p.m.	75% Large, 25% Small
Satellite	24	40	8:30-9:30 a.m.; 5:30-6:30 p.m.	65% Large, 35% Small
Satellite	20	70	6:00-7:00 a.m. 4:00-5:00 p.m.	33% Large, 67% Small

Note: Large trucks include semitrailers with 45-foot, 48-foot, and 53-foot trailers and twin-trailers with two 28-foot trailers. Small trucks include single-unit (straight) trucks and semitrailers with a single 28-foot trailer.

IX. LOADING DOCK AND LOADING ZONE FOR TRUCKS

A. Introduction

1. An essential task of freight transportation in urban areas involves the pickup of goods from shipper locations and the delivery of goods to receiver locations. For this task to be performed efficiently there is to be adequate space/facility for the parking of trucks, and commonly there are two types of these spaces/facilities:
   - Off-street loading docks/space
   - On street loading zones

2. It should be noted that the expression loading dock is associated with off-street loading/unloading facilities at buildings where trucks back up and where the truck's or trailer's floor height matches closely with the building/dock floor. The expression loading zone, on the other hand, is associated with on-street or curbside spaces usually in the form of parallel parking, where a truck can pull in and park for loading/unloading of goods and eventual pickup/delivery service meant for nearby buildings.

B. Number of Off-Street Loading Docks/Spaces

1. All commercial establishments and large residential buildings should provide adequate space for truck parking within their premises. This is especially important in congested areas such as the Central Business District (CBD) where on-street or curbside space for truck parking is difficult to provide. As an urban area grows the traffic in CBD also grows, and this usually leads to the removal of on-street parking to add more roadway capacity.

2. Urban areas should require adequate off-street loading space to be provided in large new buildings. Example of requirements of two areas are presented. An example of a good set of standards for off-street loading spaces can be found in Montgomery County, MD. The requirements of the Montgomery County Department of Transportation are presented in Table 76. It should be noted that the number of spaces required varies according to the land use. For example, retail establishments in non-CBD and CBD locations need more spaces than offices or hotels/motels after the initial threshold level is reached. The way this table is to be used is explained with the two examples given below.

3. Example 1. A new office building has been proposed to be built with a gross floor area of 350,000 sq. ft. The number of off-street loading spaces required is calculated as shown below:
   - The first 10,000 sq. ft. of floor area (threshold level) needs 1 space.
   - Remaining floor area = 350,000 - 10,000 = 340,000 sq. ft. Using the increment area, the number of off-street loading spaces required (for the remaining floor area) = 340,000 divided by 100,000 = 3.4, approximately 3.
   - Total off-street loading spaces required = 4.

Table 76. Loading Space Requirements in Montgomery County, MD.

Land Use	Threshold Level (in gross square feet)	Increment Area (in square feet)
Industrial		
Manufacturing	5,000	40,000
Warehouse	5,000	40,000
Storage	10,000	25,000
Terminal	5,000	40,000
Commercial		
Wholesale	10,000	40,000
Retail, Non-CBD	10,000	20,000
Retail, CBD	20,000	40,000
Office Building	10,000	100,000
Service Establish	10,000	40,000
Community Recreational Bowling Alleys	10,000	25,000
Auditorium, Arena	10,000	100,000
Restaurant	10,000	25,000
Hotel	10,000	100,000
Laundry	10,000	25,000
Funeral Home	10,000	100,000
Residential		
Res. Building Over 4 stories in Height	25,000	100,000
Apartment Hotel	25,000	100,000
Institutional		
School	10,000	100,000
Hospital, Sanitarium	10,000	100,000

Note: When a given use of building contains a combination of uses as set forth in the table, loading facilities are to be provided on the basis of the sum of the required spaces for each use.

4. Example 2. A new restaurant is proposed to be built in the CBD with a gross floor area of 13,000 sq. ft. The number of off-street loading spaces required is calculated as shown below:
   - The first 10,000 sq. ft. of floor area (threshold level) needs 1 space.
   - Remaining floor area = 13,000 - 10,000 = 3,000 sq. ft. Using the increment area, the number of off-street loading spaces required (for the remaining floor area) = 3,000 divided by 25,000 = less than one = none.
   - Total off-street loading spaces required = 1.

5. It should be pointed out the Montgomery County's policy also sets maximum limits, and more than four off-street loading spaces are not required for a given residential use or building and more than five spaces are not required for a nonresidential use or building unless the Director of Transportation determines that the nature of the use or design of the building warrants additional spaces. Also, for a building with a combination of uses, the requirements for loading spaces are determined for each land use individually and then summed for total requirements.

6. Dallas, Texas, provides another good example of requirements for off-street loading spaces. These requirements, presented in Table 77, are included in the zoning ordinance of the city, where this type of requirements are commonly found.

7. To illustrate the use of these requirements, Dallas requirements are applied to Example 1 above. If the office building with a gross floor area of 350,000 sq. ft. were to locate in Dallas, TX, the number of off-street loading spaces required would be calculated as follows:
   - For the first 50,000 sq. ft., no space is required.
   - For the next 100,000 sq. ft., one space is required.
   - For the remaining 200,000 sq. ft., two spaces are required, one for each 100,000 sq. ft.
   - Total spaces = 3.
8. A major difference the Dallas requirements and those of Montgomery County is that Dallas has no maximum limit on loading space requirements. In Montgomery County, there are commonly used maximum limits, which are four spaces for residential uses and five spaces for nonresidential uses unless this Director of Transportation Department determines that more spaces are required.

C. Size of Off-Street Loading Area and Spaces

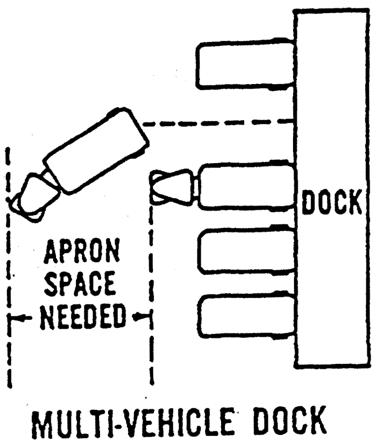
1. The design and layout of loading docks are important requirements.

   - If the design of the entire area is not adequate, loading spaces cannot be used. The loading dock area should have ample room for maneuvering large trucks. The space in front of an actual parking space is called the "apron" area as shown in Figure 74. The needed length/depth of a loading space and the depth of an apron area, of course, depend on the truck size. It is desirable that the apron depth be 1.25 to 1.5 times as long as that of a loading space.

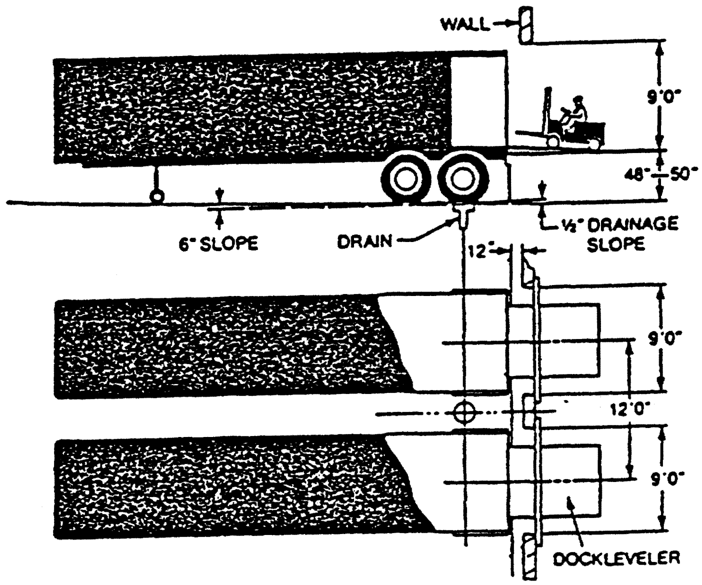
Table 77. Minimum Off-Street Loading Requirements of Dallas, TX.

Land Use	Square Feet of Gross Floor Area in Structure	Total Required Spaces or Berths
Office Uses	0 to 50,000	None
	50,000 to 150,000	1
	Each Additional 100,000 or fraction thereof	1 additional
Retail Sales, Personal Services, and Custom Craft Uses	0 to 10,000	None
	10,000 to 60,000	1
	Each Additional 60,000 or fraction thereof	1 Additional
Commercial and Industrial Uses	0 to 10,000	None
	10,000 to 50,000	1
	50,000 to 100,000	2
	Each Additional 100,000 or fraction thereof	1 Additional
Hotel and Motel Uses	0 to 50,000	None
	50,000 to 100,000	1
	100,000 to 300,000	2
	Each Additional 200,000 or fraction thereof	1 Additional
Food and Beverage Service Uses	0 to 5,000	None
	5,000 to 25,000	1
	25,000 to 50,000	2
	Each Additional 50,000 or fraction thereof	1 Additional

Source: Adapted from Article XXI, Chapter 51, Comprehensive General Zoning Ordinance, Dallas City Code.



(a)



(b)

Sources: (a) Goodwin, Charles A. "How to Get No-Jam Truck Traffic." *Factory Management and Maintenance*, October 1958, p. 202; (b) Kelley Company, Inc. *Modern Dock Design*. Milwaukee, WI, 1979.

Figure 74. Truck Docks and Aprons.

- The dimensions of a loading space depends on the size of trucks expected to occupy it. Specifications for loading space size from Montgomery County and Dallas are presented below.

2. Montgomery County, MD.

   - The minimum size of a loading space for industrial land uses and for wholesale, retail and office commercial land uses is 50 feet in length, 14 feet in height, and 14 feet in width.

   - Where the director has determined that the proposed use does not warrant large-size spaces, small-size spaces may be permitted in the following cases (1) when the gross area of the proposed use is less than a sum equal to the threshold level plus half of the increment area as described on the table below, (2) for additional spaces when more than one space is required.

   - The minimum size of a loading space for all other commercial land uses and for residential and institutional land uses and public buildings is 30 feet in length, 14 feet in height, and 12 feet in width.

3. Dallas, TX. The requirements specified in the zoning ordinance related to loading space size are presented in a tabular form in Table 78.

D. **Height of Loading Docks**

1. The height of loading docks depend on the type of truck expected to use the facility.

2. For single unit trucks (straight trucks), the dock floor usually is 3 feet to 3 feet 6 inches higher than the level of the parking area. For large trailers or comination trucks the dock floor should be 4 feet to 4 feet 6 inches high. Usually dock levelers are used to accommodate trucks with different floor heights varying within a range of 6 to 9 inches.

E. **Curbside Loading Zone**

1. Due to the lack of off-street loading spaces, pickup and delivery trucks are forced to park on-street along curbside to be able to perform their job. This is a legitimate need for the viability of the activities that require the pickups and deliveries by trucks.

2. Certain restrictions on truck parking along curbside may have to be used both timewise and locationwise for the sake of avoiding serious traffic problems. However, wherever possible curbside truck loading zones should be provided to serve the adjacent business establishments.

Table 78. Loading Space Size Required in Dallas, TX.

	Proportion of Loading Space Sizes		
Land Use	Large 55' x 11'	Medium 35' x 11'	Small 20' x 10' 25' x 8'
Office	-	40%	Balance
Retail and Personal Services (<60,000 sq. ft.)	-	40%	Balance
Retail (>60,000 sq. ft.)	25%	25%	Balance
Commercial/Industrial	-	40%	Balance
Hotel/Motel	1 space	75%	Balance
Food and Beverage Services	-	40%	Balance

Note: A space of larger size can be substituted for one of a lower size.

F. **Vehicles for Curbside Loading Zone**

1. For developing a sound policy for loading zones, a distinction must be made of the following types of vehicles:
   - Trucks
   - Courier Vehicles
   - Service Vehicles

2. Trucks are freight carrying vehicles in the true sense. Most of the pickup and delivery trucks are single-unit vehicles, which are commonly referred to as straight trucks. These trucks usually have two axles and six tires. However, there is a variety of configuration of these straight trucks, and a few common types are listed below:
   - Beverage trucks used by softdrink and beer suppliers
   - Trucks used by United Parcel Service and Roadway Package System
   - Trucks used for furniture and office supply companies
   - Trucks used for delivery of food items to restaurants

3. The drivers of these trucks usually deliver and/or pickup heavy goods items that often require the use of dollies or hand carts. The duration of the occupancy of a loading zone by these trucks may be fairly long in some cases depending on the number of business located on that block of the street. In some location a truck operated by Coca-Cola or United Parcel Service may require to occupy a loading zone for several hours to be able to serve all customers on the block.

4. Courier vehicles typically are small vans used by such companies as Federal Express and Air Borne. The driver of these vehicles usually carry light items such as overnight/express letter packs and small parcels. These vehicles usually require a short time period to complete their pickup and/or delivery at one location.

5. Service vehicles usually are small vans and may even be automobiles. These vehicles are used by repair persons such as electricians, plumbers, and office machine service persons. These are not freight carrying vehicles although the repair person sometimes may have to carry replacement parts. The needs of these vehicles for curbside loading/unloading is not as urgent as the needs of trucks and courier vans. Further, if allowed to use a loading zone, these vehicles may occupy it for a long time and prevent a truck with more urgent need from using the space. In many cases, service vehicles can be parked in parking lots or garages meant for automobiles.

G. **Design Guidelines fpr Curbside Loading Zone**

1. Clear definitions of a few selected categories of freight vehicles should be developed, using easily identifiable physical features such as the number of tires and/or axles. Commercial licence tags are not a sound criteria to identify true freight carrying vehicles.

2. Loading zones should be restricted to vehicles that truly carry freight and these vehicles should be identified by using the definitions developed for different categories of freight vehicles. It also should be specified that loading zones are to be occupied only for loading/unloading of freight.

3. Service vehicles should be prohibited from using loading zones unless they obtain permission for special occasions.

4. Loading zones should be marked clearly by distinctive curbside signs and painting of the curb. The signs should clearly specify the time periods when these spaces are reserved for freight vehicles only.

5. Loading zones should be at least 40 feet in length and 9 feet in width, measured from curb-face. This space on the pavement may be marked out with a bordering yellow line and 45 degree diagonal "zebra" striping in yellow color.

6. If separate spaces are provided for courier vehicles, then those should be 22 feet long.

7. Ideally loading zones should be provided on every block of CBD.

8. On major thoroughfares in CBD, parking of any kind may not be allowed during rush hours: 7:30 to 8:30 a.m. and 4:30 to 5:30 p.m. Otherwise loading zones should be reserved for trucks during 7:00 a.m. to 6:00 p.m. during weekdays.

9. Loading zone regulations must be enforced.

X. RAIL-TRUCK INTERMODAL TRANSPORTATION AND TERMINALS

A. Introduction

1. Rail-truck intermodal terminals are playing an increasingly significant role in the freight transportation system of the U.S.

2. Several acronyms are used in the context of these terminals.
   - TOFC
   - COFC
   - Piggyback
   - Fishyback
   - Double-Stack
   - Ramp
   - ICTF
   - TEU

B. Terms

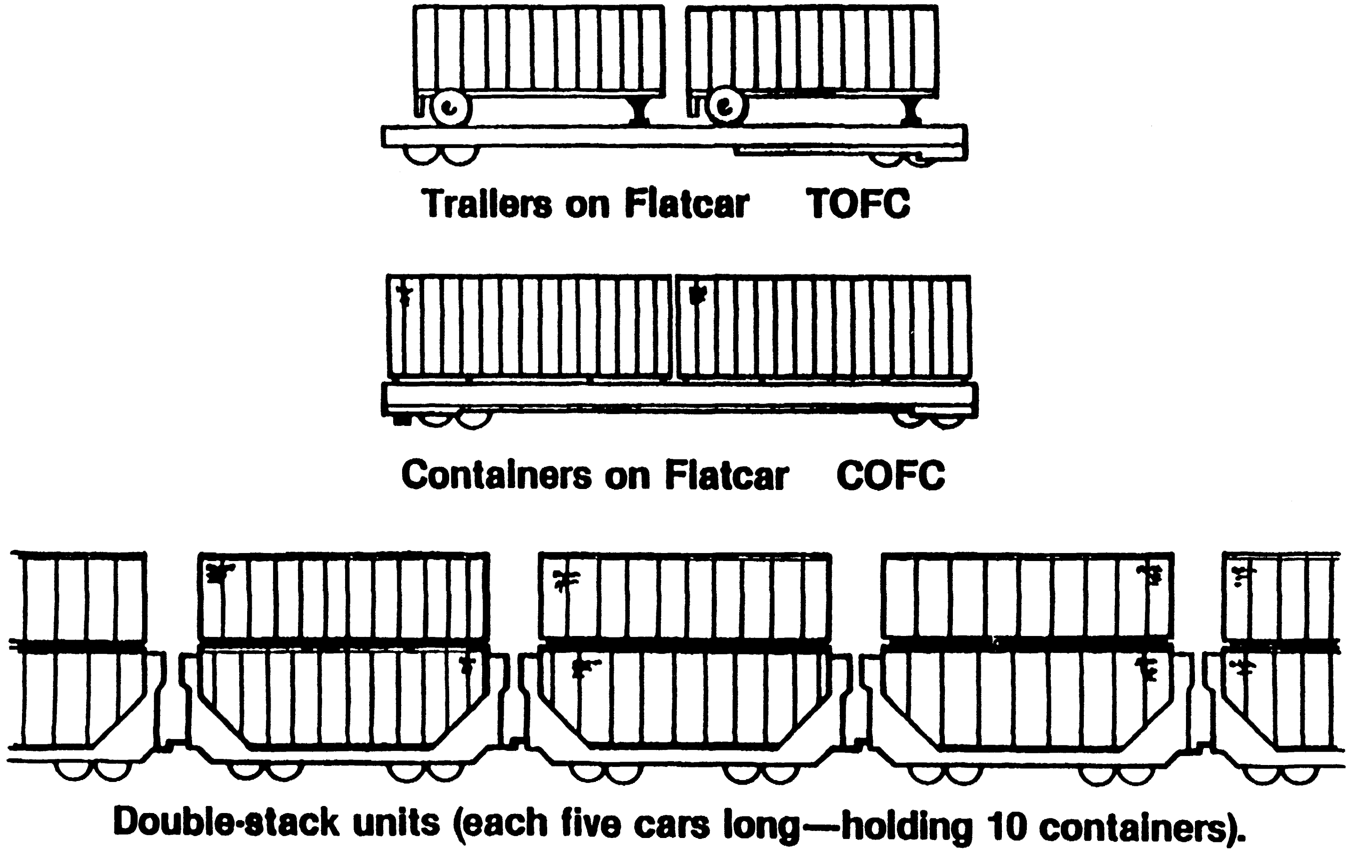
1. TOFC stands for Trailer-on-Flatcar and refers to truck trailers with rubber tired wheels placed on rail flatcars.

2. COFC stands for Container-on-Flatcar and refers to containers without any wheels placed on rail flatcars.
   - It should be noted that a container when moved on highways by truck tractors usually is placed on a chassis, from which it is usually detached when it is placed on a rail flatcar. However, in some cases containers with chassis attached may be placed on rail flat cars, and those cases would be similar to TOFC.
   - Figure 75 shows TOFC and COFC pictorially.

3. The expression piggyback is used to refer to TOFC. In some cases this word is used in a broad sense to include both TOFC and COFC.

4. Another expression fishyback is used to refer to COFC involving containers transferred from oceangoing ships at seaports.

5. There is a variety of rail flatcars available to carry trailers and containers. Some of these are designed to carry two containers vertically, that is one container placed on top of the other. This arrangement is referred to as a double-stack.
   - A common unit assembly of rail cars for double-stack trains consists of five articulated cars each carrying two containers as shown in Figure 75.
   - A double-stack train is formed with several of these five car units, thus a single double-stack train can carry a large number of containers. For example, a train containing 20 of these five-car units will carry 200 containers.



Source: Gerhardt Muller. *Intermodal Freight Transportation*, Third Edition. Eno Transportation Foundation and Intermodal Association of North America, Lansdowne, VA, 1995, p. 49.

Figure 75. Three Forms of Containers on Flatcars.

- Double-stack trains have a significant cost advantage. However, double-stack trains need adequate vertical clearance at under passes and tunnels. There is a variety of heights of containers requiring different clearance heights. The American Railway Engineering Association recommends a clearance of 23 feet to accommodate all types of double-stack trains (40).
- Figure 76 shows typical intermodal trains and their clearance requirements including TOFC and double-stack COFC.

6. Truck-rail intermodal yards are operated by rail companies, and usually each yard accommodates both TOFC and COFC operations. An intermodal terminal is also referred to as a ramp, especially by persons working in the railroad and trucking industry.

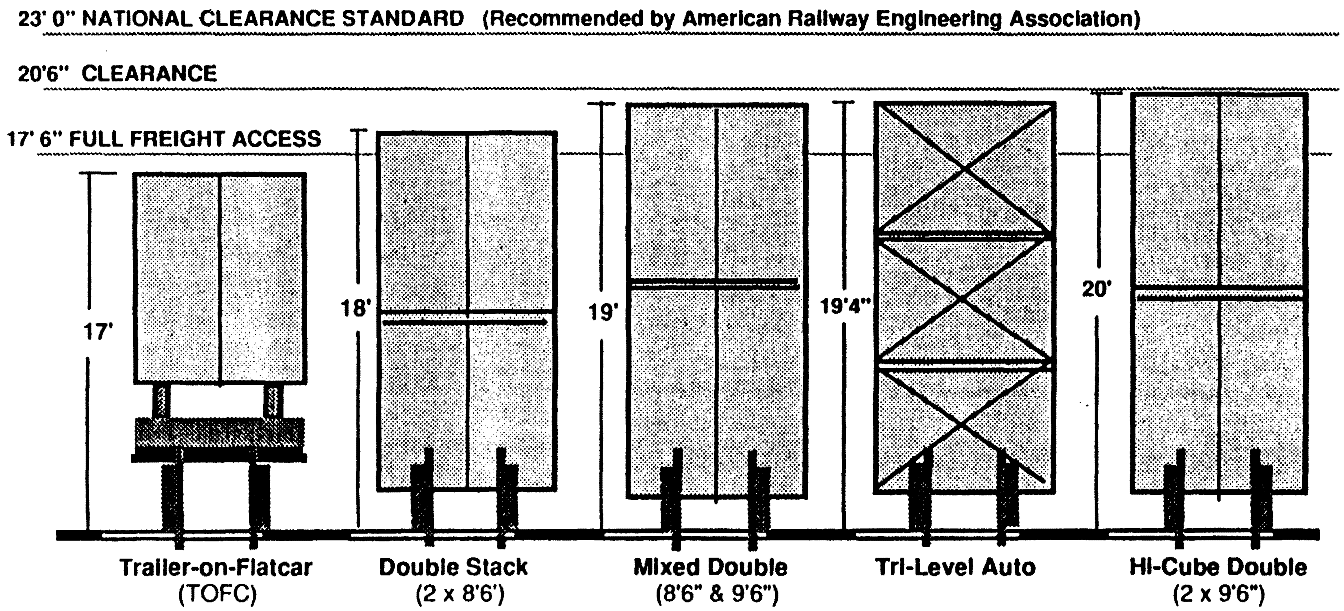
7. There are also intermodal terminals specializing in the transfer of containers to and from rail cars. These are call Intermodal Container Transfer Facilities (ICTF). Usually these container handling rail terminals are found at or near major container seaports.

C. Size of Trailers and Containers and TEU

1. Truck trailers vary in length as well as height.
   - The length of small trailers used for twin-trailers or doubles is 28 feet. These are referred to as "pups."
   - The lengths of large trailers usually are 45 feet, 48 feet, and 53 feet.
   - The most common height of containers is 8 feet 6 inches.
   - The height of so called high-cube containers is 9 feet 6 inches.
   - The most common lengths of containers are 20 feet and 40 feet. Containers of 45-foot length also are used, especially for domestic transportation.

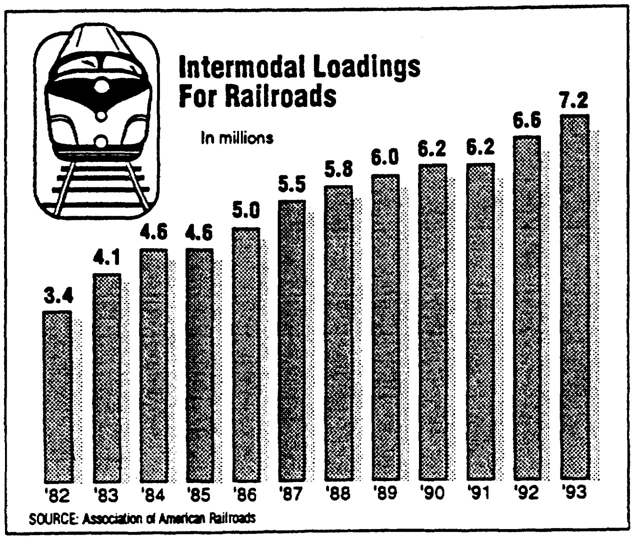
2. There has been a tremendous growth of intermodal traffic in the United States. The growth in intermodal loadings for railroads is depicted in Figure 77. The major corridors of intermodal rail traffic are shown in Figure 78.

3. The use of different sizes of containers presents a problem for tracking the growth of container freight over time and for comparison of container business handled by different ports and railroads. The use of mixed sizes is also problematic for expressing capacities of trains and ships. To resolve these difficulties common unit should be used and the Unit of TEU has been adopted for this purpose. TEU stands for "Twenty Foot Equivalent Unit". For the purpose of expressing a mixed size of containers in TEU, containers larger than 20 feet in length are converted to their appropriate equivalent numbers. For example, a 40-foot container will be equivalent to 2 TEUs.



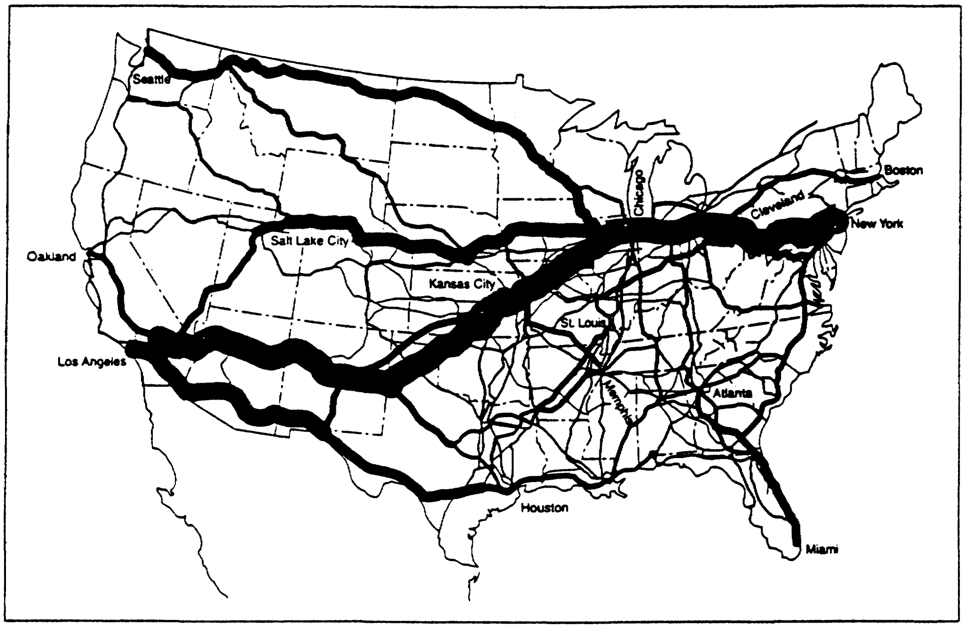
Source: Gerhardt Muller. *Intermodal Freight Transportation*, Third Edition. Eno Transportation Foundation and Intermodal Association of North America, Lansdowne, VA, 1995, p. 51.

Figure 76. Intermodal Rail Clearances.



Source: Gerhardt Muller. *Intermodal Freight Transportation*, Third Edition. Eno Transportation Foundation and Intermodal Association of North America, Lansdowne, VA, 1995, p. 58.

Figure 77. Growth of Intermodal Loadings for Railroads.



Source: Gerhardt Muller. *Intermodal Freight Transportation*, Third Edition. Eno Transportation Foundation and Intermodal Association of North America, Lansdowne, VA, 1995, p. 59.

Figure 78. Intermodal Volumes on Railroad Mainlines in 1987.

D. Size and Hierarchy of Intermodal Terminals

1. The size of rail-truck intermodal yards varies considerably at different locations. Each major railroad company has a hierarchy of these terminals. The "hub and spoke" type arrangement or relation among terminals can be found in many cases, although this concept is not as clearly or rigidly used as in the case of airports.

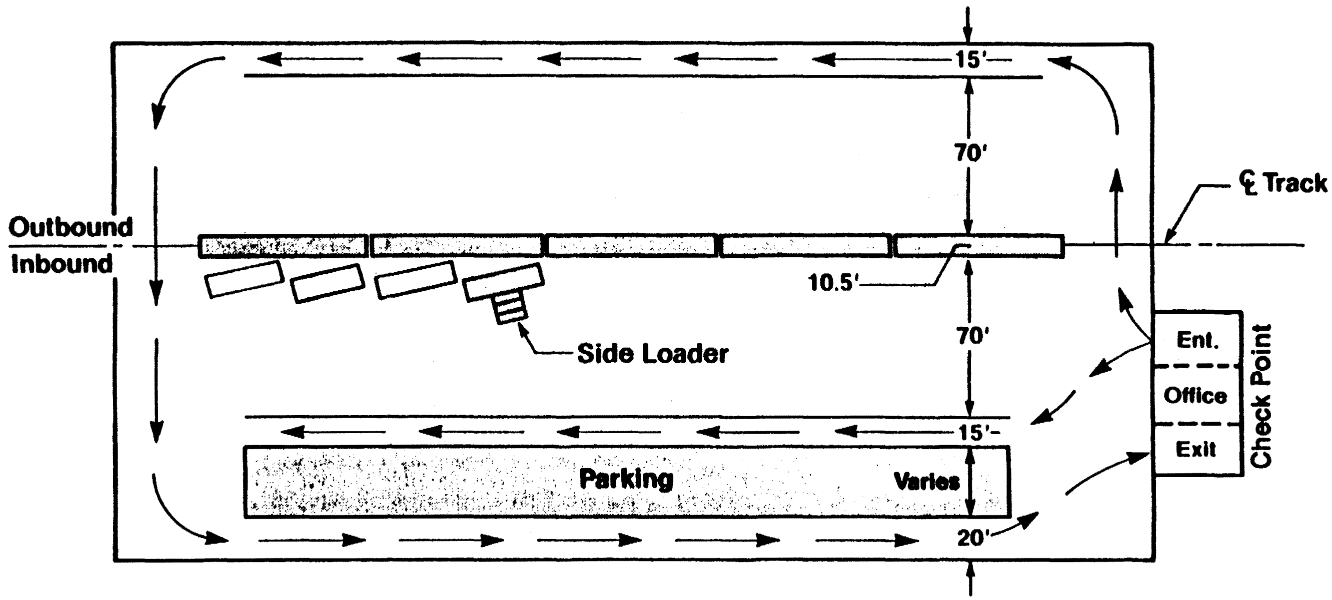
2. The size of an urban area has some influence on the importance and size of an intermodal terminal.
   - For example, cities of the size of Chicago, St. Louis, and Atlanta usually have large "hub" type terminals.
   - City size is always not a good indicator of the number of trains going through the city and its terminal, which is perhaps the most important factor affecting the size and nature of an intermodal yard. Some small urban areas have heavily used rail lines, and very large rail intermodal facilities can be found in some of these locations. For example, the new terminals at relatively small communities of Marion, Arkansas; Palmer, Massachusetts; and Portland, Maine, are quite large and were designed to serve the respective regions.
   - Highway access is also an important factor that influence the size of an intermodal terminal.

E. Physical Layout and Internal Operation

1. Rail-truck intermodal yards or ramps vary greatly in size. These can occupy as few as 5 acres to as much as 1,000 acres depending on the number of trains served and trailers/containers handled. Common facilities in an intermodal terminal include the following:
   - Entrance/Exit Gates
   - Office Building and Automobile Parking
   - Circulation Area
   - Parking Areas for Trailers and Containers
   - Storage Areas for Container Chassis
   - Rail Tracks
   - Lifts and Cranes
   - Yard Tractors/Hostels

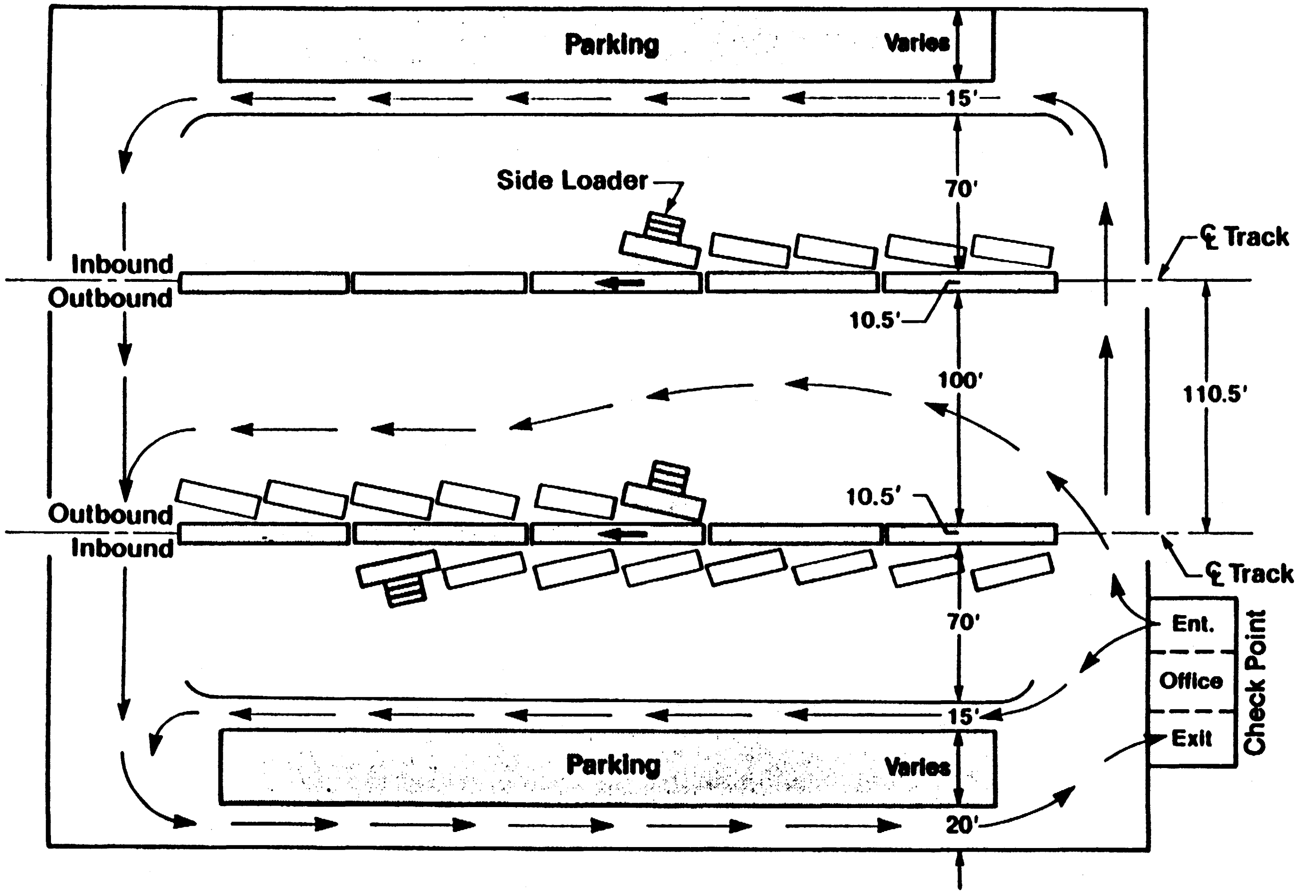
2. Conceptual layouts of intermodal yards are presented in Figures 79-85 (41,42).

3. A variety of methods is used for the loading/unloading of trailers/containers which are exchanged between trains and trucks as well as between trains. For small operations, trailers/containers are lifted on and off rail cars by giant forklift trucks, vertical-lift trucks with overhead booms, or straddling yokes (trailer/container handlers which operate from the side of a train). For large operations, traveling rubber-tired gantry (straddle cranes) are used. These cranes straddle/span over rail tracks and move along the tracks on rubber-tired wheels. These gantries are used in addition to trailer/container handlers which operate from the side.



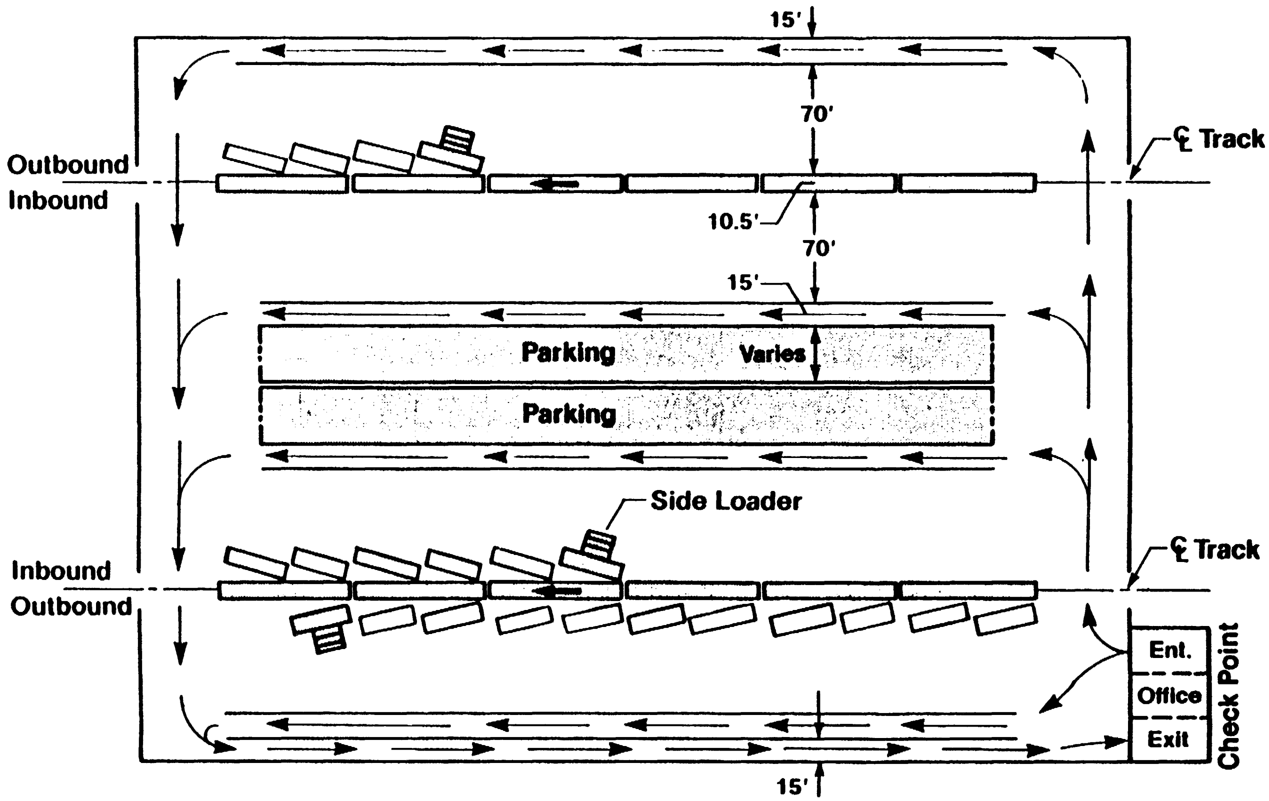
Source: Americal Railway Engineering Association. *1990 Manual for Railway Engineering*. American Railway Engineering Association, Washington, D.C., 1990, Volume II, Section XIV, Figure 2.

Figure 79. Low Volume Terminal with Side Loading.



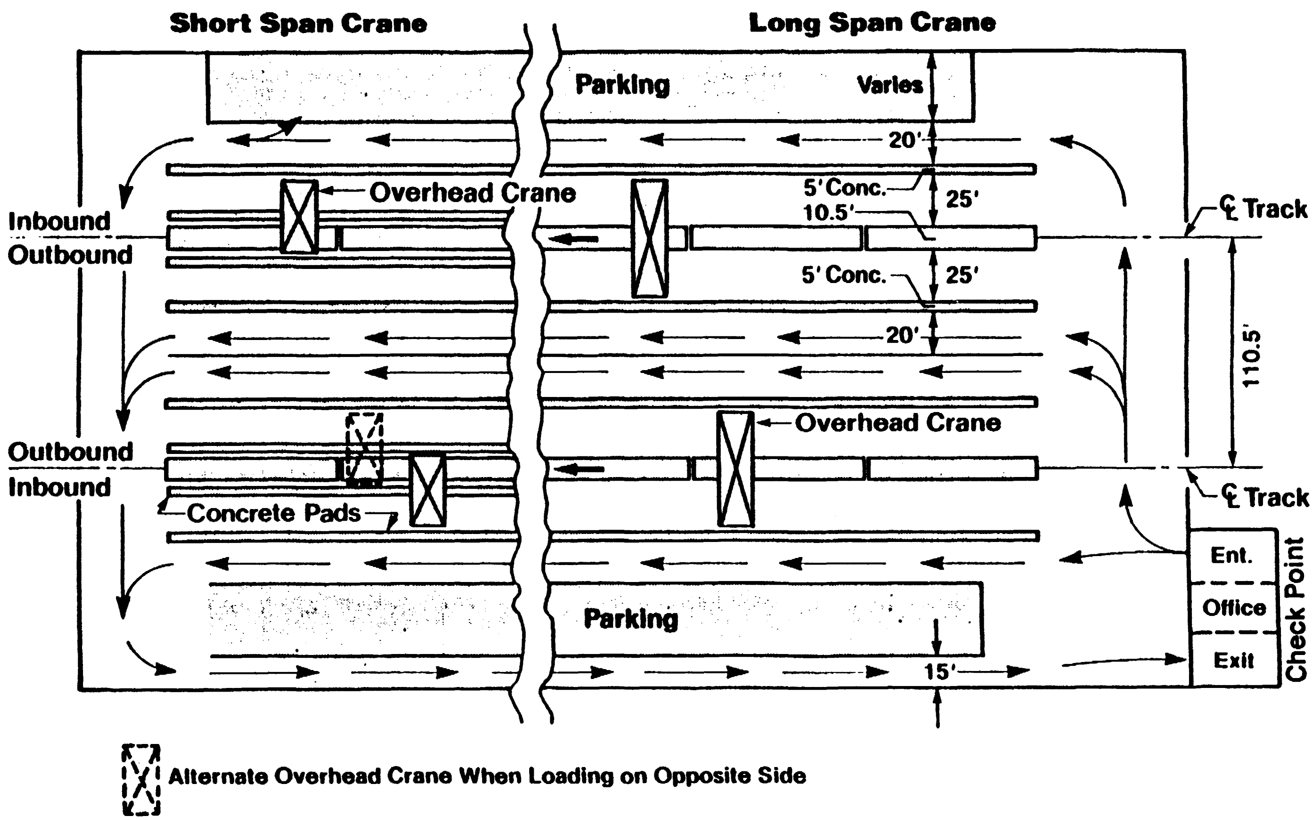
Source: Americal Railway Engineering Association. *1990 Manual for Railway Engineering*. American Railway Engineering Association, Washington, D.C., 1990, Volume II, Section XIV, Figure 3.

Figure 80. Medium-Volume Terminal with Side Loading and Outside Parking.



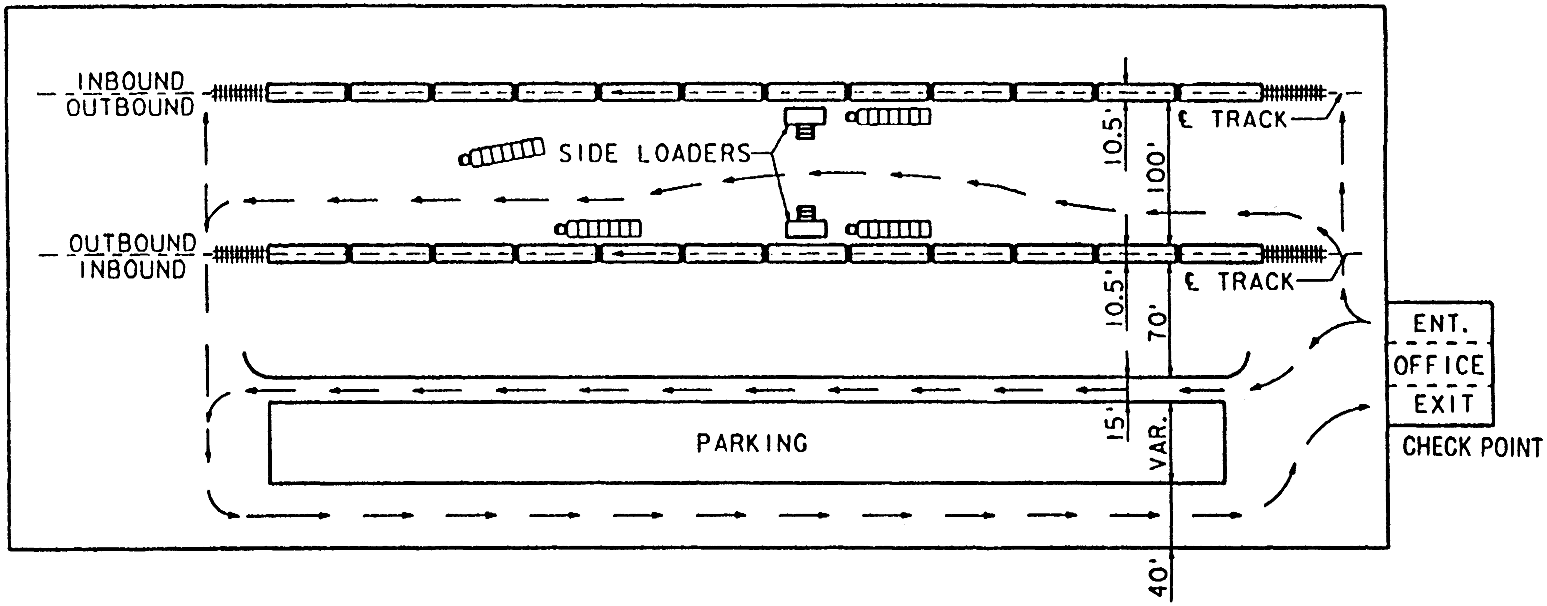
Source: Americal Railway Engineering Association. *1990 Manual for Railway Engineering*. American Railway Engineering Association, Washington, D.C., 1990, Volume II, Section XIV, Figure 4.

Figure 81. Medium-Volume Terminal with Side Loading and Inside Parking.



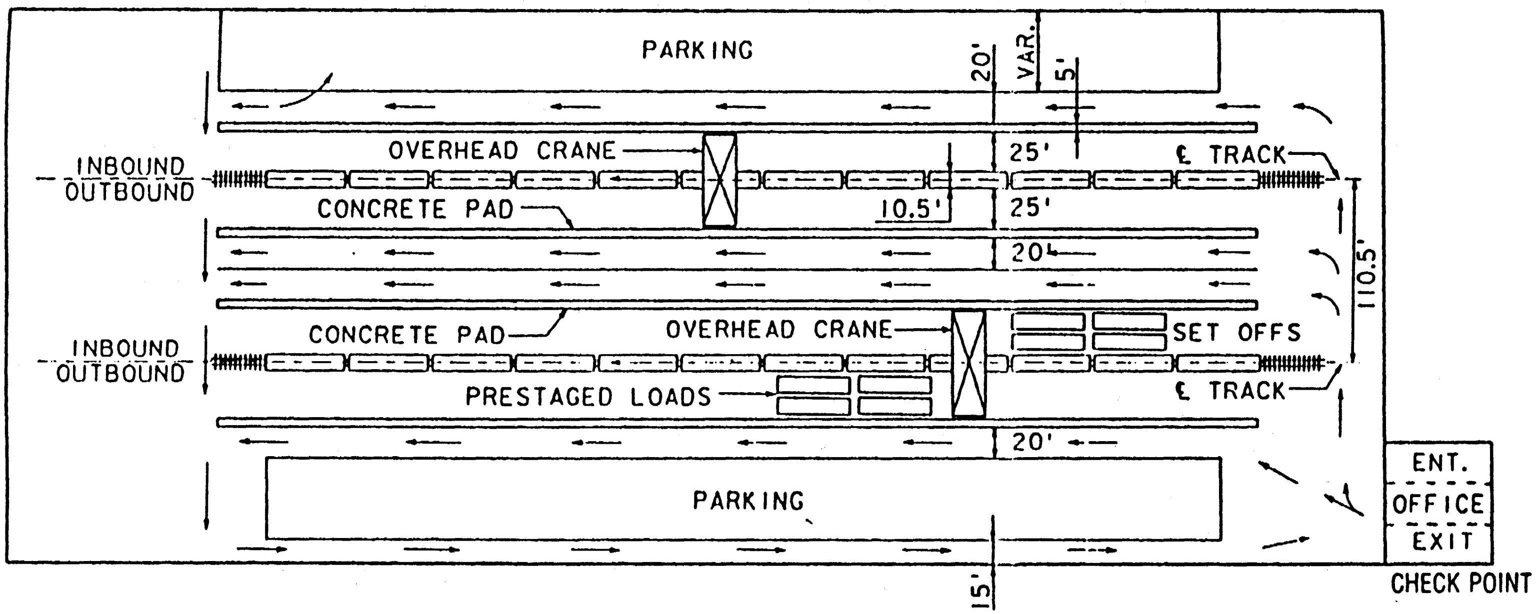
Source: Americal Railway Engineering Association. *1990 Manual for Railway Engineering*. American Railway Engineering Association, Washington, D.C., 1990, Volume II, Section XIV, Figure 5.

Figure 82. High-Volume Terminal, Crane Loading with Outside Parking.



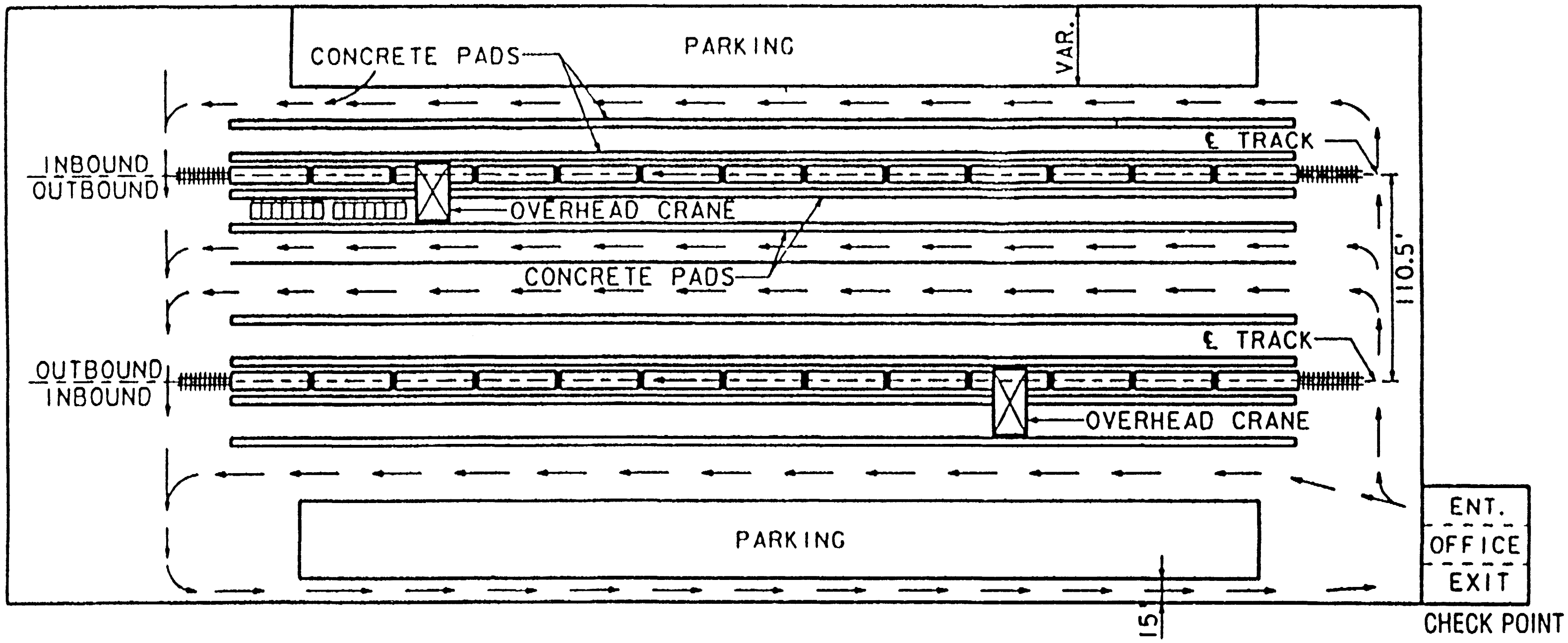
Source: Americal Railway Engineering Association. *1995 Manual for Railway Engineering*. American Railway Engineering Association, Washington, D.C., 1995, Volume II, Section XIV, Figure 9.

Figure 83. Side Loading Double Stack Cars Between Parallel Tracks.



Source: Americal Railway Engineering Association. *1995 Manual for Railway Engineering*. American Railway Engineering Association, Washington, D.C., 1995, Volume II, Section XIV, Figure 10.

Figure 84. Long Span Crane, Single Track with Double Stack Cars.



Source: Americal Railway Engineering Association. *1995 Manual for Railway Engineering*. American Railway Engineering Association, Washington, D.C., 1995, Volume II, Section XIV, Figure 11.

Figure 85. Short Span Crane, Winglr Track with Double Stack Cars.

4. The type and size of the loading equipment dictates the speed of each loading or unloading (Table 79). The larger crane and side lift manufacturers advertise the ability to load or unload at a rate of one minute or less per trailer/container. Smaller types of lifting equipment are reported to have handling time of two to three minutes depending upon the need to move the trailer/container to or from the train and whether the train involves single or double stack loading.
5. The design and layout of railroad facilities are presented in Appendix D.

F. Transportation Issues involving Intermodal Yards

1. The major issues involving an intermodal yard located in an urban area usually include land use compatibility and traffic problems along access routes to/from the terminal.

2. Intermodal yards usually are located on or near existing rail tracks. The location of these terminals are dictated by the historical development of rail tracks and these terminals cannot be moved easily unless new rail tracks are laid elsewhere. Therefore, land use planner should pay attention to the zoning surrounding rail terminals and prevent incompatible development from occurring.

G. Drayage

1. The access routes to intermodal terminals deserve close attention from transportation planners.

2. Figures 86 and 87 show conceptually how truck movements occur to and from a shipper location to a TOFC/COFC yard. These movements are called drayage. The movements at the other end of the road from an intermodal yard to a receiver location also are called drayage.

3. Drayage distance varies widely from customer to customer. However, the average drayage distance usually is less than 100 miles, and the maximum usually is 300 miles. In a few cases there may exist specific long corridors of travel along with drayage movements are concentrated. In most cases, however, drayage movements would be increasingly dispersed as the distance from a terminal increases.

4. The area within a 5-mile radius of a terminal deserves a careful study for truck movements. Specific routes, intersections, and interchanges where drayage movements experience difficulties and problems usually can be found by interviewing terminal managers and drayage company managers along with traffic counts at selected locations.

H. Truck Trip Generation

1. A rail-truck intermodal yard generates truck trips in and out of the facility, and the number of truck trips depends on the size of its operation. The size of operation of

Table 79. Intermodal Yards — Typical Applications.

Yard Layout	Demand (Container Movements/ Day)	Train Length[1]	Type of Loader	Time to Load One Unit	Total Time to load a Cut of Cars
Figure 80	200	1,000 ft.	Side Loader	3-4 Minutes	45 Minutes- 1 Hour
Figure 81	400	1,000 ft.	Side Loader	2-3 Minutes	30-40 Minutes
Figure 82	500+	2,000 ft.	Overhead Crane	1 Minute	30-40 Muintes
Figure 83	500-1,500	2,000-3,000 ft.	Side Loader	3 Minutes	90 Minutes
Figure 84	500-1,500	2,000-3,000 ft.	Long Span Crane	2-3 Minutes	75 Minutes
Figure 85	500-1,500	2,000-3,000 ft.	Short Span Crane	2-3 Minutes	75 Minutes

[1]1,000 feet is equivalent to 10 cars.

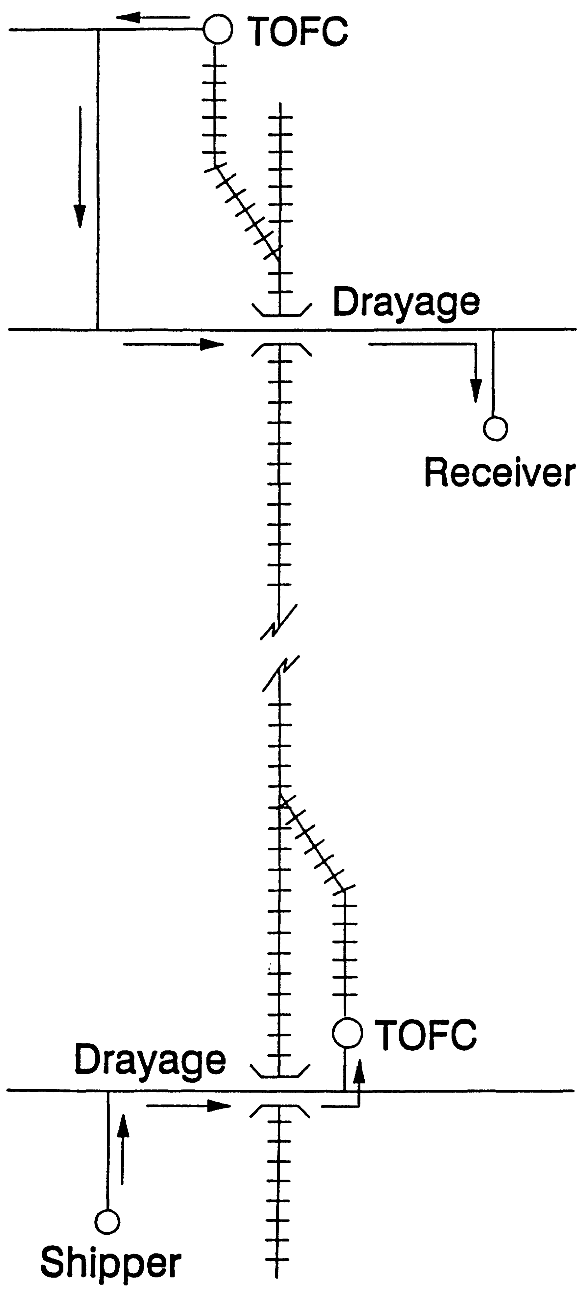
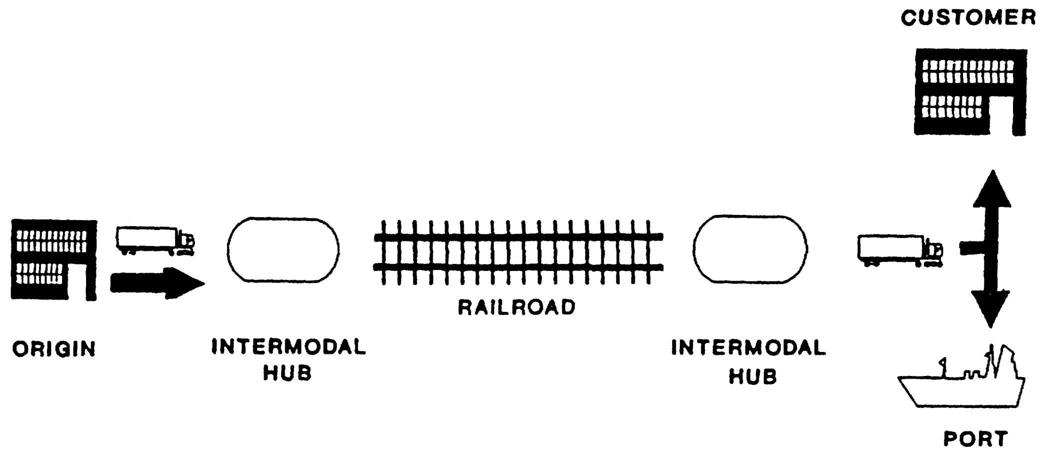


Figure 86. Drayage.



Sourec: Flatland Professional Services.

Figure 87. Truck-Rail Intermodal System.

an intermodal yard may be described by different parameters such as the number of lifts (of trailers and containers), number of trains served, number of acres of area occupied, etc. However, it is not possible to select any single characteristic/parameter that can explain the variation in the number of truck trips generated completely. The number of lifts often is used to measure the size of operation, however, all lifts are not directly related to truck movements. In the case of a "hub" terminal, trailers/containers are exchanged between trains, and these lifts are not related to truck movements.

2. An expression commonly used to measure/quantify truck trips is "gatemoves." Every time a truck carrying a trailer or a container passes an entry/exit gate, it generates a gatemove. Thus gatemoves are synonymous with trip ends.

3. Table 80 presents data collected from five rail-truck intermodal yards. In addition to truck trips it contains information on terminal characteristics including train movements.

4. It should be noted that the size of an urban area alone is not indicative of the magnitude of intermodal activities. For example, the city of Charlotte, NC, may be compared with Charleston, SC. Although Charlotte is a much larger city than Charleston, it is primarily a truck oriented distribution center and its rail intermodal yards are not as active as those in Charleston, which has a major seaport with a large volume of international container traffic. Therefore, the numbers presented in Table 80 should be used for general guidance only. Whenever possible, data should be obtained for specific terminals by contacting the managers of the facilities.

Table 80. Trip Generation Characteristics of Truck-Rail Intermodal Terminals.

Urban Area Size	Role of Terminal	Daily (Weekday) Intermodal Trains	Daily (Weekday) Gatemoves (Truck Trips)	Type and Size of Vehicles	Peaking Pattern	Terminal Area	Lifts per Day
1. 2 Million Population	Hub	8 In and 8 Out	900	50% Containers; 50% Trailers	Variable	75 Acres	1,500
2. 750,000 Population	Non-Hub	1 In and 1 Out	300	50% Containers (40 foot); 50% Trailers (45 and 48 foot)	Little Peaking; p.m. Busier	6 Acres	100
3. 500,000 Population	Non-Hub	5 In and 5 Out	400		10 a.m.; 2 p.m.; 5 p.m.	85 Acres	300
4. 200,000 Population	Non-Hub; Serves a Seaport	2 In and 2 Out	400	90% Containers (40 foot); 10% Trailers	10 a.m. 4 p.m.	10 Acres	300
5. 200,000 Population	Non-Hub; Serves a Seaport	3 In and 3 Out	200	80% Containers (20 and 40 foot); 20% Trailers (45 and 48 foot)	8 a.m. 2 p.m.	6 Acres	150

XI. AIR CARGO

A. Characteristics of Air Cargo Markets

1. Air cargo attracts high value goods with a high time value such as perishables, electronic parts, and pharmaceuticals. Because of time advantages, shippers are willing to pay three times ocean transport rates to deliver goods such as electronics, apparel, shoes, and printed material in days versus weeks. High value cargo moved by air is less sensitive to cost and shipped by air to ensure high reliability and rapid delivery (43).

   - Tables 81-83 show the top air imports and exports at Sea-Tac Seattle airport (44) and the Port of New York-New Jersey (45). Airports in both metropolitan areas handle high volumes of exports and imports.

   - Air penetration is highest for high value of export/import groups. In 1993, air penetrated 51 percent of all imports and 45.3 percent of all exports with a value of $16 or more per kilogram. Air even maintained a token penetration in lower value groupings (Figure 88) (46).

   - Domestic air cargo is very sensitive to economic conditions with a growth rate of revenue ton-mile of 5.6 percent in 1993 and 12.4 percent in 1994. The forces and constraints for air cargo are complex and focus on economic conditions, technology, marketing, exchange rates, and many other factors (Figure 89) (46, 47)

   - Air cargo is comprised of different segments — express, mail, chartered, and scheduled freight. Scheduled freight historically has been the dominant component, but since 1982 the revenue ton-miles of express has doubled and now comprises 56 percent of all revenue ton-miles (Figure 90). For example, while domestic air cargo increased 5.6 percent in 1993, express increased 13.4 percent while nonexpress cargo decreased 3.7 percent in revenue ton-miles (46).

2. In 1993, other airfreight markets grew faster than the U.S. domestic market. For example, while the U.S. domestic market grew 5.6 percent in revenue ton miles, the Asia-North American market grew 13.6 percent (46).

3. While airfreight growth is dependent on market conditions, it has been forecasted by Boeing that long-term air cargo growth will be 6.5 percent per year in revenue ton-mile to the year 2013. The forecast is bracketed by a high forecast of 8.6 percent per year to a low forecast of 4.3 percent per year. The trend line from 1975 to 1993 is 7.8 percent per year. At an average rate of 6.5 percent growth per year, air cargo will triple by year 2013. The airfreight component of air cargo will grow faster (6.5 percent per year) than air mail (4.2 percent per year) (46).

Table 81. Port of Seattle Top Air Imports and Exports
Based on Dollar Value (1993)

Rank	Product	Value
Exports		
1	Aviation components	$356.6 million
2	Data processing, office machinery	$262.2 million
3	Test & measurement equipment	$121.9 million
4	Input/Output units for data processing	$120.7 million
5	Recorded sound media	$108.1 million
6	Digital processing units	$104.0 million
7	Integrated circuits/micro assemblies	$103.1 million
8	Electro-diagnostic apparatus	$ 93.4 million
9	Turbojets, gas turbines, parts	$ 44.4 million
10	Storage units for data processing	$32.4 million
Imports		
1	Reaction engines	$1,304.5 million
2	Special transactions and commodities	$185.4 million
3	Aircraft and associated equipment	$77.7 million
4	Data processing, office machinery	$49.0 million
5	Input/output for data processing	$30.0 million
6	Transmission appl. for radiotelephony	$15.3 million
7	Footwear	$11.3 million
8	Machinery	$10.2 million
9	Shirts, mens/boys	$10.0 million
10	Access for telecommunications	$9.9 million

Source: Finan, Terence. "Converging Tradewinds Spur Success." *Tradewinds*, Port of Seattle, Washington, Spring 1995, pp. 2-9.

Table 82. Port of New York-New Jersey Leading Air Cargo Import Commodities.

Commodity	Long Tons 1994	Long Tons 1993	% Change
Clothing	179,169	166,311	7.7
Footwear	30,516	27,571	10.7
Vegetables Fresh or Frozen	25,219	27,662	-8.8
Machinery (general)	24,849	17,310	43.6
Printed Matter	19,672	17,093	15.1
Office Machinery	15,962	13,377	19.3
Electric Motors and Generators	14,296	14,203	0.7
Fish and Fish Products	13,800	13,609	1.4
Woven Fabrics (Except Cotton)	13,792	12,385	11.4
Scientific Apparatus	13,245	12,969	2.1
Electrical Machinery	12,609	12,420	1.5
Telecommunications Apparatus	10,389	8,497	22.3
Toys and Sporting Goods	9,694	8,184	18.5
Nursery Stock	9,576	9,609	-0.3
Plastic and Rubber Manufacturers	8,623	7,179	20.1
Travel Goods	8,618	7,258	18.7
Metal Household Manufacturers	8,322	6,190	34.4
Pharmaceuticals	7,845	7,230	8.5
Special Fabrics	7,594	6,754	12.4
Jewelry	7,026	6,754	4.0

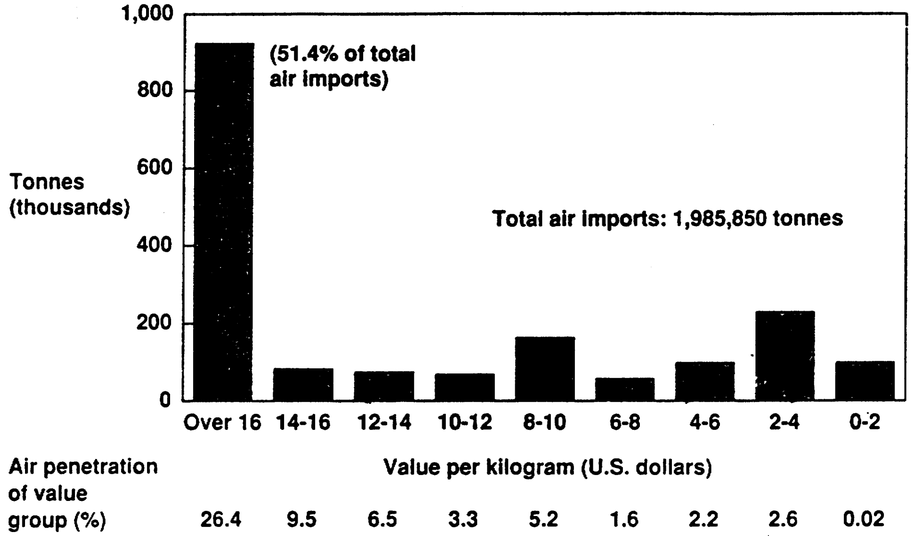
Source: *VIA*, Port Authority of New York and New Jersey, July/August 1995.

Table 83. Port of New York-New Jersey Leading Air Cargo Export Commodities.

Commodity	Long Tons 1994	Long Tons 1993	% Change
Office Machinery	29,846	29,174	2.3
Machinery (General)	24,311	22,469	8.2
Fish and Fish Products	22,524	18,855	19.5
Printed Matter	21,799	20,001	9.0
Electrical Machinery	17,713	15,219	16.4
Scientific Instruments	16,501	16,080	2.6
Electric Motors and Generators	13,544	12,718	6.5
Telecommunications Apparatus	13,132	12,267	7.1
Plastic Materials	12,365	10,340	19.6
Paper and Paperboard Manufacturers	10,509	9,034	16.3
Clothing	10,308	10,694	-3.6
Paper and Paperboard	8,837	7,456	18.5
Road Motor Vehicles and Parts	8,593	7,822	9.9
Pharmaceuticals	8,315	8,214	1.2
Aircraft and Parts	8,201	9,191	-10.8
Woven Fabrics (except cotton)	6,584	7,474	-11.9
Electro-Medical Apparatus	6,343	6,224	1.9
Sound Recorders	6,235	6,661	-6.4
Plastic Manufacturers	6,037	5,090	18.6
Machinery for Special Industries	5,841	6,973	-16.2

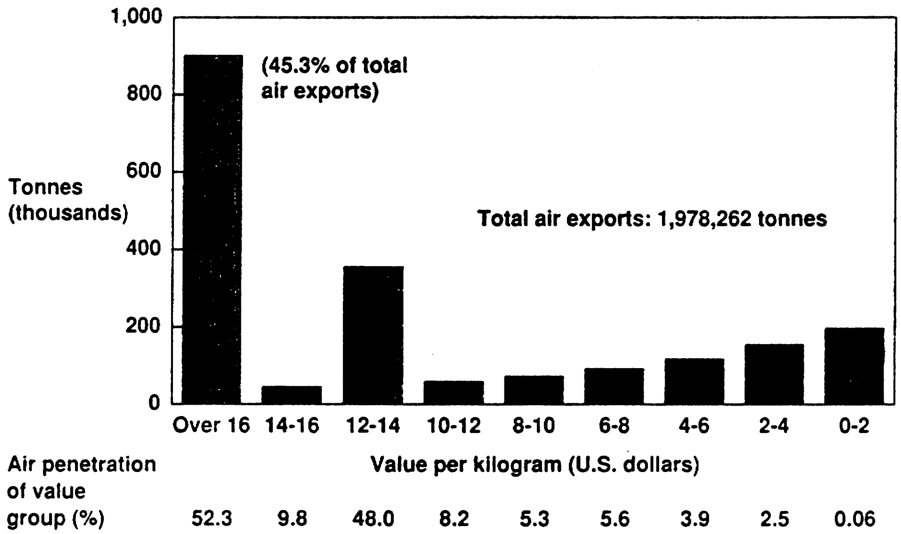
Source: *VIA*, Port Authority of New York and New Jersey, July/August 1995.

1993 U.S. Airborne Import Commodities Are Contained in All Value Groups*



* Preliminary

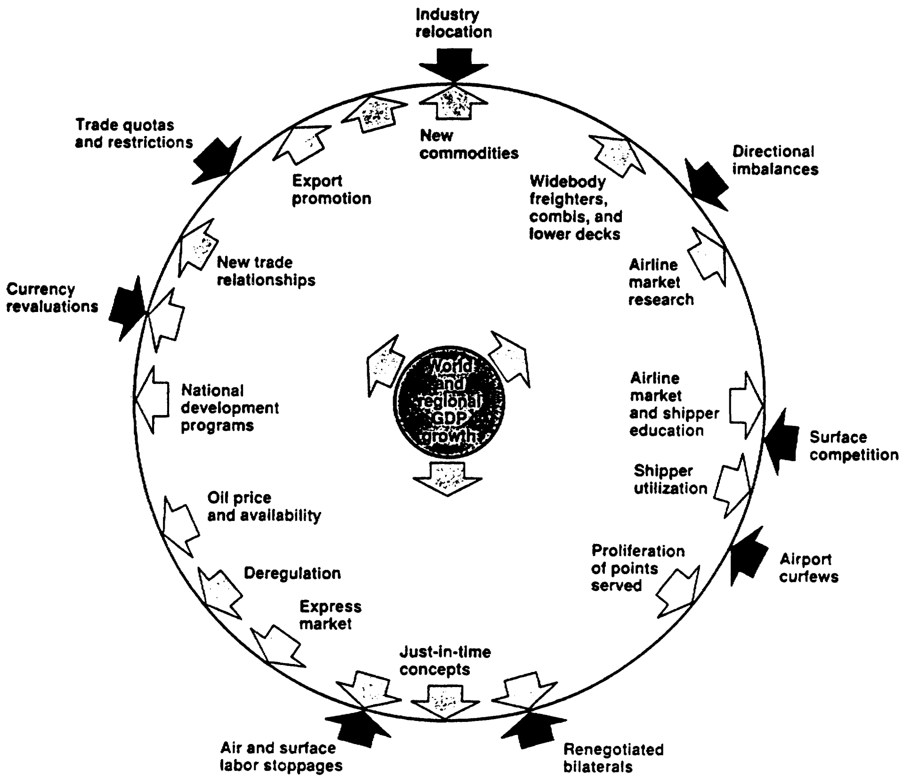
1993 U.S. Airborne Export Commodities Are Contained in All Value Groups*



* Preliminary

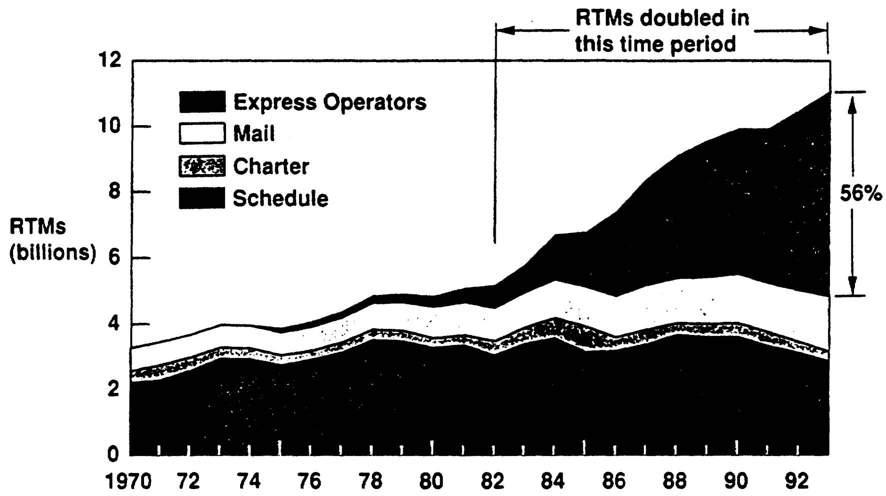
World Air Cargo Forecast. Boeing Commercial Airplane Group, Seattle, Washington, July 1994.

Figure 88. Relationship Between Unit Value and Air Penetration.



Source: *World Air Cargo Forecast*. Boeing Commercial Airplane Group, Seattle, Washington, July 1994.

Figure 89. Forces and Constraints for Air Cargo Growth.



Source: *World Air Cargo Forecast.* Boeing Commercial Airplane Group, Seattle, Washington, July 1994.

Figure 90. Air Cargo Movements for Carrier Type.

4. On a national level air freight represents less than 1 percent of intercity tons shipped or intercity ton-mile, but represent over 4 percent of the revenue generated (9).

5. Air cargo moving through the Sea-Tac Airport in Seattle is equivalent in weight to 2.5 percent of total containerized tonnage passing through the Ports of Tacoma and Seattle (43).

   - All air cargo operators represent 16,000 annual take-offs and landings at Sea-Tac Airport in 1993.

   - 54 percent of tonnage is carried on all-cargo flights and 46 percent of tonnage is carried on passenger flights. In 1970, only 12 percent was carried on all-cargo flights and in 1989 only 36 percent was carried on all-cargo flights. Because of capacity limitations and market conditions, a greater component of air cargo is moving by dedicated all-cargo aircraft (40).

   - The domestic airfreight industry is a 5-6 day a week business, relying on overnight deliveries. The international airfreight market typically peaks on Friday and Saturday, with little volume on Monday (40).

B. Characteristics of Air Cargo by Community Size

1. Communities which are classified as air traffic hubs are standard metropolitan statistical areas receiving aviation services. Communities are classified[1] as large, medium, small, or non-hubs. Air freight can be stratified as enplaned revenue tons by freight or mail. Freight can further be identified as carried by a dedicated freight carrier or air carrier serving both passengers and freight.

2. Table 84 shows 1993 the freight and mail tonnages by hub type.

3. Figures 91-92 depict the relative tonnage of air freight and mail by all hubs for 1993. The statistical relationships, stratified by hub size, are presented in Appendix E.

   - On a national level, the annual totals for airfreight and airmail are 118 lbs. per capita and 0.34 lbs. per capita, respectively.

   - Table 85 indicates how the tonnage varies by air traffic hub size. In the presentation of the statistics, the "hub centers" of some dedicated air freight carrier such as Memphis and Dayton were removed.

---

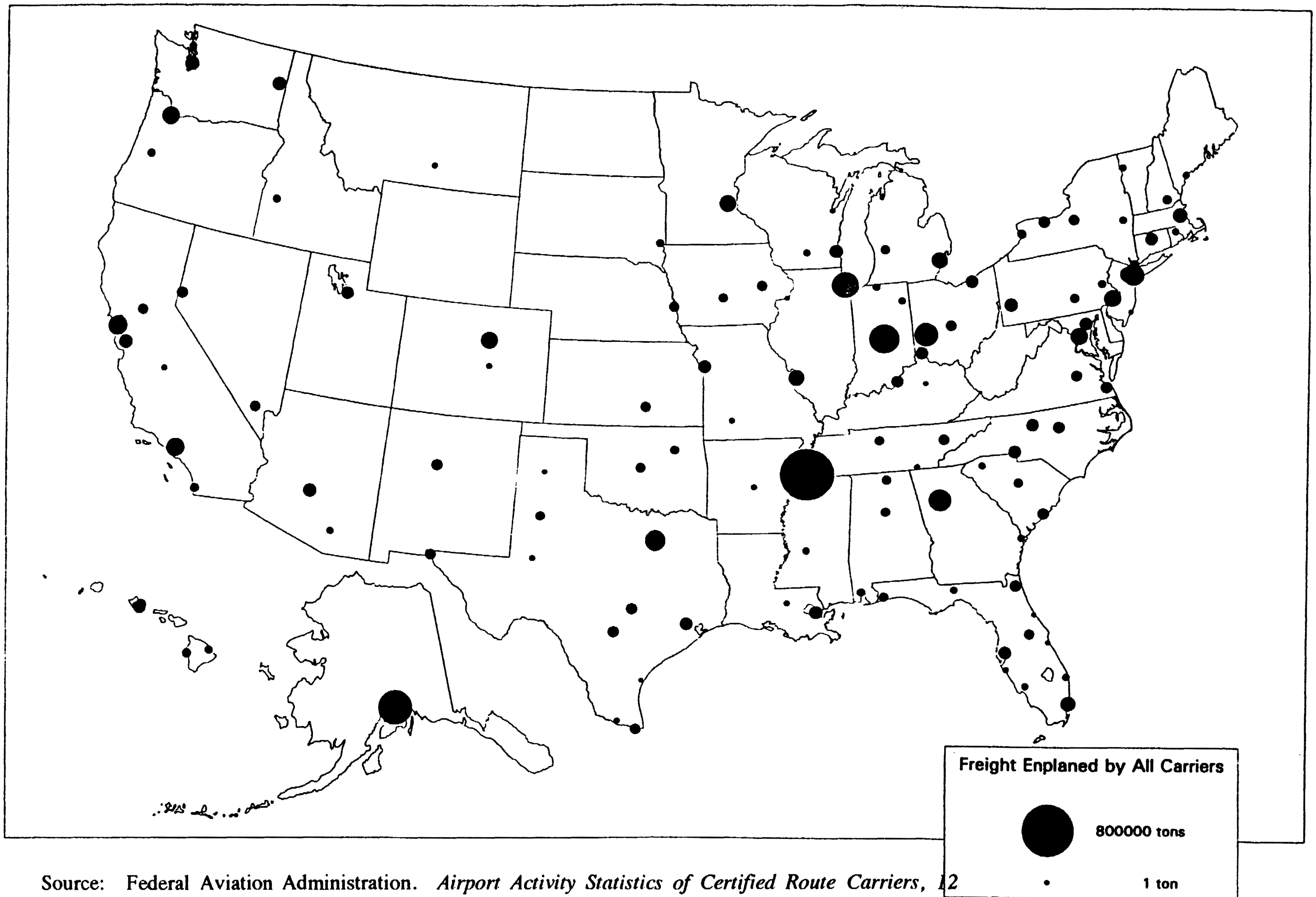
[1]Classifications are based on each community' percentage of the total enplaned passengers in scheduled and nonscheduled service of the domestic certified route carriers. The classifications are: Large, 1.00% or more; Medium, 0.25% to 0.999%; Small, 0.05% to 0.249%; and Nonhub, less than 0.05%.

Table 84. 1993 Freight and Mail Movements by Hub Type.

Hub Type	Freight Tons (x 1,000)	Freight %	Mail Tons (x 1,000)	Mail %	Number of Traffic Hubs
50 states	6,262.6	-	1,811.6	-	12
Large	3,678.8	58.7	1,320.2	72.8	25
Medium	1,857.9	8.2	324.4	17.9	30
Small	516.2	8.2	152.7	8.4	68

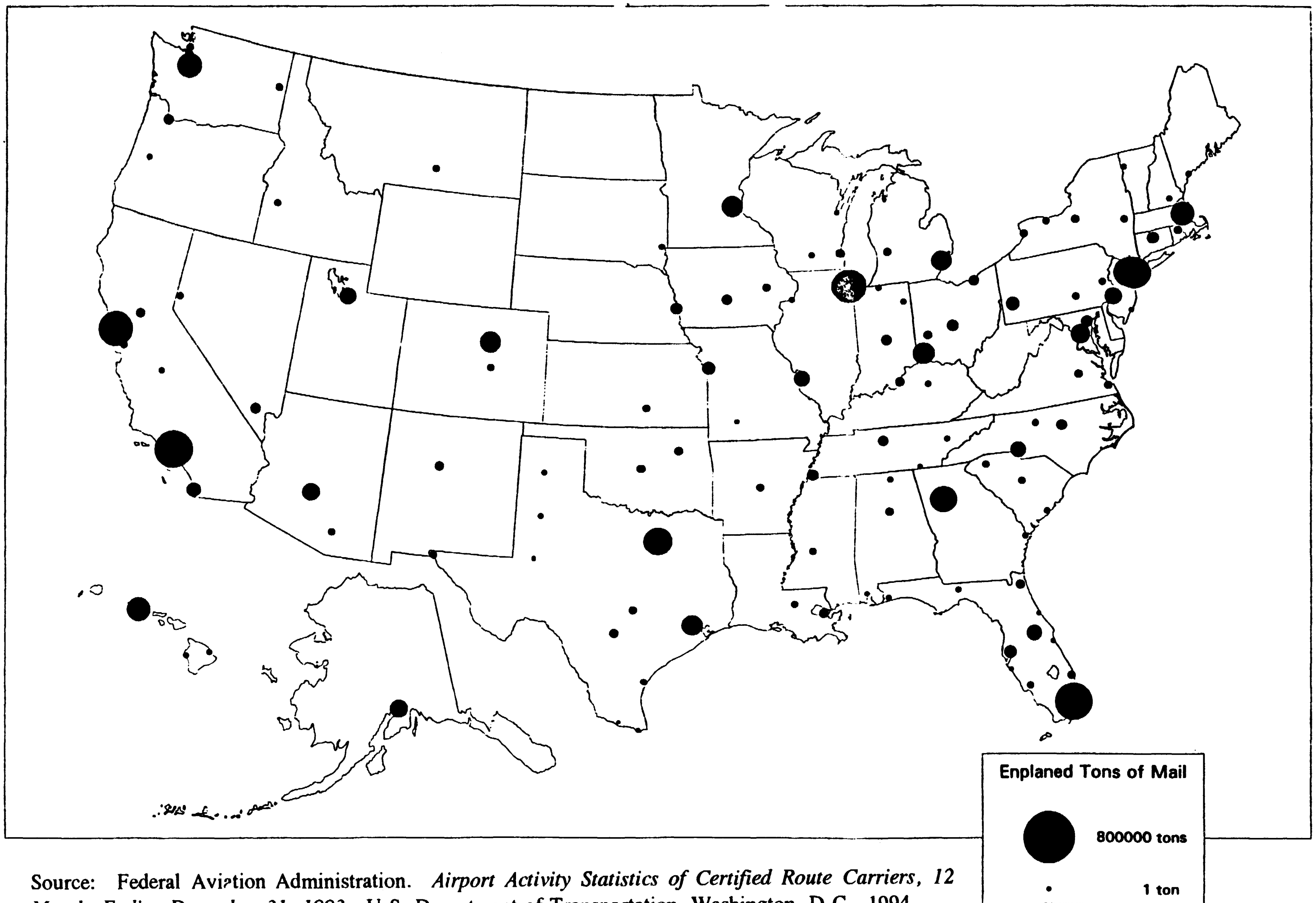
Note: Table considers scheduled and nonscheduled freight and mail handled by large certified air carriers for 12 months ending December 31, 1993. Does not include non-hubs.

Source: Federal Aviation Administration. *Airport Activity Statistics of Certified Route Carriers, 12 Months Ending December 31, 1993*. U.S. Department of Transportation, Washington, D.C., 1994.



Source: Federal Aviation Administration. *Airport Activity Statistics of Certified Route Carriers, 12 Months Ending December 31, 1993.* U.S. Department of Transportation, Washington, D.C., 1994.

Figure 91. Freight Enplaned by All Carriers, All Hubs.



Source: Federal Aviation Administration. *Airport Activity Statistics of Certified Route Carriers, 12 Months Ending December 31, 1993.* U.S. Department of Transportation, Washington, D.C., 1994.

Figure 92. Mail Enplaned by All Carriers, All Hubs.

Table 85. Relationship of Tons as a Function of Population.

	Airports	R Square	Regression Equation[1]	Maximum Tons per Capita	Average Tons per Capita	Cargo Hubs Excluded
All Airports						
Freight Carried by Dedicated Freight Carriers Only	117	0.05	y = 1469 + .014p	0.851	0.034	None
Freight Carried by All Airlines	117	0.26	y = 7608 + .038p	1.343	0.059	None
Mail Carried by All Airlines	117	0.62	y = 659 + .014p	0.269	0.017	None
All Airports (Selected Hubs Excluded)						
Freight Carried by Dedicated Freight Carriers Only	113	0.32	y = 3059 + .015p	0.143	0.017	Anchorage, Dayton, Memphis, Indianapolis
Freight Carried by All Airlines	113	0.55	y = 6708 + .040p	0.214	0.027	Anchorage, Dayton, Memphis, Indianapolis
Mail Carried by All Airlines	113	0.65	y = 1645 + .014p	0.047	0.01	Anchorage, Dayton, Memphis, Indianapolis
Large Hub Airports						
Freight Carried by Dedicated Freight Carriers Only	27	0.06	y = 42015 + .069p	0.125	0.027	None
Freight Carried by All Airlines	27	0.29	y = 52560 + .0293p	0.214	0.058	None
Mail Carried by All Airlines	27	0.40	y = 19337 + .0104p	0.047	0.019	None

Table 85. (continued).

	Airports	R Square	Regression Equation[1]	Tons per Capita	Maximum Tons per Capita	Average Cargo Hubs Excluded
Medium Hub Airports						
Freight Carried by Dedicated Freight Carriers Only	25	0.36	y = 3542 + .007p	0.032	0.012	Anchorage, Memphis, Indianapolis
Freight Carried by All Airlines	25	0.17	y = 8140 + .009p	0.663	0.044	Anchorage, Memphis, Indianapolis
Mail Carried by All Airlines	25	0.53	y = 656 + .008p	0.017	0.013	Anchorage, Memphis, Indianapolis
Small Airports						
Freight Carried by Dedicated Freight Carriers Only	61	0.21	y = 1386 + .0084p	0.143	0.017	Dayton
Freight Carried by All Airlines	61	0.14	y = 2767 + .009p	0.247	0.029	Dayton
Mail Carried by All Airlines	61	0.15	y = 623 + .004p	0.26	0.013	Dayton

[1]p = SMSA population.

Note: Appendix E includes scatter diagrams showing these relationships.

Source: Federal Aviation Administration. *Airport Activity Statistics of Certified Route Carriers, 12 Months Ending December 31, 1993.* U.S. Department of Transportation, Washington, D.C., 1994.

- Table 85 also identifies simple linear regression equations between freight and mail carried by SMSA population of the community. The scatter diagrams are presented in Appendix E.

C. All-Cargo Aircraft

1. Table 86 indicates the percentage of freight (by weight carried) by all-cargo aircraft type by hub size.

2. Approximately 58.3 percent of the domestic air freight is carried by dedicated freight carriers. The dedicated freight carriers carry 76.4 percent of freight tonnage going to small hubs and 79.0 percent of freight tonnage going to medium hubs, but only 45.3 percent of tonnage going to large hubs (48). Most air freight is transported by jet aircraft. The use of non-jet aircraft is fairly consistent across all air traffic hubs. The percentages of tonnage by aircraft type are: small jets, 41.0 percent; non-jets, 27.1 percent; medium jets, 23.7 percent; and large jets, 8.2 percent.

3. The plane used most frequently for domestic freight is the Boeing 727 which carried 31.2 percent of freight tonnage, followed by the Cessna Caravan, and DC-8 with 20.5 percent and 19.8 percent, respectively (48).

4. All-cargo aircraft frequently follow different schedules than passenger air carrier aircraft. The number of departures vs. populations and tons of enplaned freight are presented in Figures 93-95.

5. Table 87 provides a relationship between aircraft size and equivalent truck trips. The data are for United Parcel Service and the movement of express packages.

D. Air Cargo Intermodal Characteristics

1. Air cargo interfaces with motor carriers and not directly with rail or marine carriers, so air-truck is the only intermodal aspect of air cargo service.

   - The common containers used in marine, truck, and rail modes (6 ft. x 8 ft. x 20 ft.) are not compatible with the size limitations of aircraft (except for the Boeing 747) and tare weight considerations. Currently, the containers are specifically designed for air cargo and are configured to fit the contours of the aircraft fuselage (40).

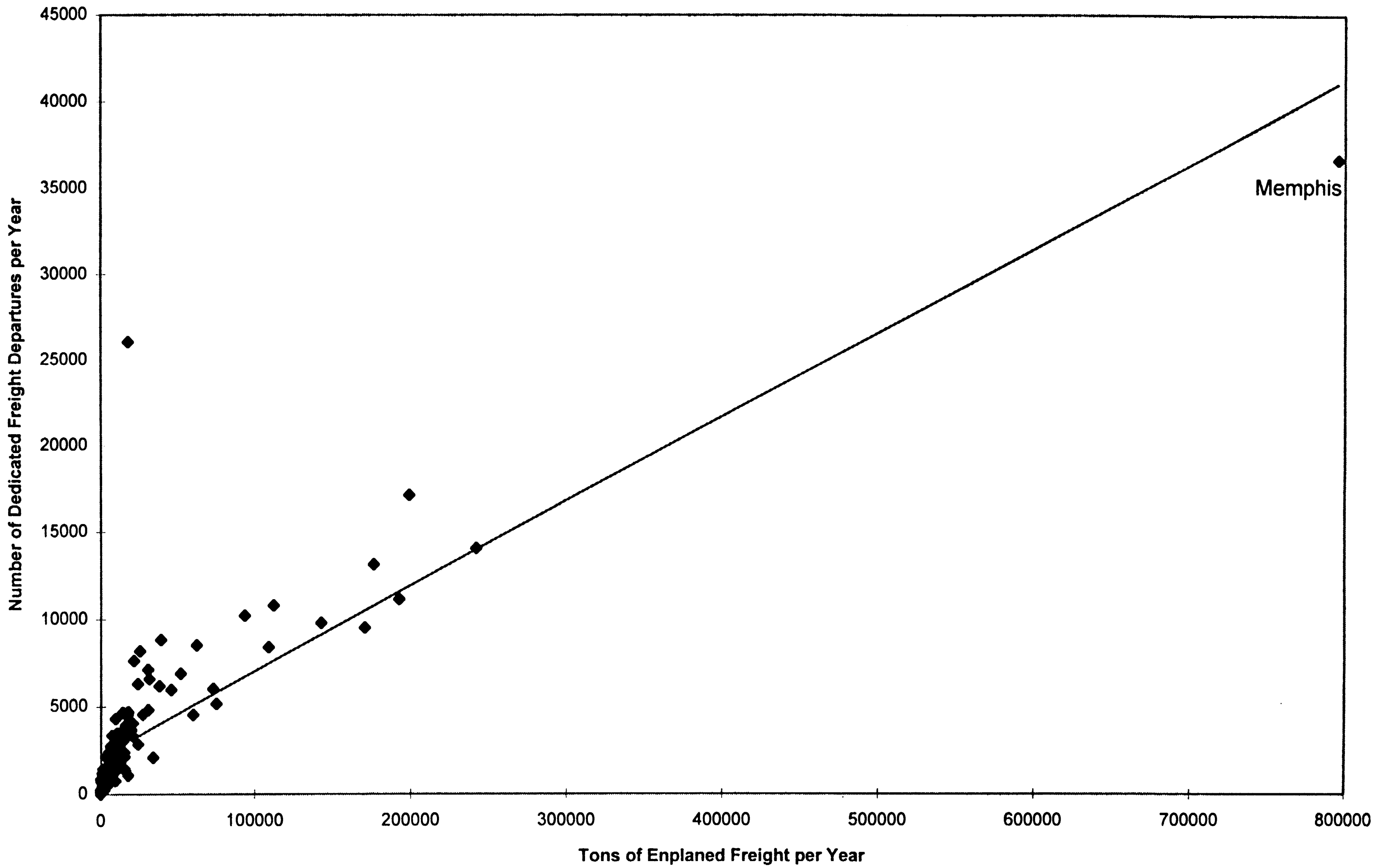
   - Air containers are not intermodal but must be loaded/unloaded at the dock of a air cargo warehouse. At large airports, freight consolidation facilities located near the airport make cargo compatible for air or surface carriage (40).

   - Airlines handle cargo in the belly of passenger aircraft. The cargo is loaded or unloaded in air cargo containers or on pallets (49). Domestic freight moves

Table 86. Air Freight by Aircraft Type for Dedicated All-Cargo Carriers.

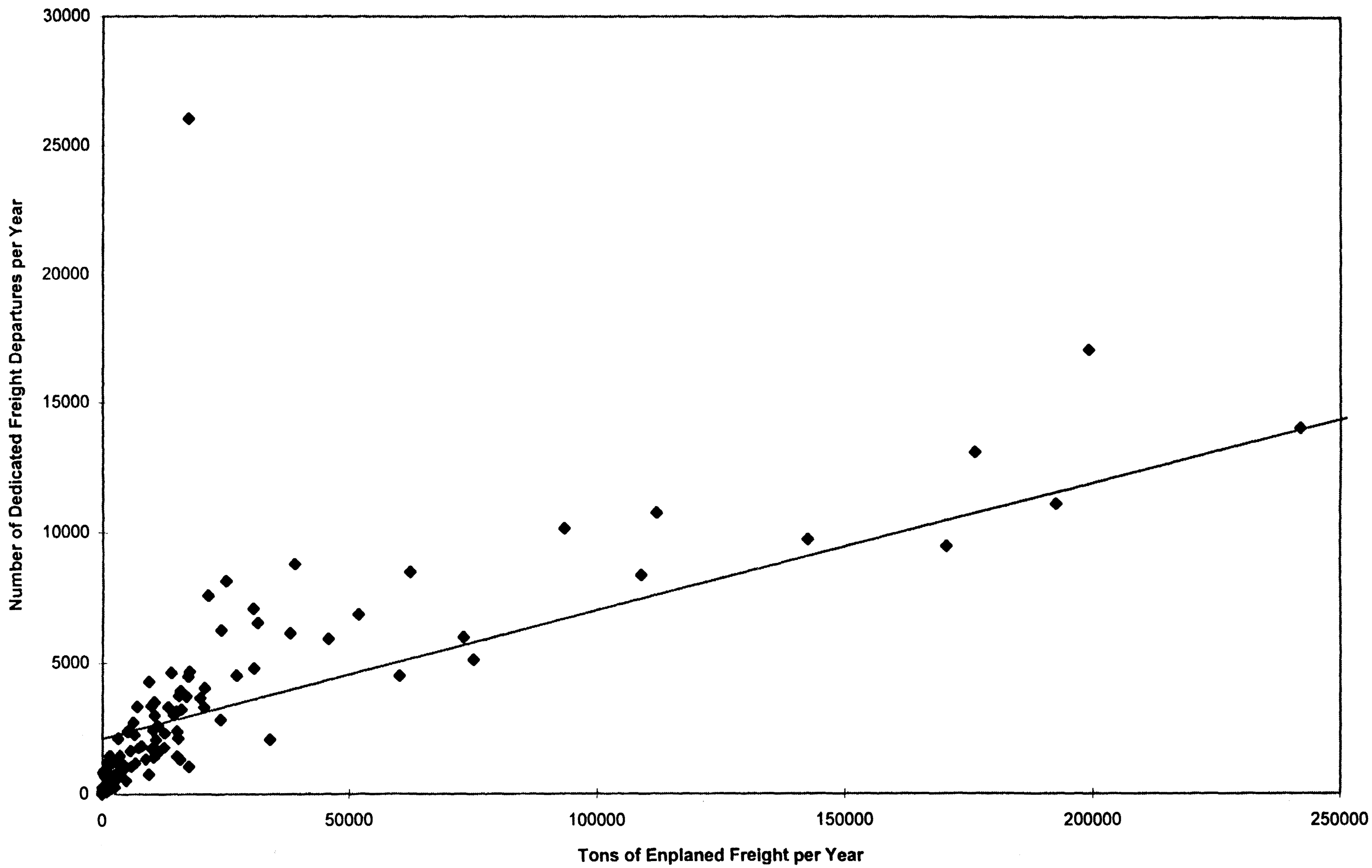
Characteristic	All Hubs (%)	Large Hubs (%)	Medium Hubs (%)	Small Hubs (%)
Aircraft Size				
Large Jet (over 50 tons)	8.23	9.64	11.60	1.50
Medium Jet (30-50 tons)	23.65	25.09	13.75	33.50
Small Jet (less than 30 tons)	40.99	38.83	49.84	33.72
Non-Jet	27.14	26.45	24.81	31.28
Aircraft Type				
Boeing 727	34.18	30.57	41.69	31.17
Cessna Caravan	16.48	14.66	15.86	20.48
DC-8	15.74	18.37	8.78	19.80
Boeing 757	6.91	5.26	4.32	13.10
DC-10	4.20	4.63	6.95	0.01
BH-18/19	3.45	4.29	3.36	1.94
DC-9	3.18	3.45	5.15	0.24
Boeing 747	3.13	3.87	3.41	1.49
Swear Metro I	2.18	1.17	1.24	5.15
Boeing 737	1.47	2.55	1.12	0.00
Total Top Ten	89.46	86.26	90.84	93.4

Source: Federal Aviation Administration. *Airport Activity Statistics of Certified Route Carriers, 12 Months Ending December 31, 1993.* U.S. Department of Transportation, Washington, D.C., 1994.



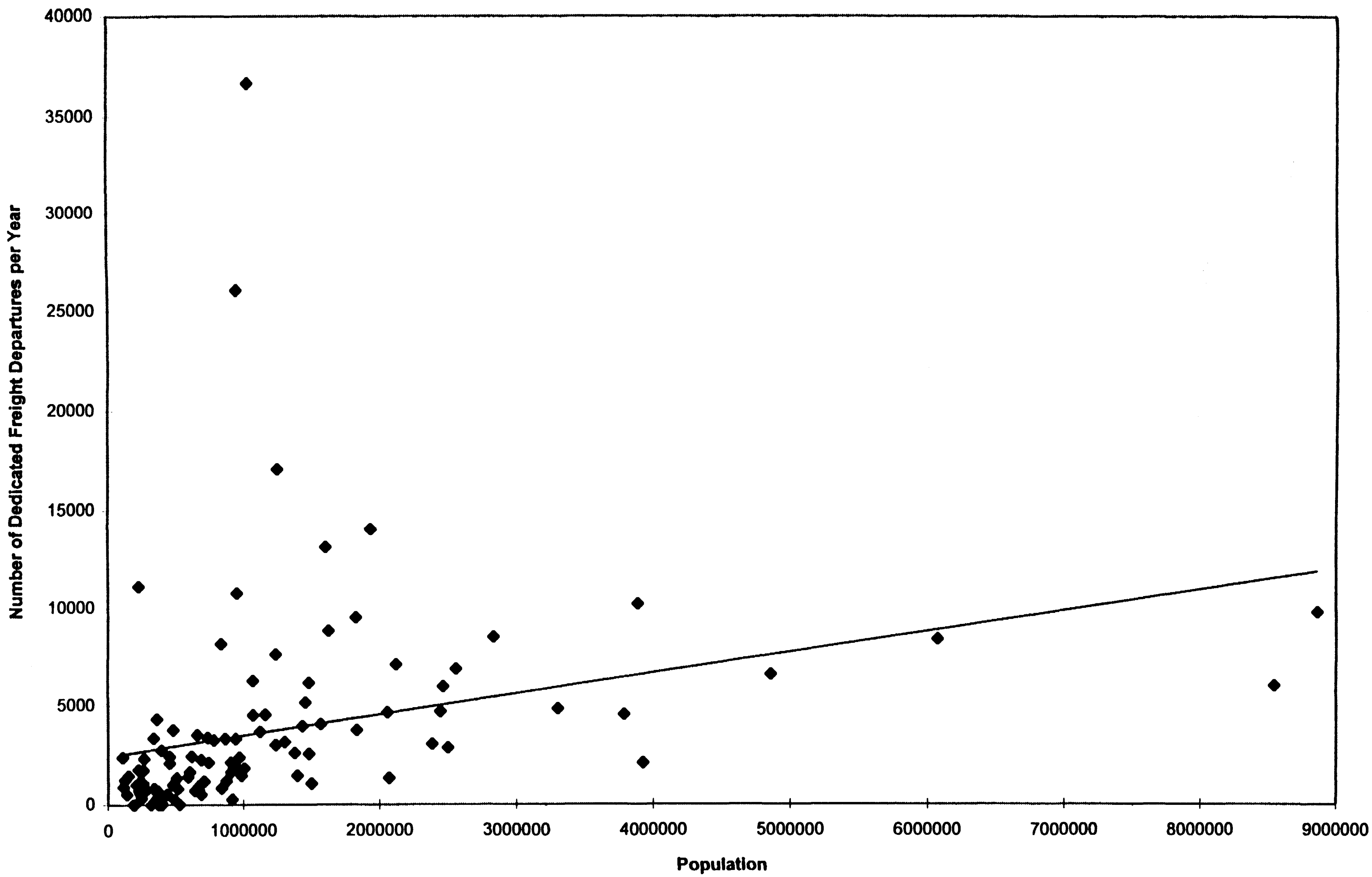
Source: Federal Aviation Administration. *Airport Activity Statistics of Certified Route Carriers, 12 Months Ending December 31, 1993.* U.S. Department of Transportation, Washington, D.C., 1994.

Figure 93. Dedicated Freight Carriers — Annual Enplaned Freight vs. Departures.



Source: Federal Aviation Administration. *Airport Activity Statistics of Certified Route Carriers, 12 Months Ending December 31, 1993.* U.S. Department of Transportation, Washington, D.C., 1994.

Figure 94. Dedicated Freight Carriers — Annual Enplaned Freight vs. Departures, Excluding Memphis.



Source: Federal Aviation Administration. *Airport Activity Statistics of Certified Route Carriers, 12 Months Ending December 31, 1993.* U.S. Department of Transportation, Washington, D.C., 1994.

Figure 95. U.S. Cities — Population vs. Dedicated Freight Carriers.

Table 87. Equivalent Truck Trips for United Parcel Service Aircraft.

Aircraft	Containers	Approximate Number of Packages	Equivalent Tractor-Trailer Trips Moved Between Aircraft and Sort Facility[1]
747	29	14,923	16
767	24	12,674	12
757	15	7,660	8
DC-8	17	8,506	10
727-100	8	3,630	4
727-200	11	5,193	6

[1]Includes movement to and from airport.

rapidly using frequent flights to reduce storage needs (40, 49). At some large airports mail is loaded/unloaded at the ramp and drayed on airport by air cargo vehicles to special U.S. Postal Service mail centers located at the airport.

- Integrated air carrier handle air cargo by air freighters. Federal Express, the U.S. Postal Service, and United Parcel Service have their own air cargo centers, fleets of air freighters, and fleets of trucks. The cargo capacities of different aircraft are listed in Table 88.

2. Truck access/egress is the intermodal link to air freight.

   - Truck access/egress to airports for air freight cargo represent a fairly small percentage of total airport traffic (50).

   - As summarized, "Airports which we have had direct experience or on which we have reviewed literature report no significant truck access problems apart from background congestion. . . . Typical strategies to deal with freight access include the establishment of 'cargo cities' or consolidated freight-handling areas and the designation of specific truck routes, both of which generally attempt to concentrate airport truck traffic in areas separate from passenger traffic" (50, p. 3.2).

   - Air cargo passing through Sea-Tac Airport is equivalent to 20,000 fully loaded five-axle truck per year or 50-60 truckloads per day (43).

   - For Portland, the distribution of truck by size into the air freight complex is noted in Table 89 (51).

   - With the growth in road feeder service (RFS) in which air freight is alternatively carried by truck, the significance of truck operations at airports is likely to increase. Boeing reports that RFS operators have increased from 4,000 frequencies per week in 1985 to 15,800 frequencies per week in 1993 (46).

3. As an example, Wilmington, Ohio, is the air cargo hub of Airborne Express and the site of a large sorting and distribution operation (39). Airborne operates a "deferred delivery service" where long haul trucks are used rather than aircraft. Also overnight delivery destination within 250 miles of Wilmington are transported by trucks. The characteristics of truck movements are as follows:

   - Day Sort Vehicles. According to Airborne officials, the day sort operation, which runs Tuesday through Saturday, currently receives/dispatches 18 trucks per day (36 trips). All day sort vehicles are tractor-trailers. Trucks typically arrive and depart between 11:00 a.m. and 1:00 p.m.

   - Night Sort Vehicles. Currently, the night sort operation receives/dispatches 30 vehicles (60 trips) between 11:00 p.m. and 3:00 a.m. Vehicle composition is

Table 88. Aircraft Cargo Capacities.

Aircraft	Max. Payload (lbs.)	Max. Capacity (cubic feet)
Boeing 707-300C	92,300	7,505
Boeing 727-100	43,699	4,410
Boeing 727-200	50,600	6,365
Boeing 737-300	38,175	3,605
Boeing 757-200	87,510	8,430
DC-8-63/73	113,767	10,420
DC-9-30	37,863	4,043
Boeing 747-200	255,264	25,325
Boeing 767-300	127,930	15,459
DC-10-10	135,300	17,055
MD-11	192,240	20,886
Airbus A-310-200	83,345	9,626
Lockheed L-1011	110,675	16,778

Source: *Freighter Airplane Comparision Handbook.* Boeing Commercial Airplane Group, Seattle, Washington, April 1994.

Table 89. Air Cargo Truck Percentages by Time of Day in Portland.

Hour Ending	Truck Type Single (%)	 One Unit (%)	 Multi-Unit (%)
01:00 a.m.	0.00	2.48	50.00
02:00 a.m.	0.00	1.24	0.00
03:00 a.m.	0.00	1.24	0.00
04:00 a.m.	0.96	3.73	0.00
05:00 a.m.	0.00	1.86	0.00
06:00 a.m.	0.00	1.24	0.00
07:00 a.m.	1.91	4.35	0.00
08:00 a.m.	4.31	3.11	0.00
09:00 a.m.	7.18	1.86	0.00
10:00 a.m.	5.74	3.73	0.00
11:00 a.m.	7.18	4.97	0.00
12:00 p.m.	6.22	2.48	0.00
01:00 p.m.	6.22	9.32	0.00
02:00 p.m.	5.74	5.59	0.00
03:00 p.m.	5.74	8.07	0.00
04:00 p.m.	2.87	4.97	0.00
05:00 p.m.	10.53	5.59	0.00
06:00 p.m.	11.96	8.70	0.00
07:00 p.m.	6.22	3.11	0.00
08:00 p.m.	6.70	4.35	50.00
09:00 p.m.	2.39	4.35	0.00
10:00 p.m.	4.78	6.83	0.00
11:00 p.m.	3.35	5.59	0.00
12:00 a.m.	0.00	1.24	0.00
Number of Observations	209	161	2

Source: Lahsene, Susie, Transportation Program Manager, Port of Portland. Letter to Dr. Frederick J. Wegmann, The University of Tennessee, September 12, 1995. Attachments included raw data on traffic and truck counts around Port of Portland facilities.

60 percent tractor-trailer and 40 percent straight truck (24-foot or 48-foot trucks).

- Extra Trucks. In addition to the scheduled night and day sort vehicles, Airborne officials estimate that approximately 30 ad-hoc trucks are received each day/night. These vehicles exhibit travel patterns similar to those of the day and night sorts.

- Support Trucks. According to airport officials, the airport currently receives 250 support trucks a day (500 trips). This amount does not include package delivery vehicles from the sorting facility or fuel trucks. Of the 250 trucks received daily, approximately:
  - 30 percent are tractor trailers, with the remainder being straight trucks and vans.
  - 82 percent arrive and depart between 7:00 a.m. and 2:30 p.m.
  - Less than 30 percent are local in nature (i.e., originate in the Wilmington area).

- Fuel Shipment Trucks. All jet fuel is currently transported by truck to the airport. Fuel shipments averaged 25 loads/day (50 trips) during 1992 and were expected to average 29 loads/day during 1993. Fuel is currently received at the airport Monday-Friday. However, increasing demand for fuel will require weekend shipments to begin in the near future. In addition to jet fuel, the airport also receives eight loads/month of auto gasoline and two loads/month of aviation gasoline (39)

- Airborne Express Commerce Park. The Airborne Commerce Park is a 400 acre fully integrated industrial park and distribution center, adjacent to the airport and sort facility. The Commerce Park offers custom warehouse and office space, a foreign trade zone, an on-site U.S. Customs facility and brokerage service, and the Airborne Stock Exchange. The Airborne Stock Exchange offers customers a state-of-the-art critical parts warehousing and rapid delivery service. According to company officials, the Airborne Commerce Park currently receives/dispatches 182 trucks per day (364 trips). Approximately 90 percent of inbound freight is carried by motor carrier, with 50 percent being hauled by tractor-trailers. About 75 percent of outbound freight is carried by Airborne Express trucks for overnight delivery (usually staged trailers).

- Total. The privately owned Wilmington Airport which serves as a major package sort location for Airborne Express and has an adjacent industrial park and distribution center generates on the average 539 trucks per day (1,038 trips) (39).

4. Characteristics of Air Cargo-Truck Movements

- A study of the John F. Kennedy International Airport in New York City (a major gateway for imports and exports) identified several tractor-trailer truck trends (52). Straight trucks and vans were not included in the survey.

- Of weekdays tractor-trailer movements, 54 percent were for cargo pickup, 34 percent were for cargo delivery, and 12 percent were for both delivery and pickup. This reflects the imbalance of imports to exports.

- On Saturdays, deliveries were dominant, with 50 percent of trips for cargo pickup, 38 percent of trips for cargo delivery, and 12 percent of trips for both cargo delivery and pickup.

- The origins of tractor-trailers delivering air cargo include: local area, 24 percent; New York State, 13 percent; New Jersey, 18 percent; Connecticut, 9 percent; outside tri-state region, 29 percent; and Canada, 7 percent.

- Truck terminals were the most common origin for trucks going to Kennedy while warehouse and plants were the most common destination points.

	Origin	Destination
Truck Terminals	45%	41%
Other Airports[2]	25%	12%
Warehouse/Plant	26%	42%
Other	4%	5%

- Slightly more than one-third of trucks make multiple stops at the airport.

No. of Stops	Weekday	Saturday
1	64%	53%
2	14%	15%
3	6%	7%
4+	16%	25%

- For those making one stop, one half spent three hours or less at the airport, but 15 percent spent more than eight hours at the airport.

[2]Includes Logan (Boston), Mirabel (Montreal), and Newark airports.

XII. PORTS OF THE UNITED STATES

A. Introduction

1. Transportation by water continues to be a vital element in the transportation system of the United States. The deep water ports along the three U.S. seaboards are an important link to foreign trade. At present, railroad lines linking eastern and western coastal seaports provide a bridge for container traffic moving from the Far East to Europe. The shallow draft ports on the inland waterways system along with the Great Lakes ports and ports along the Intracoastal waterways move vast quantities of domestic cargo to various locations in the United States. The Mississippi River and its tributaries primarily provide for the north-south movement of domestic cargo by barge linking Canada and the Americas. Ports are designed to provide an interface between ocean and waterways transportation and other surface modes.

2. In summary, the port industry in the United States as it exists today involves (50):

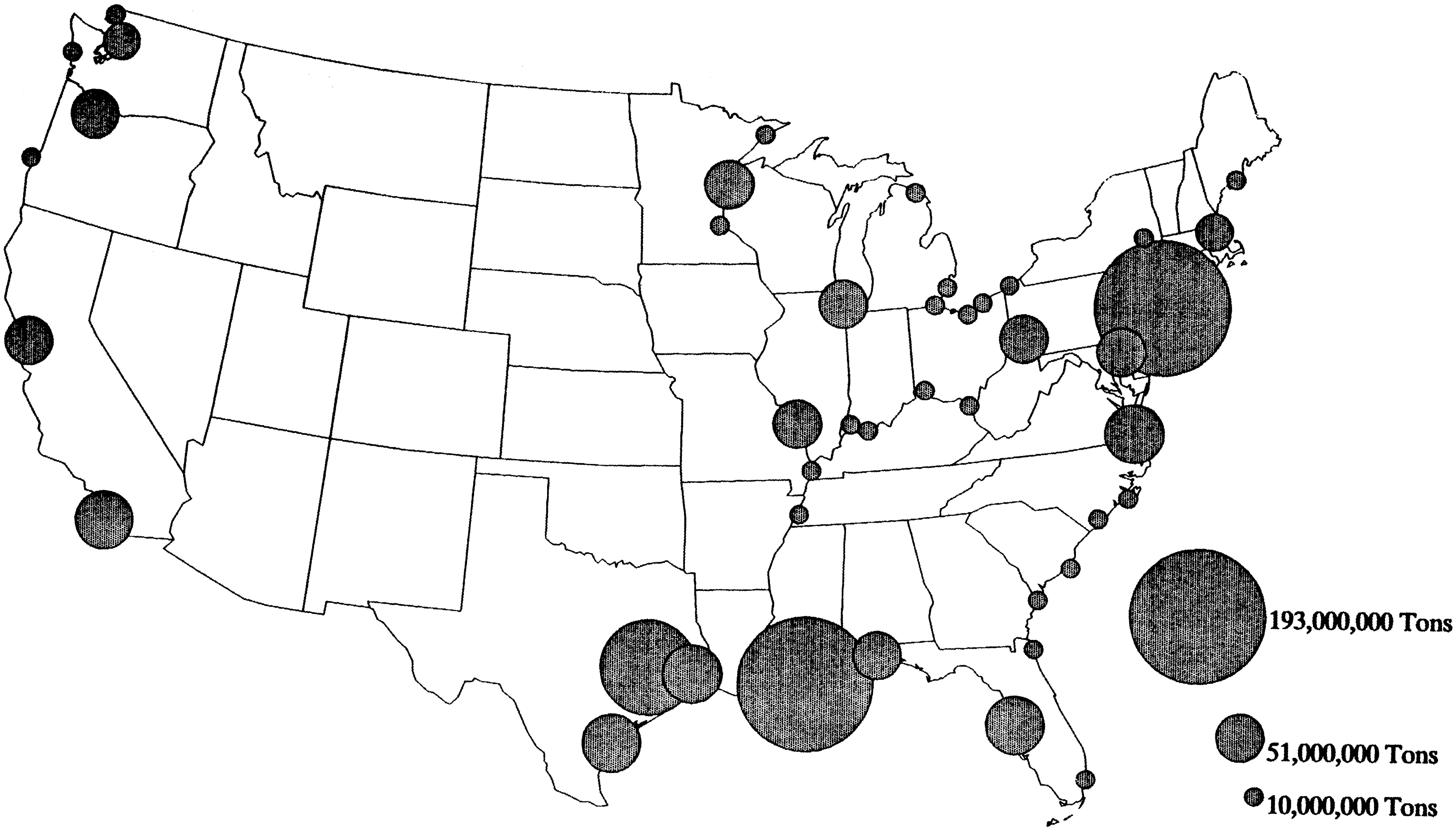
   - 967.5 Million short tons of cargo worth $467.3 billion.
   - 185 commercial deep draft ports.[1]
   - 3,214 ship berths.
   - 1,914 terminals.
   - 28 terminal and beltline railroads.

3. Figure 96 shows the cargo throughput in tons for major U.S. ports in 1993. Most of the activity is concentrated in seaports on the Atlantic and on the Gulf of Mexico.

4. U.S. ports are generally grouped according to the geographical location of the waterway on which the port is located.

   - Inland Waterways System.
     - Atlantic Coast: Atlantic Intracoastal Waterway links coastal ports from Miami to Norfolk.
     - Gulf Coast: includes the Gulf Intracoastal Waterway, Mobile River, and tributaries.
     - Mississippi River: largest system consisting of the Illinois River, Ohio River, and Upper, Middle and Lower Mississippi Rivers.
     - Pacific Coast: Columbia-Snake River system links deep-water ports on the Columbia River with inland ports in Washington, Oregon, and Idaho.

[1]Deep draft ports includes coastal seaports and great lakes ports.



Source: Adapted from Bureau of Transportation Statistics. *Transportation Statistics Annual Report 1994*. U.S. Department of Transportation, January 1994, p. 78.

Figure 96. Cargo Throughput for Selected U.S. Ports, in Tons, 1993.

- Figure 97 shows the geographic location of each inland waterway segment.

- Ocean Waterways System includes seaports on the Atlantic, Pacific, and Gulf of Mexico.

- Great Lakes System includes ports located on Lakes Superior, Michigan, Huron, Erie, Ontario, St. Clair, and other connecting waterways such as the St. Mary's River, St. Lawrence Seaway, and Hudson River.

5. Figure 98 shows the location of the U.S. seaports and the Great Lakes ports.

6. The majority of U.S. waterborne activity takes place in the coastal seaports. Figure 99 illustrates that they accounted for 1,288 million tons (63%) of domestic and international cargo in 1993.

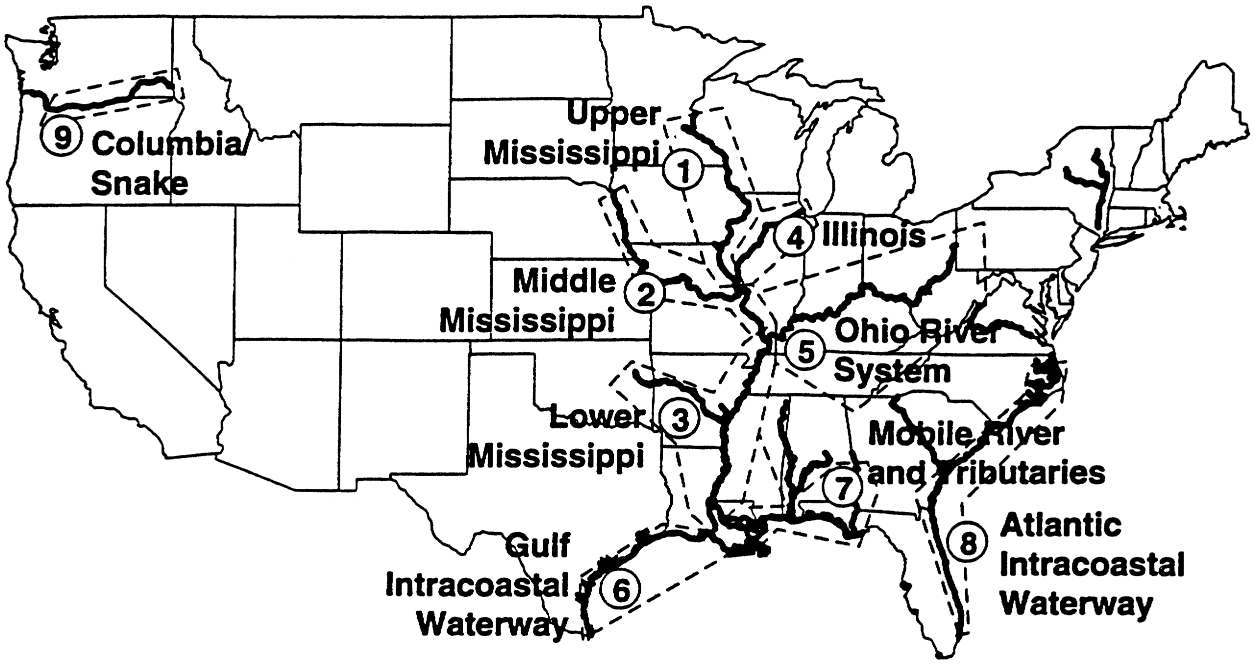
B. Inland Waterway Ports

1. The inland waterway system of the United States includes approximately 12,400 miles of navigable waterways. Table 90 lists the length and the tonnage moved by each segment. The largest and most frequently used system is the Mississippi River and its tributaries which accounted for 86% of the domestic traffic in 1993. Figure 100 ranks the segments in terms of tonnage per system mile. Since the majority of the inland waterway traffic takes place on the Mississippi River and other inland rivers, the remainder of this section of the report will focus on inland river ports. The coastal ports operate as inland waterways moving domestic commodities along the coast as well as seaports moving international traffic. Subsequent subsections of this chapter provide information pertaining to the international movement of goods by the coastal seaports.

2. An inland port is, first of all, an intermodal transportation and distribution center. Its secondary activity is industrial production and processing. It can also be defined as a complex of adjacent or isolated terminal facilities operating under some degree of influence or control by a state or (interstate) chartered port authority. Figure 101 shows a special situation where a port may consist of a number of fragmented terminals spaced miles apart that operate under a single port authority. A port generally includes the terminal facilities in the area in which the port was developed. A terminal refers to isolated facilities which are not in the organized port area.

3. The types and quantities of commodities to be loaded and unloaded at a port are important in determining wharf requirements. Inland river ports generally handle fewer types of commodities than seaports. The types of commodities handled by inland ports can be categorized as general cargo, dry bulk, or liquid bulk.

   - General cargo includes a variety of commodities, such as automobiles and construction equipment, which is moved via deck barges or paper products and packaged goods transported by covered barges.



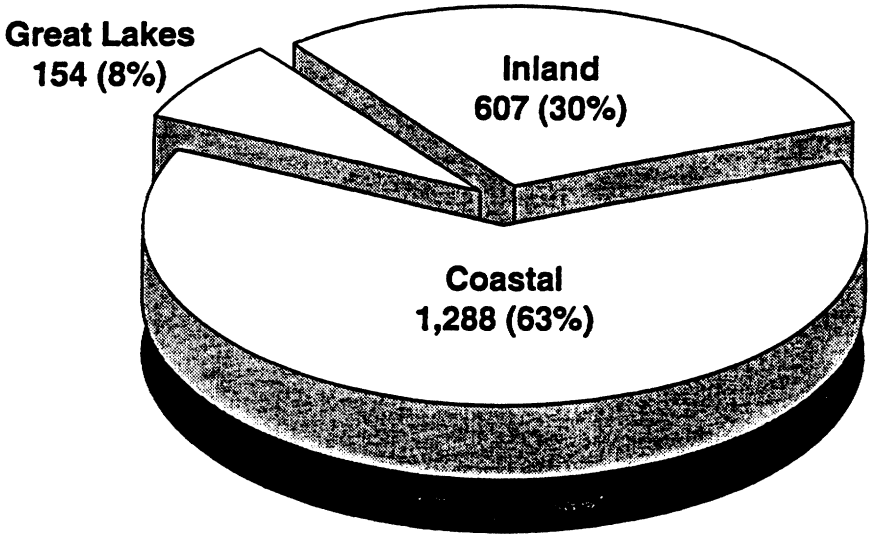
Notes: Atlantic Coast, Segment 8. Gulf Coast, Segments 6 and 7. Mississippi River, Segments 1-5. Pacific Coast, Segment 9.

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 2.6.

Figure 97. Inland Waterway System.

Source: U.S. Army Corps of Engineers

Figure 98. Location of Coastal and Great Lakes Ports.



Note: Numbers represent millions of tons of domestic and international freight.

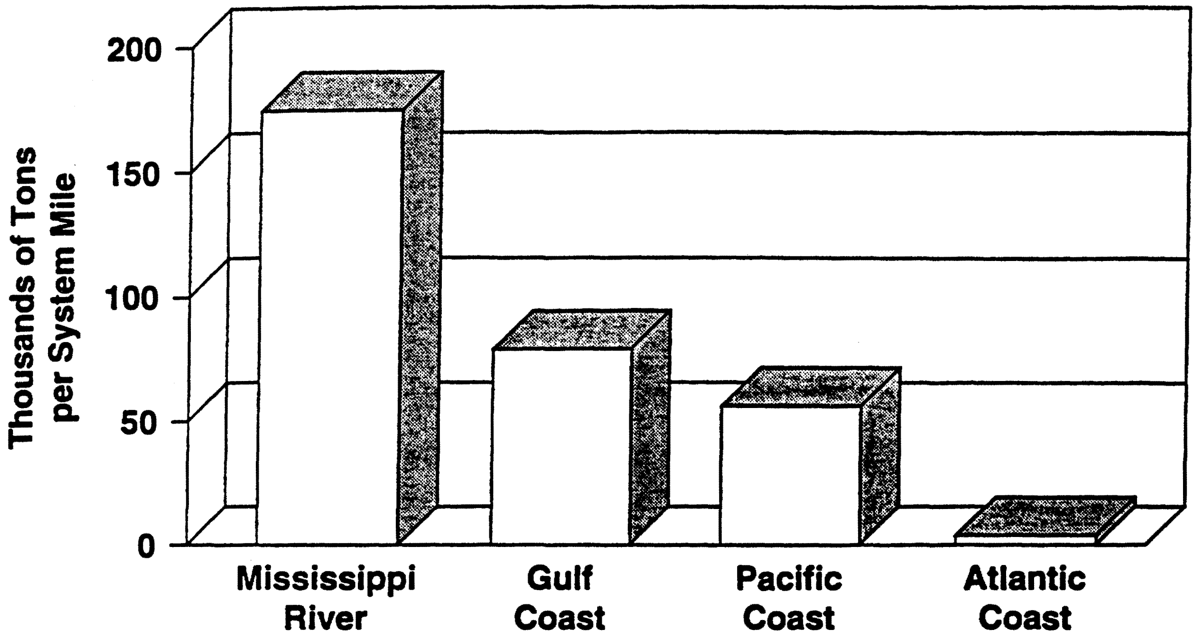
Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 2.28.

Figure 99. Geographic Distribution of U.S. Waterborne Activities, 1993.

Table 90. Domestic Traffic by Inland Waterway System, 1993.

System	Components	Miles	Tons (millions)
Atlantic Coast	2	1,142	4.8
Gulf Coast	8	2,301	181.1
Mississippi River	16	8,229	1,434.8
Pacific Coast	3	722	40.4

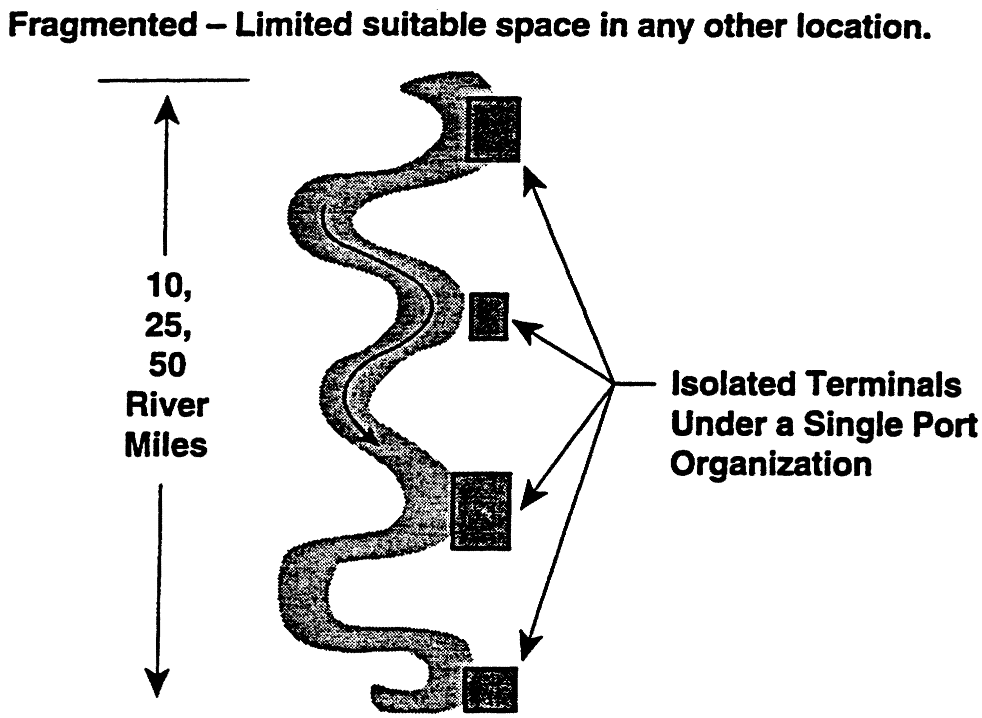
Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 2.30.



Note: Gulf Coast, Pacific Coast, and Atlantic Coast intensities reflect inland waterway movements.

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 2.31.

Figure 100. Intensity of Use for the Inland Waterway System.



Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 2.33.

Figure 101. Example Where Isolated Terminals Operate Under a Single Port Authority.

- Dry Bulk is dry cargo shipped by barges in a free-flowing state. Dry bulk commodities include grain, coal, salt and other minerals, petroleum coke, and scrap metal.

- Liquid Bulk is liquid cargo shipped via barge and transferred via pipeline. Crude and refined petroleum, chemicals, and molasses are typical liquid bulk cargoes.

4. Inland port commodities by volume (in millions of tons) for 1993 are shown in Figure 102. The largest commodity moved on the inland system was coal. Coal accounted for approximately 178 million tons of the waterborne traffic through the inland port system. Petroleum products were the second largest commodity transported accounting for 115 million tons.

5. The Port of Pittsburgh has throughout the decade moved the most tonnage of all of the inland river ports. In 1993, the Port of Pittsburgh moved 44.5 million tons of commodities the majority of which was coal. The Port of St. Louis placed second in tonnage moved; 27.6 million tons were transported through the Port of St. Louis in 1993. Figure 103 shows the tonnage moved by the top five inland ports.

6. Terminals are facilities built on the waterfront for loading and unloading barges. Usually, each terminal is an intermodal transportation hub. There are three types of inland rivers terminals.

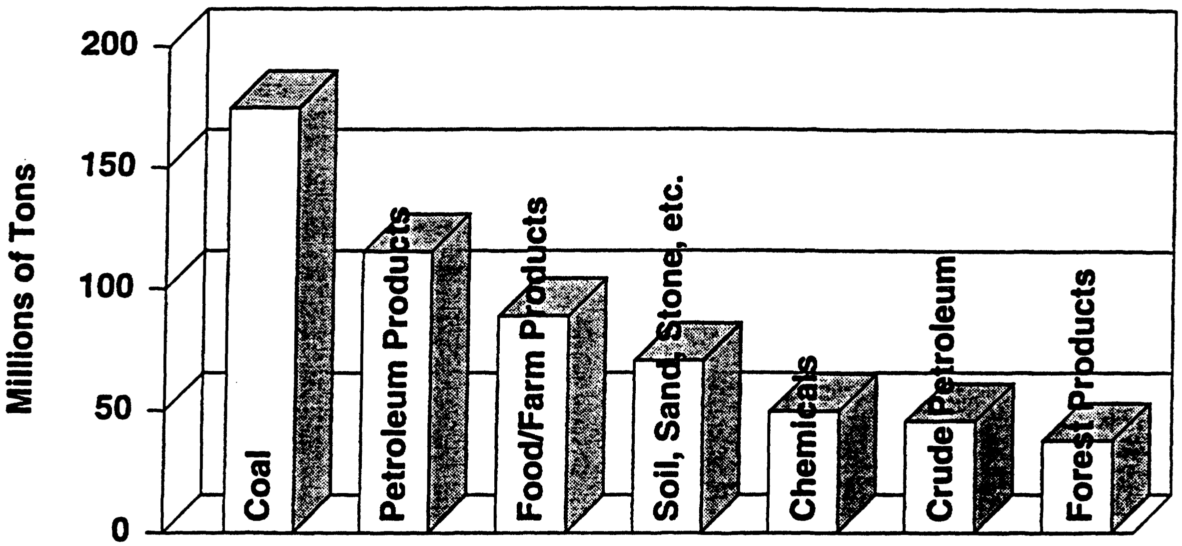
   - General purpose terminals handle a wide variety of bulk commodities often in bundles, coils, large bags, drums, and pallets.

   - Special purpose terminals are designed to handle only one type of commodity rapidly in very large tonnages. Grain, fertilizer, coal, petroleum products, cement, sand, gravel, and stone are good examples of the types of commodities handled by these terminals. The majority of the terminals found in inland river ports are of this type. They require specialized loading, unloading, and transfer equipment. Storage and/or warehousing facilities are also required.

   - Industrial terminals are not a portion of the intermodal system but are used to service a specific industrial plant or processing facility. They are similar to special purpose terminals in their equipment and storage requirements.

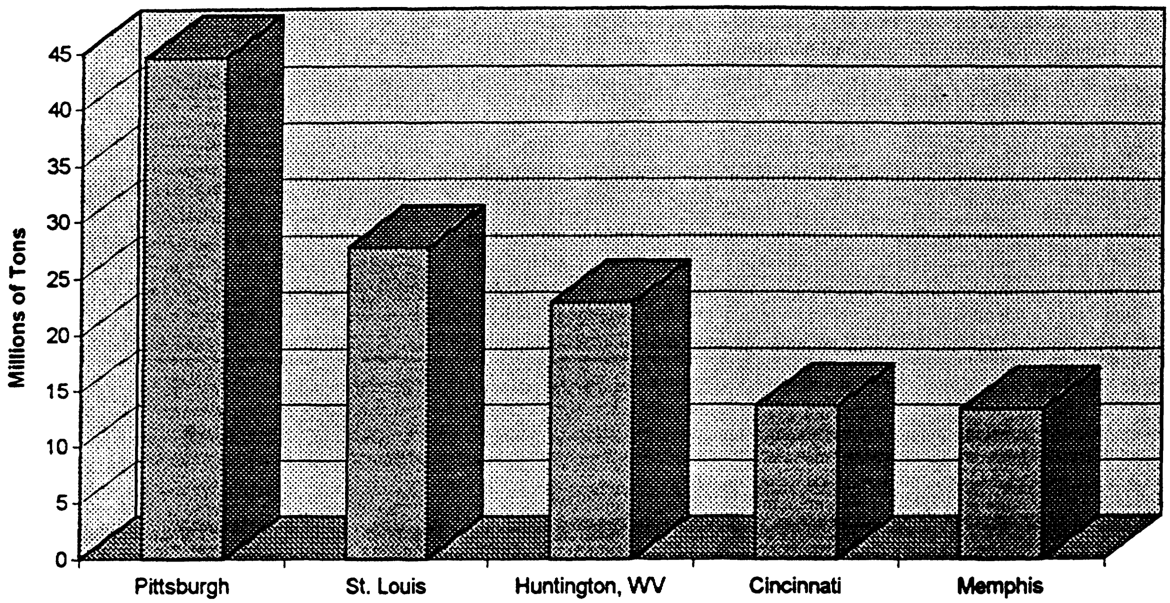
7. General purpose terminals generally occupy at least 20 acres and may be much larger. Special purpose and industrial terminals usually occupy 6-10 acres (53, p. 76).

8. The planning and development of new inland river ports or the expansion of existing facilities require an understanding of the requirements of all transportation modes, warehousing and storage needs, and the demands of industries located within the port. The general characteristics of a port include:



Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 2.29.

Figure 102. Commodity Volumes for Inland River Ports, 1993.



Source: *The U.S. Waterway System — FACTS.* Navigation Data Center, U.S. Army Corps of Engineers, 1995.

Figure 103. Tonnages of Leading Inland Ports, 1993.

- Transportation facilities. Railroads, roads, and pipelines provide linkages to off-port transportation, distribution, manufacturing, and commercial facilities. Connectivity to existing and planned highway and rail network is a key consideration in site selection.

- Distribution facilities. Storage facilities required include transit sheds, warehouses, open storage areas, liquid storage tanks, grain elevators and other bulk storage facilities. Acreage must be made available for these facilities. Tables 91-93 show some storage characteristics by cargo type for a number of selected inland river ports.

- Materials handling equipment. Cranes, liquid and pneumatic pipelines, conveyor systems, front end loaders, and forklifts are required to transport various cargo between modes. Tables 91 and 94 provide data on crane characteristics for various inland ports. Table 94 also lists some throughput capacities in short tons per month. Table 95 provides data for coal handling equipment in terminals within the Port of Huntington, West Virginia, and ports along the Ohio and Kanawha Rivers.

- Processing and manufacturing. Fertilizers, construction equipment, plastics, styrofoam, and automotive parts are all examples of products processed and/or manufactured at or nearby port terminals. The demands of industries utilizing the port must be taken into account. Figure 104 shows plant size preferences for typical waterfront industries. The most preferred plant size is from 5 to 20 acres (54)

- General offices. Administrative office space is needed for shipping and receiving, marketing, and many other activities required for port operation.

- Support facilities. Restaurant, grocery, auto parts and repair, lodging, medical, and banking services are typically provided. Acreage must be available for these service facilities.

9. An understanding of the different transportation modes is needed for the efficient movement of commodities. The transportation modes used at inland river ports include:

   - Barges. Towboats are used to tow a fleet of barges. The average speed of a tow is 5 mph upstream and 10 mph downstream. The standard size barge is 35 feet wide by 195 feet long and has a capacity of 1,500 tons.

   - Trucks. Trucks are the most flexible of all modes and are almost always used for inland ports. The existing and planned roadway should be evaluated with respect to providing access to the port for large trucks with heavy loads. If possible the port should be located adjacent to an Interstate facility or major highway with sufficient capacity for high volumes of truck traffic generated by

Table 91. Characteristics of General Cargo Handling Facilities for Selected Inland River Ports.

ACOE Port Series #[1]	Coverage	Number of Terminals	Average Berthing Space (ft.)	Covered Storage (ft.^{2})	Open Storage (acres)	Cranes
60	Port of Pittsburgh and others	2	975	290,000	22.5	2-15T, 2-40T, 1-25T
70	Port of St Louis and others	5	Unavailable	172,600	27	Unavailable
62	Port of Cincinnati and others	3	335	217,000	17	20T, 2-30T
61	Port of Huntington, WV and others	1	Unavailable	125,000	10	Unavailable
71	Port of Memphis and others	7	330	444,600	40	1-20T, 1-25T, 1-37T, 2-50T, 1-75T, 1-85T, 2-100T, 1-150T, 1-200T, 1-580T

[1]See Appendix F for a detailed description of the ports included in each ACOE port series.

Sources: U.S. Army Corps of Engineers Water Resources Support Center, Port Series Nos. 60, 70, 62, 61 and 71. Prepared by Navigation Data Center. U.S. Government Printing Office, Washington, DC, 1991-1993.

Table 92. Characteristics of Oil Handling and Bunkering Facilities for Selected Inland River Ports.

ACOE Port Series #[1]	Coverage	Number of Terminals	Average Berthing Space (ft.)	Number of Tanks	Storage Tank Capacity (barrels)
60	Port of Pittsburgh and others	35	535	237	3,937,300
70	Port of St Louis and others	27	438	282	14,957,800
62	Port of Cincinnati and others	31	326	181	4,942,300
61	Port of Huntington, WV and others	51	304	328	5,046,400
71	Port of Memphis and others	24	373	196	7,396,650

[1]See Appendix F for a detailed description of the ports included in each ACOE port series.

Sources: U.S. Army Corps of Engineers Water Resources Support Center, Port Series Nos. 60, 70, 62, 61 and 71. Prepared by Navigation Data Center. U.S. Government Printing Office, Washington, DC, 1991-1993.

Table 93. Characteristics of Liquid Bulk Handling Facilities for Selected Inland River Ports.

ACOE Port Series #[1]	Coverage	Number of Terminals	Average Berthing Space (ft.)	Number of Tanks	Storage Tank Capacity (gallons)
60	Port of Pittsburgh and others	22	356	247	117,305,300
70	Port of St. Louis and others	16	370	89	82,021,000
62	Port of Cincinnati and others	22	281	165	141,006,500
61	Port of Huntington, WV and others	27	351	470	177,840,000
71	Port of Memphis and others	31	367	194	243,416,700

[1]See Appendix F for a detailed description of the ports included in each ACOE port series.

Sources: U.S. Army Corps of Engineers Water Resources Support Center, Port Series Nos. 60, 70, 62, 61 and 71. Prepared by Navigation Data Center. U.S. Government Printing Office, Washington, DC, 1991-1993.

Table 94. Throughput Capacities for Selected Inland River Ports.

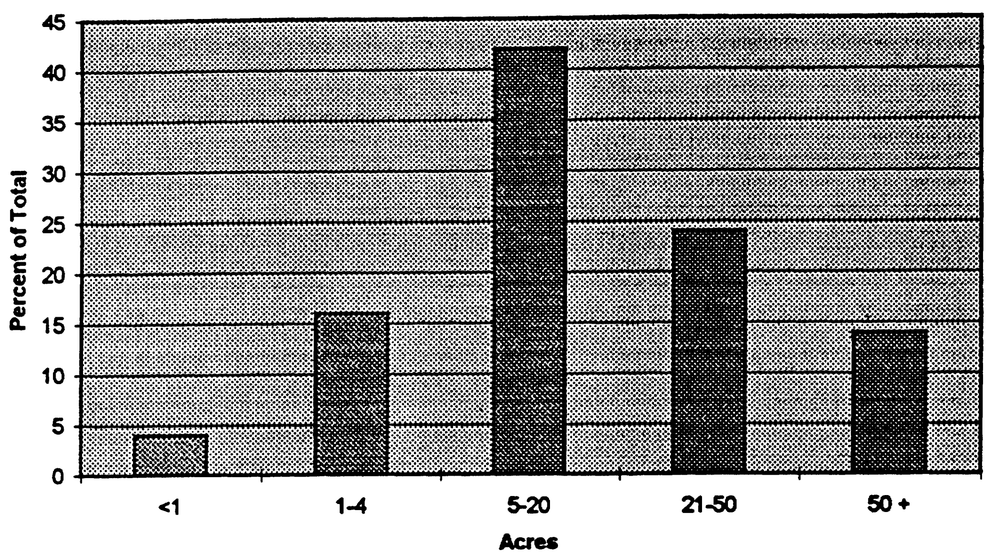
	Throughput capacity (short tons per month)			
Port	Receiving	Processing	Shipping	Equipment
Cape Girardeau, MO	72,000	NA	36,000	1-110T, 2-60T cranes
Iuka, MS	16,667	16,667	16,667	50T cranes
Louisville, KY	400,000	400,000	400,000	30T bridge crane and 2,000 TPH conveyor
Owensboro, KY	15,000	15,000	15,000	10T cranes
Rosedale, MS	9,500	9,500	9,500	1 crane and 9,000 BPH dry bulk conveyor

Table 95. Characteristics of Coal Handling Equipment for Terminals Within the Port of Huntington, WV and Ports Along the Ohio and Kanawha Rivers.[1]

Method	Number of Terminals	Range of Rates (tons/hr.)	Average Rate(Tons/hr.)
Conveyor System	17	250-3,000	900
Unloading Tower and Conveyor	14	240-3,500	1,700
Crane	4	100-150	150

[1]See Appendix F for a detailed description of the ports.

Sources: U.S. Army Corps of Engineers Water Resources Support Center, Port Series No. 61. Prepared by Navigation Data Center. U.S. Government Printing Office, Washington, DC, 1992.



Source: *Port Development Study for Phillips County Port Authority Helena-West Helena, Arkansas*. Center for River Studies, Memphis State University, Memphis, TN; and Cline-Frazier, Inc., Consulting Engineers, Helena, Arkansas, April 1993, Figure 6, p. 19.

Figure 104. Plant Size Preferences for Waterfront Industries.

port activities. Maneuvering areas should be provided for trucks leading into and away from the loading point and holding areas should be provided for trucks waiting to be loaded.

- Railroads. Railroads require extensive land use due to increasing use of unit trains, heavy cars, container cars, and curve radii. The port should have at least a small marshalling rail yard to store railcars waiting to be loaded/unloaded. Table 96 lists some railway characteristics at selected inland river ports.

- Intracity pipelines. Jet fuel pipelines from barge terminals to airports, chemical pipelines from/to plants and barges, petroleum pipelines from exploration fields to barge, and such are exceptionally valuable solutions to industry needs. At the Port of Memphis, jet fuel is transferred from barges directly to a pipeline serving the Memphis International Airport.

- Cross country conveyors. Coal field-to-barge cross country conveyor systems and pneumatic systems are used to make inland river transportation available at the doorstep of a shipper/receiver many miles away without digging a canal.

10. Barge transportation is more energy efficient than rail or truck transportation. This is primarily the result of the tremendous capacity of a barge when compared to railcars or trucks. Figure 105 illustrates the capacity of a barge compared to its competitors. In fact, on the lower Mississippi River, a single towboat can push as many as 40 barges. This tow has the carrying capacity equivalent of 600 railcars or more than 2,400 trucks. This high carrying capacity results in very economical transportation.

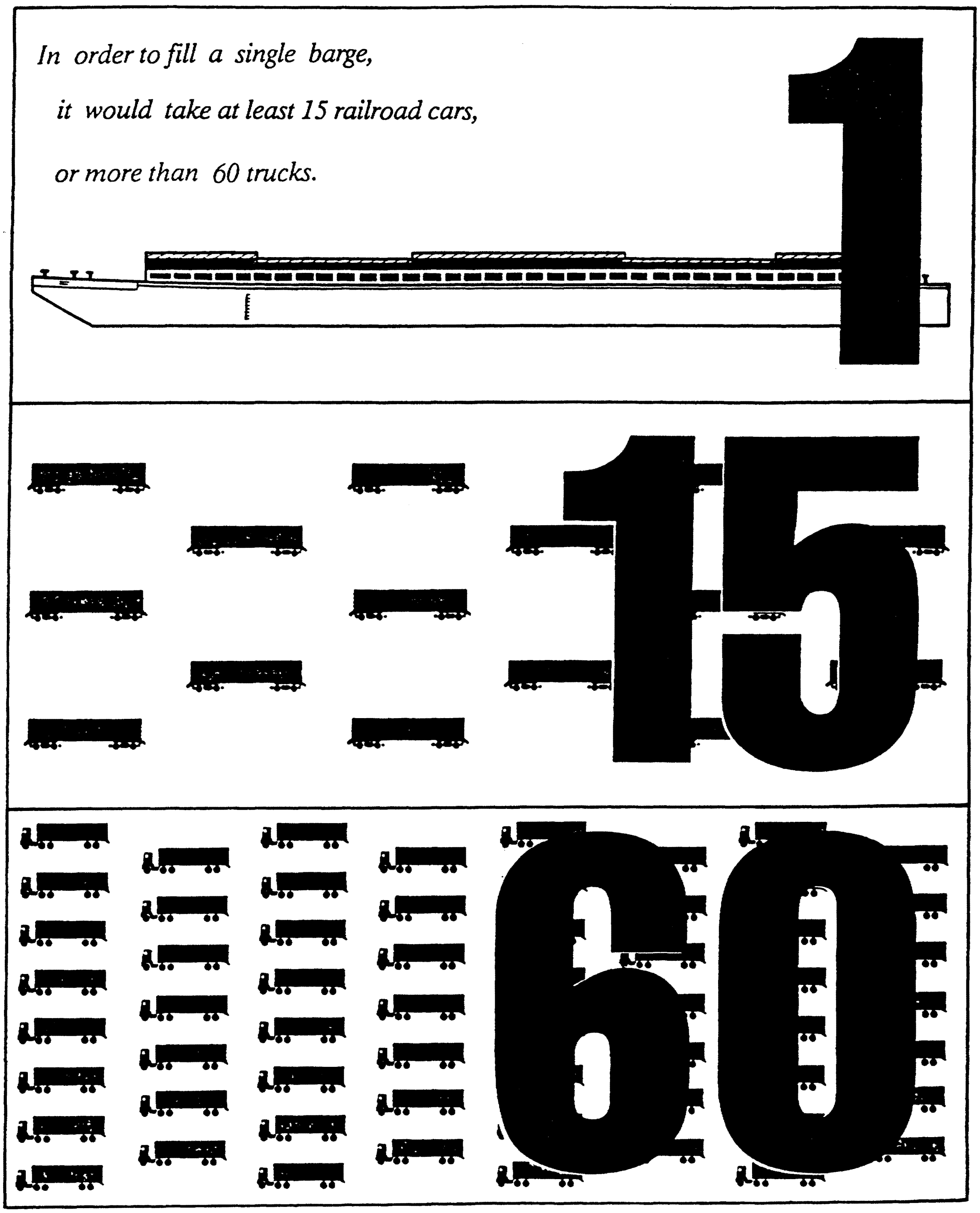
11. Table 97 provides shipping and receiving data by transportation mode for a few inland river ports.

12. An understanding of the type of operations performed in an inland river port is important to the planner of any proposed expansion of an existing terminal or the construction of a new port. Typical inland river port operations are summarized below.

    - A tow of barges arrive at a port and the cargo is transferred to a processing/ storage facility.
        - General cargo is transferred from the barge via landside cranes. Automobiles and other vehicles can be driven or towed from the barge.
        - Liquid bulk cargo transported by barges is usually pumped via pipeline into nearby storage tanks.
        - Dry bulk materials are typically unloaded by boom crane or a conveyor system into covered sheds or onto open stockpiles adjacent to the wharf.

Table 96. Railway Characteristics at Selected Inland River Ports.

	Load Track (feet)	Support Track (feet)	Total Track (feet)
Cape Girardeau, MO	400	400	800
Iuka, MS	1,320	2,640	4,960
Louisville, KY	19,000	Unavailable	Unavailable
Owensboro, KY	800	2,500	3,300
Rosedale, MS	1,200	5,280	6,480



Source: *We Can Move Mountains (Well, Almost), Some Facts About the Nation's Tug and Barge Industry*. American Waterways Operators and National Association of Inland and Coastal Tug and Barge Industry.

Figure 105. Carrying Capacity Equivalents of Inland Transportation Modes.

Table 97. Shipping and Receiving Characteristics of Selected Inland River Ports.

Port	Shipping and Receiving (Units/Month)		
	Trucks	Rail	Barges
Cape Girardeau, MO[1]	17,800	72	72
Iuka, MS	750	17	9
Louisville, KY	Unavailable	600	50

[1]Figures include totals for two terminals.

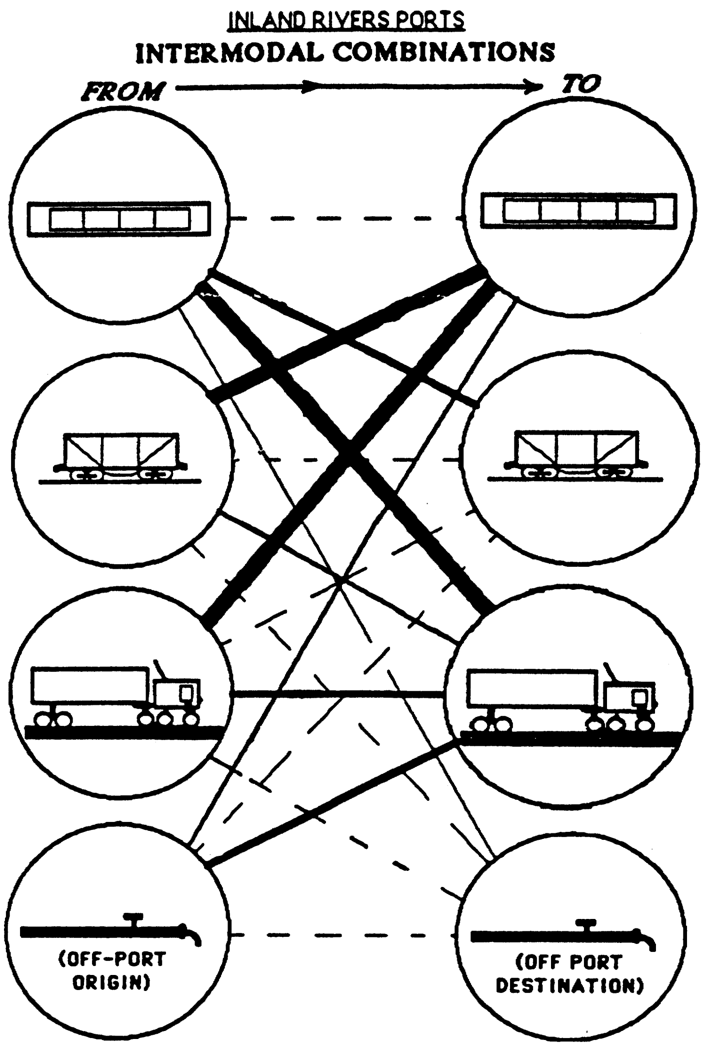
- The unloaded cargo is positioned within the terminal for transfer to the next mode.
  - General cargo is transferred to terminal storage areas or warehouses using yard equipment. Here some of the cargo may undergo some processing and/or manufacturing. For example, automobiles may be sent to a de-wax or service facility.
  - Bulk cargoes typically remain in storage awaiting their next transfer. Some bulk cargoes, such as, petroleum coke may be processed at this stage.

- Cargo is transferred to the appropriate mode in which it leaves the terminal.
  - General cargo is loaded onto trucks or railcars and transported out of the terminal.
  - Liquid bulk cargo is piped from storage tanks to pipelines, tanker trucks or tanker railcars and transported out of the terminal.
  - Dry bulk cargo is transferred from storage facilities to cross country conveyors, trucks or railcars removing the cargo from the terminal.

- Cargo is transferred to its final destination or to another modal transfer location outside of the receiving terminal.
  - Trucks deliver cargo to its final destination, to a nearby intermodal railyard, to an airport, or to a warehouse or storage yard for eventual transfer to another truck or transportation mode.
  - Trains exit the terminal and proceed to the final destination. If the train exits the terminal without a full load of railcars, it may pick up additional cars at an intermediate rail yard. The train may also release cars at different locations along the delivery route. The cargo within the railcars may be transferred to another mode (usually trucks) before reaching its final destination.
  - Cross country conveyors or intercity pipelines deliver bulk and liquid cargo to its final destination or to another transfer/storage location.

14. Figure 106 illustrates the 16 possible pairings and the frequency of use for the different inland river transportation modes. The most frequent transfers involve trucks and barges followed by transfers between barge and rail. The interaction between the different transportation modes is critical to the efficient movement of commodities. Many times the intermodal transfer of a commodity is interrupted by a disparity in the rate of delivery between modes. For example, about 60 truck loads are required to load/unload a standard barge. This interruption is referred to as materials handling. A stockpile may be used to temporarily store dry bulk materials while the barge is being loaded/unloaded.

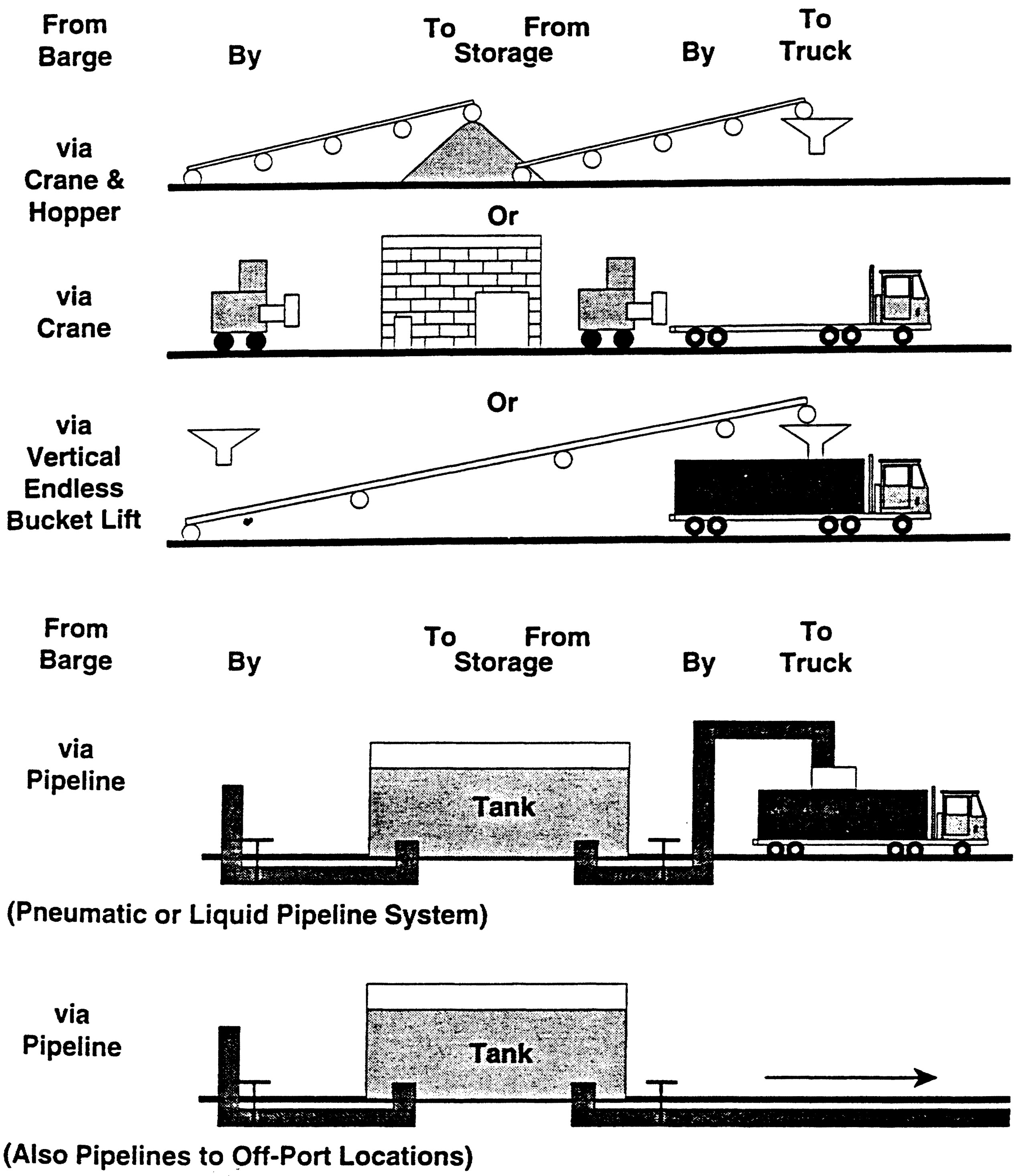
15. Tanks are frequently used to store liquid bulk commodities. The means by which the transfer takes place is called an intermodal connector. Cranes, conveyor systems, and pipelines are examples of intermodal connectors. Some examples of intermodal connectors for the transfer between barge and truck are shown in Figure 107.



Notes: most use (▬); least use (——); extremely rare use (- - -).

Source: *Inland Rivers Ports and Terminals*. Memphis State University, Memphis, TN, 1990, p. 10.

Figure 106. 16 Intermodal Planning Combinations.



Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 2.32.

Figure 107. Examples of Intermodal Connectors Between Barge and Truck.

16. In planning a new inland river port or expanding an existing port, there are some special requirements that need to be met which are unique to the inland water transportation mode. These requirements include a place to park and service barges and the need to provide in-stream servicing to the barges. A discussion of each of these requirements follows:

- Fleeting area. A very large area outside of the main channel may be required to moor barges while waiting for loading/unloading operations to be completed. In the St. Louis area, barges are moored along the riverbank for miles due to the fact that St. Louis is just south of the first set of locks on the Mississippi River.

- Service area. A service area will be required to load and unload the barges. "The average dock length is 500 to 700 feet (2.5 to 3.5 barge lengths), except for major coal terminals which average some 1,900 feet" (9, p. 34). Tables 91-93 provide additional berthing data for some selected existing inland river ports. Figure 108 illustrates the situation where a port can be located with a limited waterfront as long as there is sufficient unobstructed backup area to house the port infrastructure.

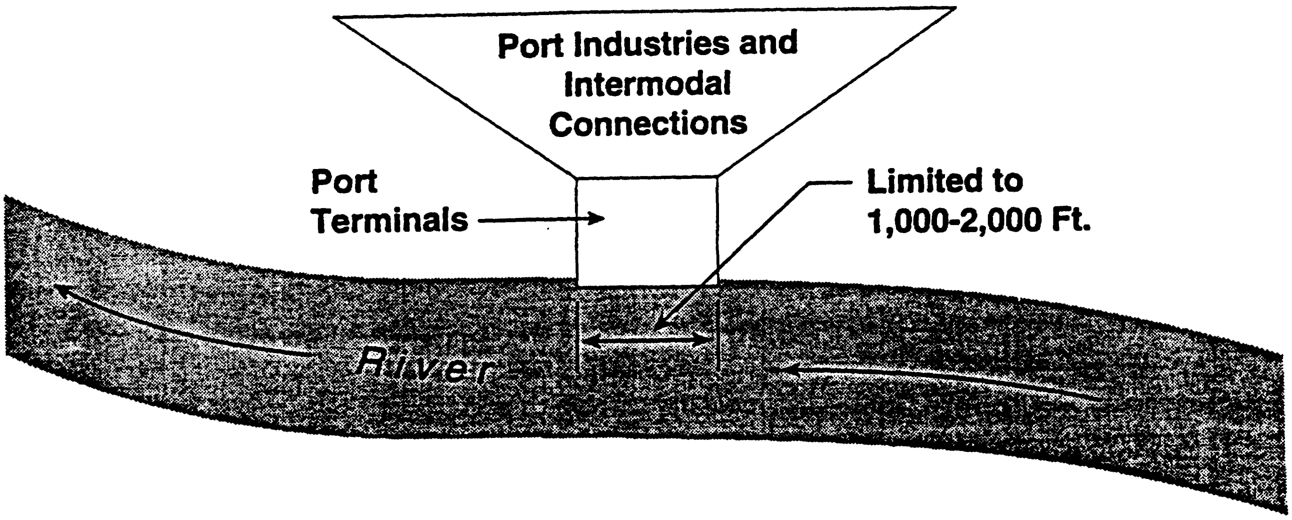
- Repair facilities. Barges and towboats are frequently damaged and must pass regular inspections by the Coast Guard. Repair facilities must be available for barges/towboats in need of repair. Facilities also may be needed for other services such as cleaning.

- In-stream servicing. A unique feature of the inland rivers transportation mode is the requirement to add/remove barges, change crews, fuel, and receive groceries during transport. There are companies that specialize in providing these services.

C. Seaports

1. The ocean waterways system provides for the movement of goods between the coastal seaports of the United States and the many international seaports throughout the world. In 1993, the foreign traffic through U.S. seaports totaled 1,016 million tons of waterborne commerce (55).

2. A seaport is a land intensive intermodal transportation and distribution center which typically handles domestic and foreign freight in very large quantities. Seaports generally handle a much wider variety of commodities than their inland port counterparts. They typically house many specialized terminals which are designed to handle specific cargoes. The Port of Los Angeles, for example, contains 28 terminals, with different terminals designed to handle different commodities. There are both public and private seaports. The public ports are generally operated by a state or interstate chartered port authority. These quasi-public port agencies operate like private companies in many respects. Private ports tend to be more specialized and smaller than public ports.



Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 2.33.

Figure 108. Examples of a Port with Limited Waterfront but with an Unobstructed Backup Area.

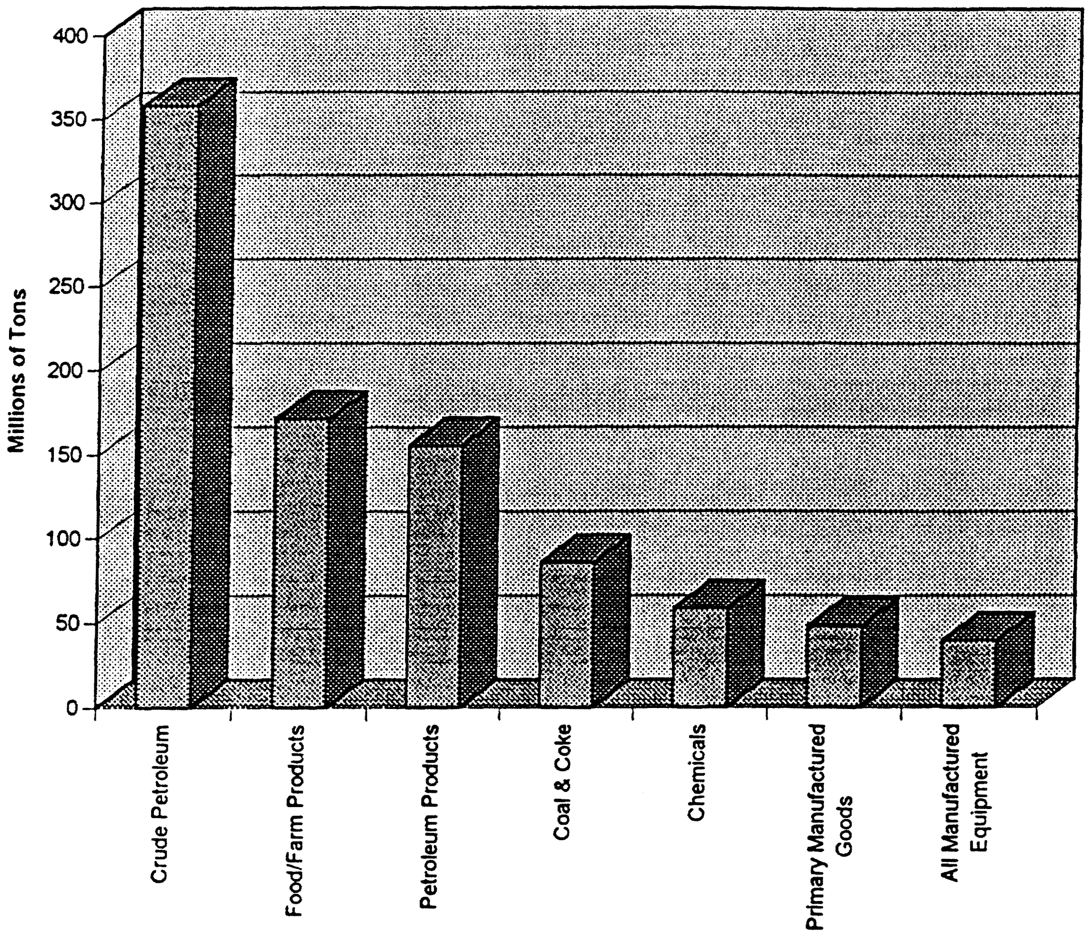
3. The types and quantities of commodities to be loaded and unloaded at a seaport are important to a planner in determining equipment and berthing needs for terminals. The many types of cargo handled at seaports includes the following:

- General Cargo.
  - Containerized. Containerized cargo is stored in large box-like containers that can be interchanged between trucks, trains, and ships without rehandling of the contents. The first generation container size is 8 ft. x 8 ft. x 20 ft. and is referred to as a "TEU" (20-foot equivalent unit). The 20-foot container accounts for approximately 20-25% of the total number of containers used at seaports. The 8 ft. x 9.5 ft. x 40 ft. container has become the dominant size and it accounts for 75-80% of total container usage. Larger containers are available with lengths up to 48 feet, but these containers are seldom used. Approximately 80% of all U.S. liner trade by volume is containerized (56, p. 17).
  - Roll-on/roll-off. Automobiles and other cargo are loaded and unloaded through doors in the ship hull. The cargo is either moved by wheeled loading devices or via the cargo's own propulsion system. This is commonly referred to as ro/ro.
  - Neo-bulk. Several different types of bulk and other forms of homogeneous cargoes are shipped in the same vehicle. Cargo separation is maintained during loading, transport, and unloading. Scrap iron, steel, lumber, automobiles, bananas, and forest products are generally considered Neo-bulk commodities.
  - Break-bulk. Break-bulk is cargo such as fruit, bagged grains, and food products that is shipped in a manner which allows for unloading, sorting, and reloading of some/all of the product. Break-bulk commodities are commonly shipped via pallets.

- Dry Bulk. Dry bulk cargo are products shipped without containers in a free-flowing state. Dry bulk commodities include coal, salt and other minerals, petroleum coke, and scrap metal.

- Liquid Bulk. Liquid bulk cargo is shipped without containers and transferred via pipeline. Crude and refined petroleum, chemicals, and molasses are typical liquid bulk cargoes.

4. Figure 109 shows the seven largest U.S. seaport commodities by volume (in millions of tons) for 1993. Crude petroleum was by far the largest waterborne commodity with 358 million tons passing through the seaports. The second largest volume of freight consisted of food/farm products with 171 million tons moved in 1993. In 1993, the Port of South Louisiana handled the largest tonnage of foreign cargo with about 94 million tons moving through the seaport. The Port of Houston ranked second with approximately 77 million tons of foreign cargo moved.



Source: *The U.S. Waterway System — FACTS.* Navigation Data Center, U.S. Army Corps of Engineers, 1995.

Figure 109. Commodity Volumes for Seaports, 1993.

5. Figure 110 shows the top 5 U.S. seaports in terms of foreign tonnage moved in 1993. The most rapidly growing segment of ocean transportation involves the use of containers. In 1995, the majority of international import and export exchanges are via containers. Seaports along the east and west coasts provide container terminals equipped with specially designed cranes for the loading and unloading of containers.

6. The pie chart in Figure 111 shows the top 10 container ports in the United States for 1993. The outputs shown are in thousands of TEUs.[2]

7. There are several types of seaport terminals which can be categorized by the types of cargo they handle. Typical seaport terminals include:

   - Automobile terminals. Automobile terminals are specially designed to load/unload and store automobiles. Most are ro/ro facilities. Figure 112 illustrates some of the activities that take place in an automobile ro/ro terminal.

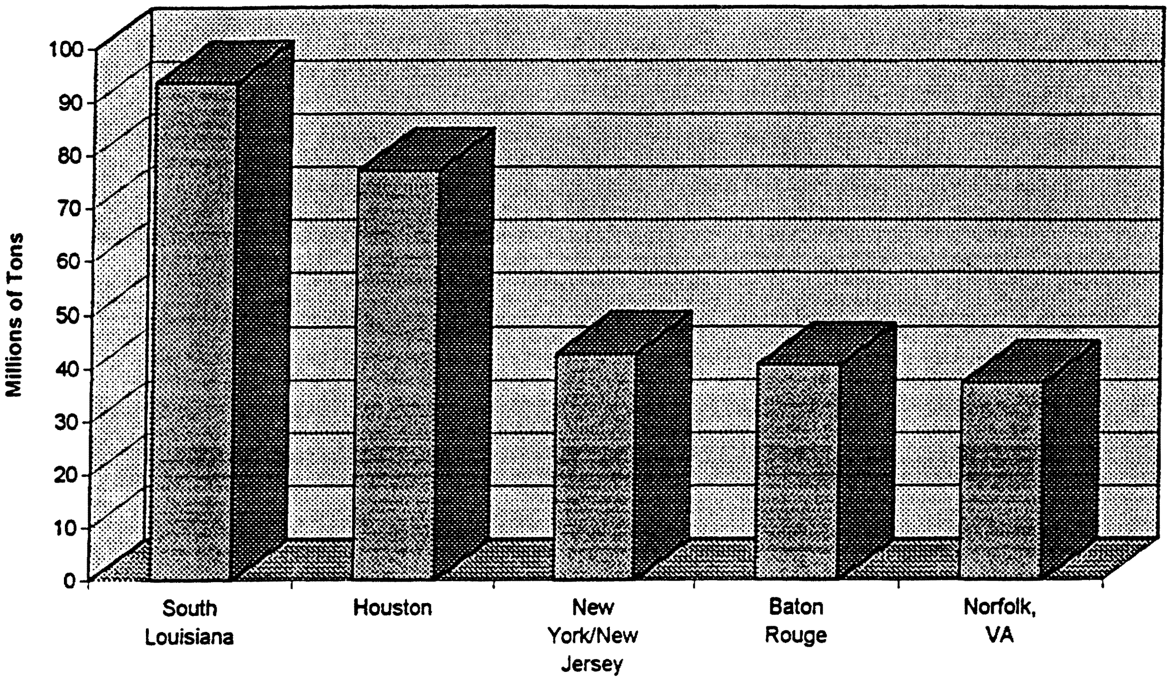
   - Container terminals. Container terminals are equipped with high-capacity cranes dedicated to handling containerized cargo (wheeled, grounded, or chassis). Many container terminals provide reefer plugs and/or portable generators for refrigerated containers. Container terminals require large open areas for storage. Figure 113 provides a schematic for a typical container terminal.

   - Dry bulk/liquid bulk terminals. Dry bulk materials such as coal and copper concentrates are unloaded by gantry cranes equipped with clamshell buckets and transferred to railcars/trucks via conveyor systems. These terminals generally provide enormous areas for stockpiling materials. Petroleum and chemicals are liquid bulk cargoes handled by these facilities. The liquids are pumped into large storage tanks while awaiting transfer to trucks or railcars. Figures 114 and 115 illustrate the types of operations performed in dry bulk and liquid bulk terminals.

   - Neo-bulk/break-bulk terminals. These terminals are designed to handle various types of noncontainerized cargo including refrigerated fruit, frozen meat, and meat products. Large transit sheds are prevalent on ports handling these types of cargo. Examples of the types of activities performed in a neo-bulk/break-bulk terminal are shown in Figure 116.

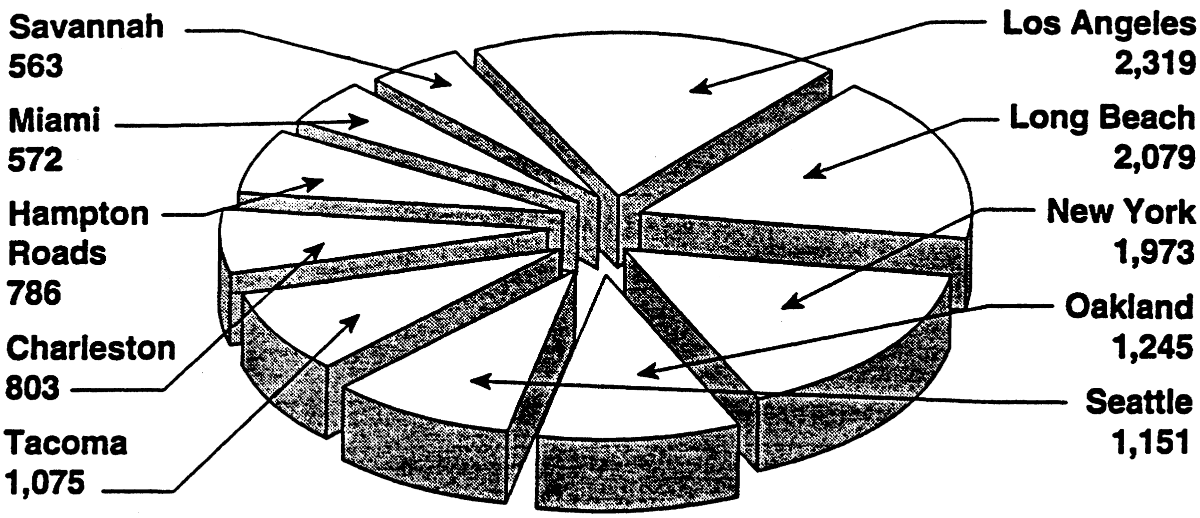
8. An understanding of the general characteristics of seaports is useful when planning for additions or improvements to a port. The general characteristics of a seaport include the following:

[2]A TEU is defined as a 20-foot equivalent unit for the purpose of describing the capacities of different sized containers. One standard 40 foot container equals 2 TEUs.



Source: *The U.S. Waterway System — FACTS*. Navigation Data Center, U.S. Army Corps of Engineers, 1995.

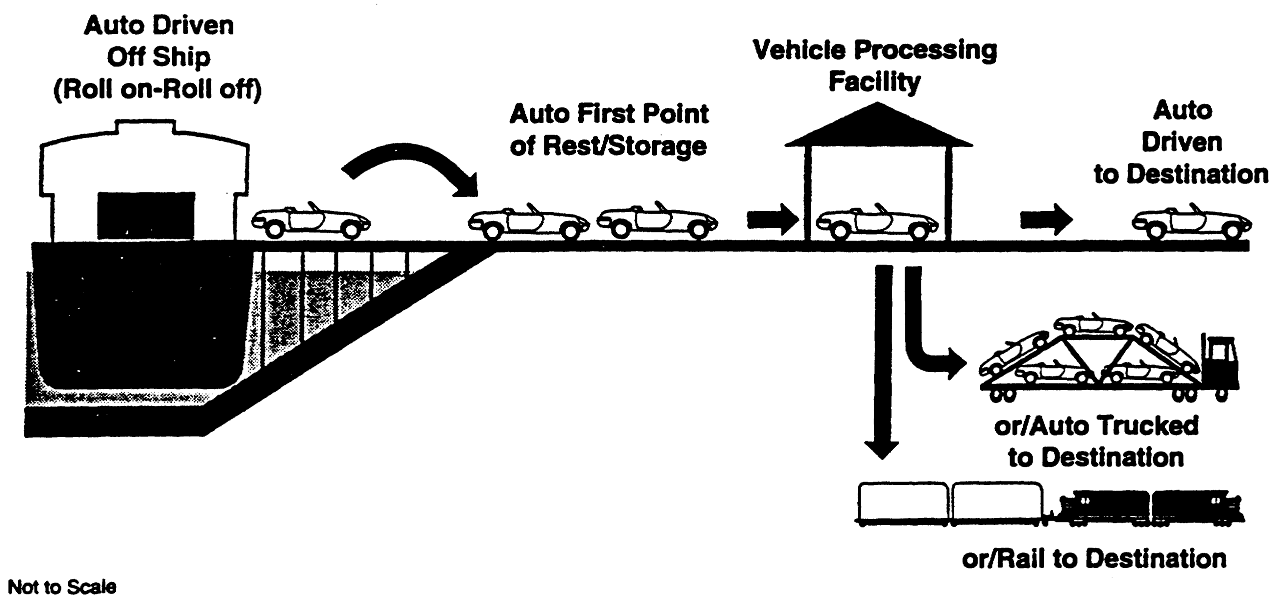
Figure 110. Foreign Tonnage of Leading Seaports, 1993.



Note: Numbers in figure represent thousands of TEUs of international cargo.

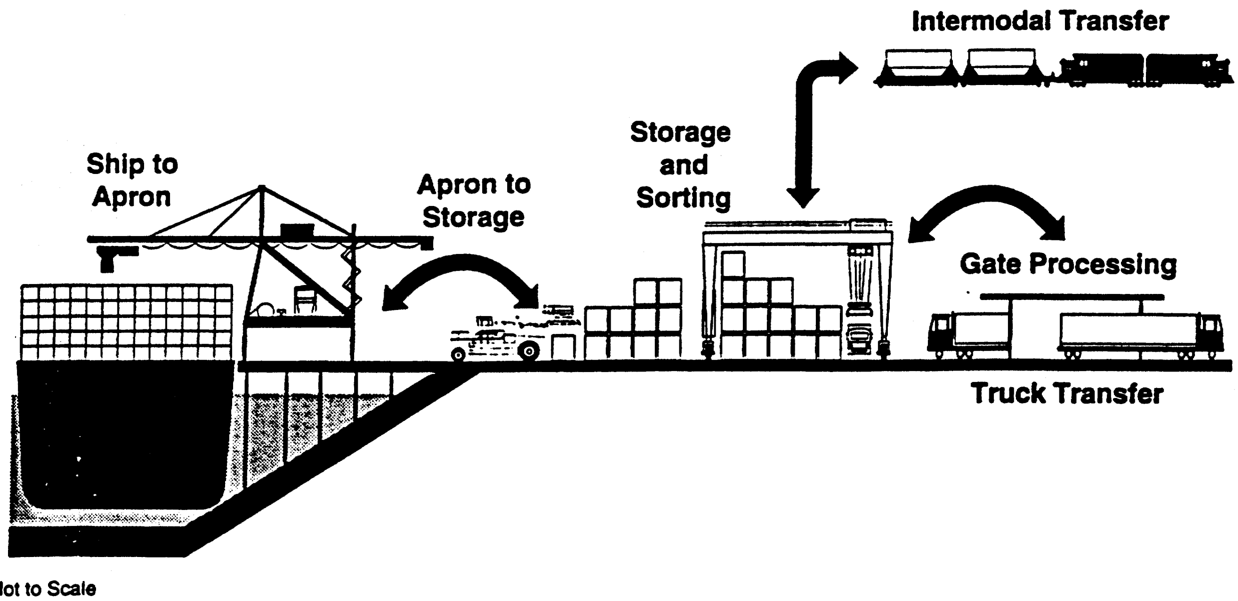
Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 2.6.

Figure 111. Top 10 U.S. Container Ports, 1993.



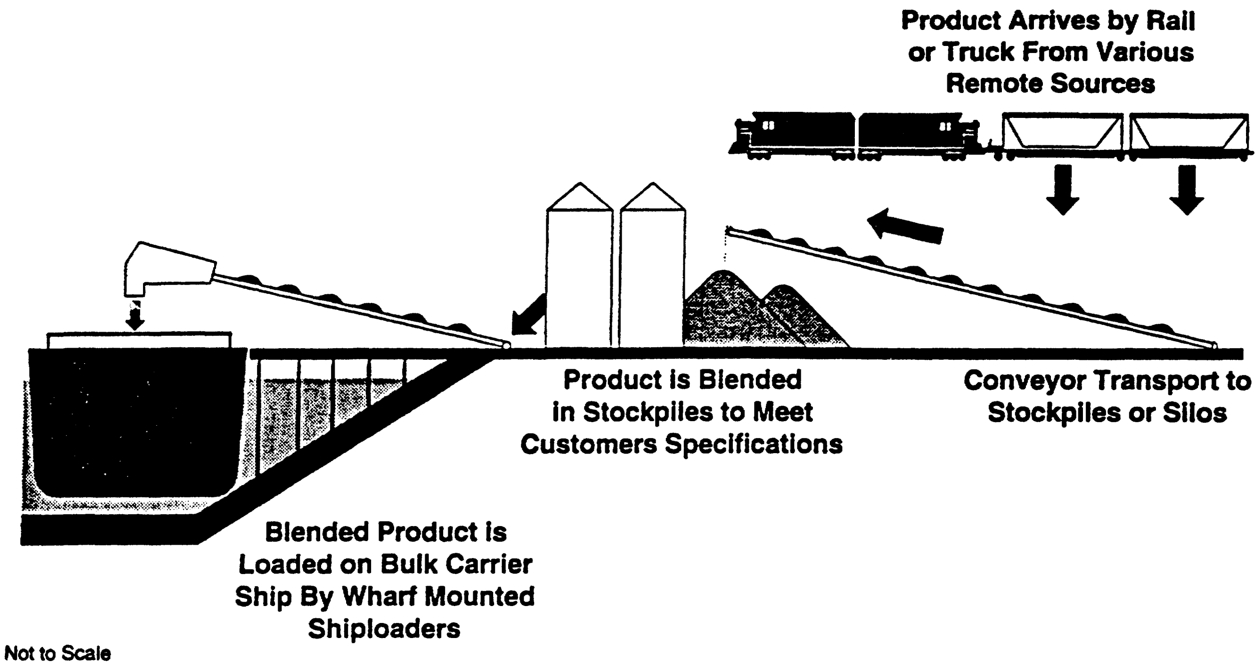
Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.5.

Figure 112. Automobile (Ro/Ro) Cargo Terminal.



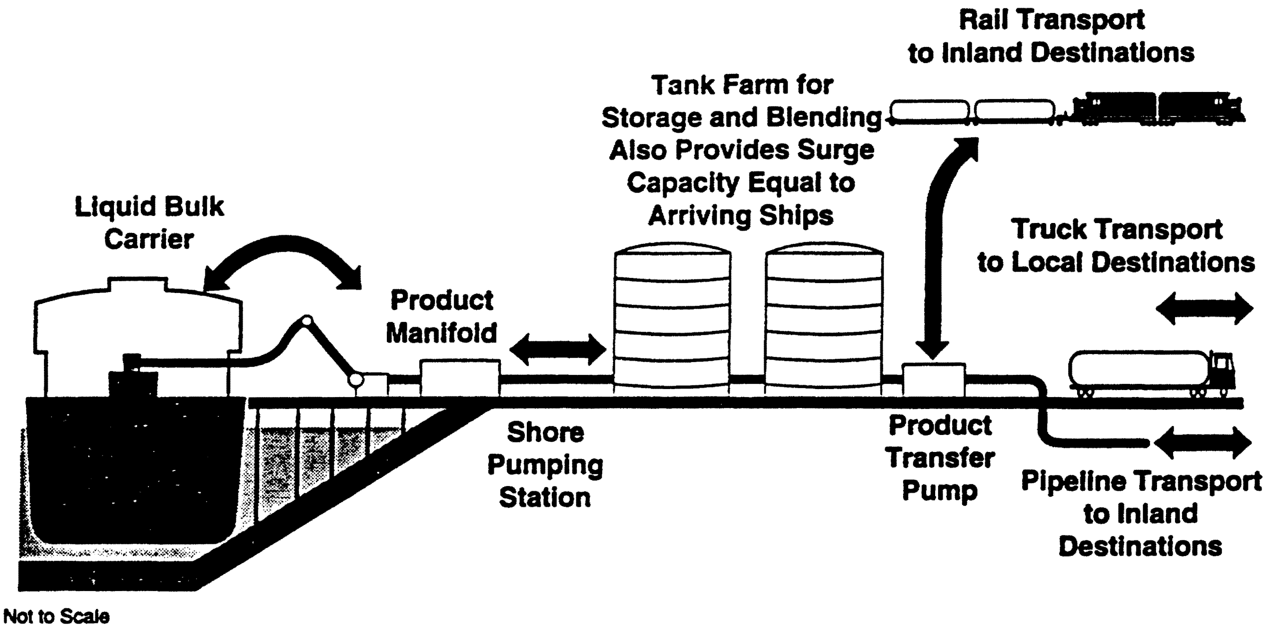
Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.4.

Figure 113. Containerized Cargo Terminal.



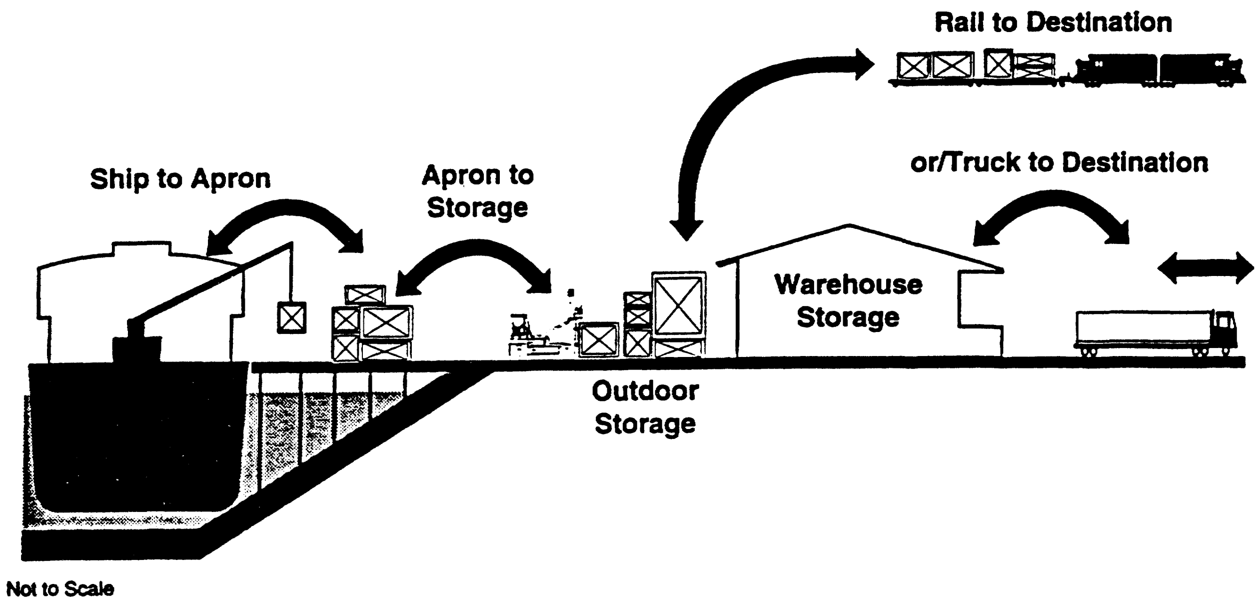
Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.6.

Figure 114. Dry Bulk Cargo Terminal.



Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.6.

Figure 115. Liquid Bulk Cargo Terminal.



Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.6.

Figure 116. Conventional Cargo Terminal (Neo-Bulk/Break-Bulk).

- Transportation facilities. Railroads, roadways, and pipelines provide linkages to transportation, distribution, manufacturing, and commercial facilities. Many of these facilities are located in or adjacent to the port. Extensive rail infrastructure is available for the loading/unloading of railcars as well as ample support track for maneuvering railcars. Table 98 shows the total rail trackage available at the ports of Norfolk and Long Beach. The ports are generally located within a radius of a few miles to one or several major interstate highway systems allowing easy access for trucks. Pipelines are provided to transport liquid bulk materials to nearby distribution and manufacturing facilities.

- Distribution facilities. Transit sheds, refrigerated and nonrefrigerated warehouses, open storage areas for automobiles, trucks and containers with or without reefer outlets, liquid storage tanks, grain elevators and other bulk storage facilities are generally provided. Tables 99-103 list storage characteristics by terminal type for selected seaports.

- Materials handling equipment. Various sizes and types of cranes are available to handle different types of cargo, such as, rail mounted gantry cranes for loading/ unloading bulk materials and containers and mobile hinged boomed cranes for break-bulk commodities. Table 100 shows the number and types of cranes used at typical container handling terminals at the ports of Baltimore, Los Angeles, Long Beach, and Tacoma. Power shovels, forklifts, bulldozers, winches, slings, chutes, scoops, drags, side loaders, yard hostels, chassis flippers, and other types of support equipment are generally available at the port terminals. In-house locomotives are available at many of the larger ports to facilitate the movement of railcars through the terminals.

- Processing and manufacturing. Automobiles, construction equipment, petroleum, bananas, meat, and meat products are examples of products processed and/or manufactured within ports.

- General offices. Administrative offices for customer services, marketing and business development, sales, planning and development, strategic and financial management, communications, logistics, and other activities required for port operations often are located at port facilities.

- Support facilities. International banks, marine fuel suppliers, consulates of foreign governments, container/chassis leasing and repair, domestic freight forwarders and consolidators, fumigation and pest control services, marine surveyors, communications, shipbuilding and repair, accounting, attorney, diving and underwater services, hotels, medical services, restaurants, and many more services are provided by the port's support facilities.

9. Long-range planning and the implementation of land use controls are important to the planner when contemplating the expansion of a seaport or for the layout of a future port. A successful seaport must have abundant land available for growth.

Table 98. Facility and Operational Characteristics for Selected Seaports.

Characteristic	Baltimore	Norfolk	Los Angeles	Long Beach
Total Land Area (acres)	Unavailable	Unavailable	7,500	3,007
Terminal Area (acres)	1,133	1,135	1,437	1,138
Number of Terminals	5	6	28	32
Number of Berths	31	26	115	77
Open Storage (acres)	589	Unavailable	Unavailable	711
Covered Storage (acres)	24	56	Unavailable	138
Number of Cranes	26	28	35	38
Rail Track (miles)	Unavailable	28	114	52
Shipping and Receiving (metric tons/month)				
Bulk	1,705,100	4,223,200	1,645,400	3,045,700
General Cargo	432,700	663,550	3,772,700	3,899,700

Table 99. Characteristics of Automobile Handling Terminals for Selected Seaports.

Seaport	Number of Terminals	Open Storage Area (acres)	Average Throughput
Baltimore	2	230	43,833 Short Tons/Month
Los Angeles	3	122	35,800 Autos/Month
Long Beach	1	111	34,200 Autos/Month

Table 100. Characteristics of Container Handling Terminals for Selected Seaports.

Seaport/Terminal	Terminal Area (acres)	Number of Berths	Typical Berth Length (feet)	Container Storage	Cranes
Baltimore					
A	275	3	1,025	104 Acres	7-50 T
Los Angeles					
A	129	6	330	Unavailable	5-40 LT
B	63	5	360	Unavailable	3-40 LT
C	88	5	360	Unavailable	4-40 LT
D	86	4	550	Unavailable	4-40 LT
E	171	16	480	14,000 TEUs	6-40 LT
F	118	8	490	Unavailable	6-40 LT
Long Beach					
A	75	3	650	58 Acres	5-40 LT
B	95	4	640	122 Acres	6-30 LT
C	123	3	770	68 Acres	3-30 LT & 4-40LT
Tacoma					
A	33	1	900	Unavailable	1-55 ST & 2-50 ST
B	40	1	950	Unavailbale	2-66 ST & 2-55 ST
C	115	2	800	2,950 conts.	5-50 ST

Table 101. Characteristics of Dry Bulk Handling Terminals for Selected Seaports.

Seaport/Terminal	Terminal Area (acres)	Number of Berths	Typical Berth Length (feet)	Open Storage	Covered Storage	Transfer Rate (tons/hr.)	Commodities Handled
Los Angeles							
A	Unavailable	5	Unavailable	170,000 MT	NA	1400	Coal
B	Unavailable	2	Unavailable	31,751 MT	NA	907	Borax
C	Unavailable	1	Unavailable	NA	86,000 $ft.^2$	454	Bulk cement
Long Beach							
A	2	2	500	87,525 $ft.^2$	50,000 T	700	Bulk cement
B	4.2	1	520	Unavailable	58,000 T	800	Bulk cement
C	22.9	4	525	782,000 $ft.^2$	430,000 T	Unavailable	Petroleum coke
D	5.1	1	1,100	117,740 $ft.^2$	NA	Unavailable	Bulk salt
E	12.8	1	1,100	291,000 $ft.^2$	NA	Unavailable	Petroleum coke
F	19.9	1	650	65,340 $ft.^2$	40,000 T	850	Bulk gypsum

Table 102. Characteristics of Neo-Bulk/Break-Bulk Handling Terminals for Selected Seaports.

Seaport/Terminal	Terminal Area (acres)	Number of Berths	Typical Berth Length (feet)	Open Storage (ft.²)	Transit Shed Storage (ft.²)	Commodities Handled
Los Angeles						
A	11	2	670	NA	211,290	Neo-bulk/break-bulk
B	13	3	575	NA	232,525	Neo-bulk/break-bulk
Long Beach						
A	30	4	550	288,600	96,000	Break-bulk general
B	22.2	1	600	432,600	15,000	Lumber and lumber products
C	19.7	2	630	673,847	180,000	Steel products, plywood, and lumber
D	22	2	600	530,000	190,000	Steel products, plywood, lumber, and fruit
Philadelphia/Camden						
A	8	2	1,000	NA	130,000	Fruit, vegetables and other perishables
B	8.5	2	855	NA	500,000	Cocoa products and other perishables
C	41	4	975	NA	2,000,000	Forest products
D	6	3	575	NA	714,000	Forest products

Table 103. Characteristics of Liquid Bulk Handling Terminals for Selected Seaports.

Seaport/Terminal	Terminal Area (acres)	Number of Berths	Typical Berth Length (feet)	Number of Storage Tanks	Storage Capacity (barrels)	Transfer Rate (barrels/hr.)	Commodities Handled
Los Angeles							
A	Unavailable	2	400	105	568,000	Unavailable	Petrochemical and petroleum products
B	Unavailable	2	410	12	592,000	Unavailable	Petroleum products
C	10	3	440	11	530,000	Unavailable	Petroleum products
D	Unavailable	3	470	18	1,000,000	Unavailable	Petroleum products
Long Beach							
A	19.9	2	1,100	NA	1,800,000	12,500	Petroleum products
B	10.7	4	495	Unavailable	245,000	32,000	Crude oil and petroleum products
C	5.7	2	530	NA	410,000	7,500	Gasoline and diesel fuel
D	4.5	1	700	Unavailable	123,810	Unavailable	Vegetable oils and tallow
E	1.2	3	500	Unavailable	159,524	Unavailable	Vegetable oils and tallow

Several seaports have experienced difficulty in acquiring land for expansion. Table 98 provides land use data and operational statistics for four major seaports.

10. The efficient transfer of commodities at a seaport is a major consideration during the planning process for seaport development. A discussion of the various transportation modes encountered at seaports follows.

    - Ships. There are many types of ships designed to handle different commodities through various means. General cargo and much of the bulk commodities are usually transported in containers. The largest ships used today are referred to as "Post Panamax" vessels because they are too large to pass through the Panama Canal. They are typically 900-1,000 feet long and can carry 4,000-5,000 TEUs. Shipping accounts for approximately 23% of the total revenue ton-miles of freight moved in the United States.

    - Trucks. Trucks account for approximately 32% of the total revenue ton-miles of freight. Truckload freight is most economical when traveling less than 500 miles. The truckload freight is combined with rail when traveling distances greater than 500 miles. Container terminals generate substantial truck traffic in the vicinity of a seaport.

    - Railcars. Railroads have become very important due to the increasing use of "landbridge" concepts where containerized cargo is unloaded at the port, transferred to railroads, and transported to inland destinations. Approximately 29% of the total revenue ton-miles of freight moved in the U.S. is attributed to railroads (40).

11. Seaport operations generally vary from terminal to terminal depending on the type of cargo that is being transferred from one transportation mode to another. A planner should be aware of the types of operations that take place in a seaport. The following summarizes typical seaport operations.

    - Ships arrive at a port and the cargo is transferred to a processing/storage facility.
        - Containerized cargo is unloaded from the ship via large landside mobile container cranes. In smaller ports, the transfer could be made with landside boom cranes or ship mounted cranes. Usually, the containers are placed on chassis although sometimes they are placed directly on the ground. Theoretically, the containers could be placed directly on railcars. Most seaports do not have direct rail access for the containers.
        - Liquid bulk cargo transported by ship/barges is usually pumped via pipeline into nearby storage tanks.
        - Dry bulk materials are typically unloaded by boom crane or a conveyor system into covered sheds or onto open stockpiles adjacent to the wharf.

    - The unloaded cargo is positioned within the terminal for transfer to the next mode.

- Containers on chassis are moved to an open storage area and parked or are taken off their chassis and placed directly on the ground or stacked vertically. In larger ports, the containers are moved to a container freight station (CFS) where some unpacking and repacking of the container contents takes place.
- Containers on ground are moved to a storage area where they may be placed on chassis, stacked vertically, or moved to a CFS.
- Other general cargo is transferred to terminal storage areas or warehouses using yard equipment. Here some of the cargo may undergo some processing and/or manufacturing. For example, automobiles may be sent to a de-wax or service facility.
- Bulk cargoes typically remain in storage awaiting their next transfer. Some bulk cargoes such as petroleum coke may be processed at this stage.

- Cargo is transferred to the appropriate mode in which it leaves the terminal.
  - Bulk or general cargo may be moved back to the wharf and loaded on another ship for export or transport to another seaport. This process is called transshipment.
  - Containerized cargo stored on chassis is picked up by a chassisless truck cab called a bobtail. Grounded or stacked containerized cargo is loaded on a truck with an attached chassis. The trucks loaded with containers are then driven out of the terminal.
  - Chassis, grounded, or stacked containers are loaded on an intermodal railcar within the terminal. Intermodal methods include container-on-flatcar (COFC), double-stack train (DST), and carless technologies, such as the "RoadRailer" which has a specially designed chassis allowing over-the-road or rail operations. COFC operations involve the movement of containers on flatcars with chassis. In DST operations, one container is stacked on top of another in single cars, multiple platform cars, or groups of these cars. A container or container with chassis can be placed on a standard flatcar. This method is called trailer-on-flat-car (TOFC) and is used less frequently than the intermodal methods. The railcar with container is then moved out of the terminal.
  - Other general cargo is loaded onto trucks or railcars and transported out of the terminal.
  - Liquid bulk cargo is piped from storage tanks to pipelines, tanker trucks or tanker railcars and transported out of the terminal.
  - Dry bulk cargo is transferred from storage facilities to conveyors, trucks or railcars removing the cargo from the terminal.

- Cargo is transferred to its final destination or to another modal transfer location outside of the receiving terminal.
  - Trucks deliver cargo to its final destination, to a nearby intermodal railyard, to an airport, or to a warehouse or storage yard for eventual transfer to another truck or transportation mode.
  - Trains exit the terminal and proceed to the final destination. If the train exits the terminal without a full load of railcars, it may pick up additional cars at

an intermediate rail yard. The train may also release cars at different locations along the delivery route. The cargo within the railcars may be transferred to another mode (usually trucks) before reaching its final destination.
- Cross country conveyors or intercity pipelines deliver bulk and liquid cargo to its final destination or to another transfer/storage location.

12. Figure 117 provides a summary of typical intermodal connections by cargo type for seaports.

13. Materials handling methods and requirements are important considerations when planning for seaports. A brief discussion of the methods used for bulk freight transfer and for the movement of containers follows:

- Intermodal equipment for bulk freight transfer.
  - Conveyor system. A conveyer system is desirable for free-flowing dry bulk materials such as coal, grains, and similar products. A conveyer system has less spillage, dust, and noise. A conveyor system requires large investment and discourages rapid change. Table 101 lists conveyor transfer rates by commodity for selected seaports.
  - Self discharging ships. Self-discharging ships are designed to handle coal, salt, and other mineral products.
  - Crane with clamshell bucket. Cranes are more reliable, easier to operate, and easier to repair than other transfer equipment and are able to remove more material than continuous equipment.
  - Power shovels, forklifts, bulldozers, winches, slings, chutes, scoops, and drags are commonly used for loading and unloading ships.

- Container ports cranes.
  - Rail-mounted gantry crane. The rail-mounted gantry crane is the most widely used type of crane at container ports. Crane capacities typically range from 30 tons up to 66 tons with a 40 ton capacity being the most commonly used size. The turnaround time of a ship is affected more by the number of cranes available than by the handling capacity of the individual cranes. Panamax vessels can be effectively served by two cranes and post-Panamax ships by three cranes (57). Table 100 lists crane characteristics for container terminals at four seaports.
  - Hinged boom crane. The hinged boom crane is a flexible crane able to pivot about its base and typically is found in terminals which handle bulk materials as well as containers.
  - Shipboard crane. Shipboard cranes are used at ports without cranes.

- Table 104 provides a comparison by activity of the different types of intermodal container handling systems.

	Truck	Rail	Pipeline	Slurry
General Cargo				
Container	●	●		
Auto and Roll-on/Roll-off	●	●		
Neo Bulk	●	●		
Break Bulk	●	●		
Liquid Bulk	●	●	●	
Dry Bulk	●	●		●

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.7.

Figure 117. Intermodal Connections for Port Cargo Terminals.

Table 104. Comparison of Container Handling Systems.

Activity	Chassis System	Straddle Carrier	Yard Gantry Crane (RTG)	Reachstackers, Front-End Top-Pick Loader
Land Area	70 TEUs per acre 173 per hectare	168 TEUs per acre 413 per hectare	325 TEUs per acre 802 per hectare	240 TEUs per acre 590 per hectare
Cost of Terminal Development	Low	Medium	High	Medium to high
Cost of Equipment (approx. 1994 prices)	Tractor $45,000; Chassis $7,000	$800,000	$1,000,000	$250,000-$500,000
Support Equipment per Container Crane	4 to 5 tractors; 1 chassis per container	3-4	1-2 cranes; 5 tractors and chassis	2 such as RTG
Operating Labor	Low	Low	Medium to High	Medium
Equipment Maintenance	Low	High	Medium	Medium
Inventory Control	Good; but frequent yard checks required	Good, but frequent yard checks required	Very good	Good
Advantages	High accessibility, low cost	Versatility, less support equipment needed	Low maintenance, good control, expandable system	Versatility, low maintenance
Disadvantages	High land requirements, large chasis requirements	High damage and maintenance cost	Initial equipment and land preparation cost	Slower productivity compared to other equipment, i.e., RTG
Security	Excellent	Good	Poor	Good

Source: Muller, Gerhardt. *Intermodal Freight Transportation*, Third Edition. Eno Transportation Foundation and Intermodal Association of North America, Lansdowne, Virginia, 1995, p. 155.

14. The direct transfer of containers from ship to rail rarely takes place. Usually an intermediate truck transfer (or movement of containers by specialized handling equipment) is involved. There are three reasons why this occurs:

- The transfer by mobile vehicles is usually more efficient since it is more difficult and costly to position each railcar in sequence along the ship.

- Railyards and rail facilities are often located at a distance away from the wharf. Extension of the track may not be feasible due to limited terminal area.

- Trucks are sometimes used to transport containerized cargo between ports and/or terminals for consolidation purposes to mesh with a ship's schedule or to form a unit train.

15. Sometimes the cargo is transferred between ship and rail without the use of containers because shippers have trouble retrieving their containers. Additional costs are incurred to the shipper when the containerized cargo has to be intermediately moved by truck. This additional cost is called a drayage charge and it can be as high as 25% of the intermodal cost. Typically, the drayage charge is between 15% and 20% (57, p.53).

16. With limited on-dock rail access available at most seaports, trucks are commonly used to transfer the containers to an Intermodal Container Transfer Facility (ICTF) where they are placed on railcars. Thus, significant truck traffic is generated in the vicinity of the seaport even when rail is the mode of choice for moving containers over long distances. The movements of trucks and trains to and from a seaport can create serious problems depending on the access routes and the land use along the routes.

- If the access routes do not have adequate geometric features and capacity to handle a high volume of large trucks, serious traffic congestion and safety problems could occur.

- Intersections with high turning volumes of trucks can be problematic if the geometric design does not allow for the turning characteristics of large trucks.

- If the truck access routes are through sensitive land use areas, such as residential areas or schools, serious controversies can develop in the community.

- Rail access to a port can create problems depending on the number of grade crossings and surrounding land uses. In many seaports, rail access follows a circuitous route creating numerous grade crossings. Each one of these crossings is a potential source of delay for automobiles and trucks operating in the vicinity of the seaport. Another potential problem is accidents occurring at the grade crossings.

17. Container and break-bulk terminals typically generate considerable truck trips. The peaking of truck trips at seaports is closely related to the arrival/departure schedule of ships. Peaking during the day varies from seaport to seaport. Usually the early morning hours are busy with arriving trucks queuing outside the terminal awaiting the opening of the gate. Late afternoon hours also experience heavy truck movements.

18. The number of truck trips generated at a seaport is directly related to the number of ships arriving/departing from the seaport. The physical characteristics of the berths and cranes serving the seaport terminals are indirectly related to the number of truck trips generated. The occupancy of berths varies among the different seaports. The arrival/departure schedule of the ships is very useful when estimating the truck trips to and from a seaport. The average number of truck trips generated at container and break-bulk terminals for several seaports on a typical weekday is presented in Tables 105 and 106. A dry bulk terminal in the seaport of Morehead City, North Carolina, typically generates 20 truck trips per day.

19. As stated earlier in this report, many seaports do not have on-dock rail access; therefore, the containers must be brought into the terminal via drayage trucks. For ports with direct rail access, the number of trains per day and the schedule of trains have significant impact on the traffic flow on surrounding roads with grade crossings. Even a single train can cause problems if it causes the closure of a road serving commuters during rush hours. The length of trains also influences the duration of interference at grade crossings. Approximately 30 railcars per day are generated at a break-bulk terminal in the Morehead City, North Carolina, seaport.

20. A more comprehensive data source for truck and rail trip generation has recently been published by MULTITRANS Transportation Consultants for the San Francisco Bay Area Seaports (57). The truck movements were broken down into two types of origins/destinations. Truck movements were estimated to and from an ICTF as well as to and from origins/destinations.

   - Table 107 shows truck and rail trip generation data for seaports in the San Francisco Bay area. Rail forecasts are given in railcars/day and trains/day. Truck forecasts are given in terms of daily, midday peak (peak hours for trucks) and afternoon peak (peak hours for all traffic). These forecasts are for terminals handling containers or bulk cargo. The terminals consisted of 22 container berths and 32 bulk cargo berths.

   - Some of the assumptions used for forecasting seaport-related land transportation traffic for the Bay Area seaports are:
     - Conversion of metric tonne forecasts to short tons: short tons = metric tonnes/0.907.
     - Short tons to containers: 12 short tons/container.
     - Conversion of annual to daily weekday freight: 250 days/year.
     - Average daily to peak daily truck trips: 1.20 peak day factor

Table 105. Truck Trips at Container Terminals for Selected Seaports.

Seaport/Terminal	Area (Acres)	Number of Container Cranes	Container Trips per Day[1]	Peak Time Periods
Charleston, SC				
A	167	6	2,800	8:30-9:30 a.m., 3:00-4:00 p.m.
B	185	6	2,200	8:30-9:30 a.m., 3:00-4:00 p.m.
C	70	3	1,600	8:30-9:30 a.m., 3:00-4:00 p.m.
Savannah, GA	Unavailable	Unavailable	3,200	9:00-10:00 a.m., 2:00-3:00 p.m.
Wilmington, NC	83	5	330	Unavailable
Baltimore, MD	275	7	880	9:00-10:00 a.m., 1:00-2:00 p.m.

[1]Total of in and out traffic.

Table 106. Truck Trips at Break-Bulk Terminals for Selected Seaports.

Port	Area ($ft.^2$)	Number of Gantry Cranes	Truck Trips per Day
Savannah, GA	Unavailable	Unavailable	600
Wilmington, NC	1,200,000	3 (plus 1 mobile)	100
Philadelphia, PA/ Camden, NJ	630,000	Only mobiles	175

Table 107. Traffic Generation by Bay Area Seaports.

	Oakland	San Francisco	Richmond	Redwood City	Benicia
Peak Daily 24-Hr. Units					
Railcars	424	105	28	27	21
Daily Trains	7.10	1.70	0.50	0.40	0.40
Trucks To/From ICTF	1,842	245	50	0	0
Trucks, Other	3,041	745	174	157	121
Midday Peak					
Trucks To/From ICTF	283	38	8	0	0
Trucks, Other	466	114	27	24	19
P.M. Peak					
Trucks To/From ICTF	198	26	5	0	0
Trucks, Other	326	80	19	17	13
Auto Trips					
Daily	5,126	916	201	108	83
Midday Peak	825	154	34	20	16
P.M. Peak	578	108	24	14	11
Total Vehicle Trips					
Daily	10,009	1,906	425	265	204
Midday Peak	1,574	306	68	44	34
P.M. Peak	1,102	214	48	31	24

Source: *Intermodal Report*. MULTITRANS Transportation Consultants, San Jose, California, December 1994, p. 8.

- Average daily to peak daily rail trips: 1.10 peak day factor.
- Daily to average hourly truck movements: 7.5 hours/day.
- Average hourly to peak hourly truck trips: 1.15 peak hour factor.
- Ratio of 40-foot to 20-foot containers: 0.70/0.30.
- Estimated percentage of containers double-stacked: 75%.
- Average railcars/train: 60.
- Short tons in a noncontainer railcar: 20.
- Short tons in a noncontainer truckload: 7.5.
- Conversion of truck peak hour to overall p.m. peak hour traffic: 70%.
- Truck miscellaneous factor (above container lift calculation): 1.30.
- Rail miscellaneous factor (above container lift calculation): 1.00.
- Factors by freight category: as shown in Table 108.

- Table 109 provides trip generation data for trucks and rail by cargo type for the ports of Oakland, San Francisco, Richmond, and Redwood City. Traffic estimates are shown for average daily and peak daily values. Traffic estimates for the midday peak and afternoon peak by cargo type for the four seaports are shown in Table 110. An inspection of Table 110 reveals that a considerable amount of automobile traffic is generated in the vicinity of the seaport.

21. Trip generation studies have typically focused on land use characteristics and revenue tons of cargo throughput to calculate demand trip rates.

    - A recent study on the Port of Houston's Barbours Cut Container Terminal included TEUs in the analysis (56). Information was gathered on the total acreage at the site, number of ship berths, and cargo throughput in revenue tons and in TEUs. Average weekday trip rates (trucks and automobiles) for each day were then calculated using the data gathered.

    - Studies showed that only 30% of the traffic generated consisted of container trucks with cars, pickups, and two-axle and three-axle trucks making up the remainder of the traffic.

    - Table 111 shows the peak hour trip rates by generator. A weighted average weekday trip rate was then computed.

    - Average weekday trip rates:
        - Per acre: 16.69.
        - Per berth: 960.
        - Per revenue ton-mile: 0.23.
        - Per TEU: 4.35.

    - These trip generation rates may not be transferable to other container terminals due to differences in facility and operational characteristics. However, the methodology and data collection techniques used in this study may be beneficial in conducting other seaport studies.

Table 108. Factors by Freight Category.

Freight Category	Berth Capacity (MT x 1000)	Rail Modal Split	Daily Auto/Truck	Peak Hour Auto/Truck
Container	649	0.40	1.071	1.1176
Break-Bulk	119	0.20	0.688	0.8421
Neo-Bulk	251	0.20	0.688	0.8421
Dry Bulk	1,163	0.20	0.688	0.8421
Liquid Bulk	121	0.20	0.688	0.8421

Table 109. Truck and Rail Daily Traffic Estimates for Bay Area Seaports, 1994.

	Average Daily Units				Peak Daily 24-Hour Units			
Port/Cargo Type	TEUs (x 1,000)	Railcars	Trucks to/ from ICTF	Trucks Other	Railcars	Trains	Trucks to/ from ICTF	Trucks Other
Oakland (includes NSC Oakland for 2020)								
Container	1,136	369	1,535	2,303	406	6.8	1,842	2,764
Break-Bulk	38	17	0	231	18	0.3	0	277
Neo-Bulk	0	0	0	0	0	0.0	0	0
Dry Bulk	0	0	0	0	0	0.0	0	0
Liquid Bulk	0	0	0	0	0	0.0	0	0
Total	1,174	386	1,535	2,534	424	7.1	1,842	3,041
San Francisco								
Container	151	49	205	307	54	0.9	245	368
Break-Bulk	20	9	0	119	9	0.2	0	143
Neo-Bulk	28	12	0	63	13	0.2	0	75
Dry Bulk	58	25	0	131	28	0.5	0	157
Liquid Bulk	1	0	0	2	0	0.0	0	2
Total	258	95	205	620	105	1.7	245	745
Richmond								
Container	31	10	41	62	11	0.2	50	74
Break-Bulk	0	0	0	0	0	0.0	0	0
Neo-Bulk	28	12	0	63	13	0.2	0	75
Dry Bulk	0	0	0	0	0	0.0	0	0
Liquid Bulk	9	4	0	20	4	0.1	0	24
Total	68	26	41	145	28	0.5	50	174

Table 109. (continued).

	Average Daily Units				Peak Daily 24-Hour Units			
Port/Cargo Type	TEUs (x 1,000)	Railcars	Trucks to/ from ICTF	Trucks Other	Railcars	Trains	Trucks to/ from ICTF	Trucks Other
Redwood City								
Container	0	0	0	0	0	0	0	0
Break-Bulk	1	1	0	8	1	0	0	10
Neo-Bulk	4	2	0	9	2	0	0	11
Dry Bulk	45	20	0	102	21	0	0	122
Liquid Bulk	5	2	0	12	3	0	0	14
Total	55	24	0	131	27	0	0	157

Source: *Intermodal Report*. MULTITRANS Transportation Consultants, San Jose, California, December 1994, pp. A-1, A-2.

Table 110. Truck and Rail Midday and P.M. Peak Traffic Estimates for Bay Area Seaports, 1994.

Port/Cargo Type	1994 Midday Peak		1994 P.M. Peak		1994 Auto Trips		
	Trucks to/ from ICTF	Trucks Other	Trucks to/ from ICTF	Trucks Other	Daily	Midday Peak	P.M. Peak
Oakland (includes NSC Oakland for 2020)							
Container	283	424	198	297	4,395	789	553
Break-Bulk	0	43	0	30	191	36	25
Neo-Bulk	0	0	0	0	0	0	0
Dry Bulk	0	0	0	0	0	0	0
Liquid Bulk	0	0	0	0	0	0	0
Total	283	466	198	326	5,126	825.0	578
San Francisco							
Container	38	56	26	40	658	105	74
Break-Bulk	0	22	0	15	98	18	13
Neo-Bulk	0	12	0	8	52	10	7
Dry Bulk	0	24	0	17	108	20	14
Liquid Bulk	0	0	0	0	1	0	0
Total	38	114	26	80	916	154	108
Richmond							
Container	8	11	5	8	133	21	15
Break-Bulk	0	0	0	0	0	0	0
Neo-Bulk	0	12	0	8	52	10	7
Dry Bulk	0	0	0	0	0	0	0
Liquid Bulk	0	4	0	3	17	3	2
Total	8	27	5	19	201	34	24
Redwood City							
Container	0	0	0	0	0	0	0
Break-Bulk	0	1	0	1	7	1	1
Neo-Bulk	0	2	0	1	8	1	1
Dry Bulk	0	19	0	13	84	16	11
Liquid Bulk	0	2	0	2	10	2	1
Total	0	24	0	17	108	20	14

Source: *Intermodal Report*. MULTITRANS Transportation Consultants, San Jose, California, December 1994, p. A-7.

Table 111. Peak Hour Trip Rates by Generator for Barbours Cut Terminal, Port of Houston.

Day	Per Acre		Per Berth		Per Revenue-Ton		Per TEU	
	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.	a.m.	p.m.
Monday	1.47	1.60	85.00	92.50	0.02	0.02	0.34	0.37
Tuesday	1.57	1.50	90.50	96.50	0.02	0.02	0.44	0.42
Wednesday	1.79	1.70	103.00	97.75	0.02	0.02	0.51	0.48
Thursday	1.90	1.74	109.80	100.50	0.02	0.02	0.45	0.42
Friday	1.74	1.46	100.50	84.50	0.02	0.02	0.47	0.39
Saturday	0.28	0.41	16.50	24.00	0.00	0.00	0.00	0.00
Sunday	0.29	0.70	16.75	40.50	0.00	0.00	7.44	18.00

Source: Guha, Tathagata, and Walton, C. Michael. "Intermodal Container Ports: Application of Automatic Vehicle Classification System for Collecting Trip Generation Data." *Transportation Research Record*, No. 1383, 1993, p. 21.

22. Another method of estimating trip generation rates is to determine the number of trips per unit of throughput for a specific type of terminal and apply it to an anticipated future throughput. This method provides a quick but rough estimate for future trips. Extensive modeling and forecasting techniques can also be applied to provide a more accurate portrayal of trip generation. Market studies can be performed to determine future throughput demand by mode and commodity type. Capacity analyses can be conducted to determine how much of the future demand can be satisfied by existing and planned facilities. Trip generation rates can then be computed based on the future throughput demand and observed traffic and terminal operating characteristics.

23. Tables 112-116 provide helpful data for estimating trip generation rates at seaports. Table 112 lists typical daily one-way truck and train trips generated by different types of state-of-the-art terminals. Daily one-way trip generation rates by terminal type are provided in Table 113. Table 114 shows yearly cargo throughput capacities for state-of-the-art terminals by terminal type. Typical annual throughput capacities for terminals, warehouses, and truck lanes are shown in Table 115. Anticipated cargo throughputs per berth by terminal type are shown in Table 116.

24. The choice between transportation modes at seaports depends on several factors. Mode splits vary according to the type of cargo handled, the size of the facility, equipment availability, and the local market area of each individual seaport. However, trucks are the predominant choice for short cargo movements. Rail service is price competitive on cargo movements of more than 500 miles for containers and 700 miles for trailer on flatcars. Table 117 provides modal split data for three seaports.

25. Truck and rail access planning for seaports should not be limited to the boundaries of the seaport but should take a system wide, total trip perspective. There are many benefits derived from improved access to intermodal facilities.

    - There are direct benefits of reduced travel time and cost, increased reliability of service, and convenience to the intermodal facility user.

    - Indirect benefits of reduced congestion and improved air quality for all transportation users.

    - Economic benefits derived from improved domestic and international freight movement.

26. Figure 118 provides a pipeline analogy to container terminal throughput capacity. This figure represents many of the issues addressed in this report regarding seaport operations. The drawing illustrates the importance of each operation to the efficient flow of cargo. The wharf must be capable of berthing the ship and must have sufficient cranes to unload the cargo. Adequate wharf storage must be available for cargoes that require it. Sufficient terminal equipment must be available to transport

Table 112. Typical Daily One-Way Trips at State-of-the-Art Terminals.

Terminal Type	Size	Truck	Train
Container	110 acres	1,150-2,250	2-4
Auto	65 acres	45	2
Liquid Bulk	varies	varies	varies
Dry Bulk	5-94 acres	150-500	0-2.5
Neo-Bulk/Break-Bulk Combination Terminal	53 acres	185	1

Note: These figures can vary significantly depending on terminal size, operating characteristics, and rail access.

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.11.

Table 113. Daily One-Way Trip Generation at State-of-the-Art-Terminals.

Terminal Type	Trucks (per acre)	Other Vehicles (per acre)	Trains (total)
Container	10-20	1-2	2-4
Auto	1	2	2
Liquid Bulk	varies	varies	varies
Dry Bulk	5-30	0.5-3	0-2.5
Neo-Bulk/Break-Bulk Combination Terminal	3.5	0.5	1

Note: These figures can vary significantly depending on terminal size, operating characteristics, and rail access.

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.11.

Table 114. Yearly Cargo Throughput at State-of-the-Art Terminals.

Terminal Type	Size	Berths	Maximum Practical Capacity
Container	110 acres	2	673,000 TEUs
Auto	65 acres	2	225,000 units
Liquid Bulk	85-89 acres	2	12,470,000 tons
Dry Bulk	94 acres	2	10,340,000 tons
Neo-Bulk/Break-Bulk	53 acres	2	990,000 tons

Note: These figures can vary significantly depending on terminal size, operating characteristics, and rail access.

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.12.

Table 115. Typical Annual Throughput Capacities.

Typical Terminal Type	Gross Area (acres)	Units/Year	Typical Average	Typical Range	Remarks
Container	30-150	TEU/Acre	4,500	2,500-6,500	7-10 metric tons per TEU
Intermodal Rail (IY)	30-150	Units/Acre (TEU/Acre)	3,800 (5,800)	2,500-5,000 (3,500-8,000)	Typically use units or lifts for IY throughput
Break-Bulk/Neo-Bulk	20-80	Metric Tons/Acre	18,000	12,000-24,000	Varies widely based on density and dwell
Automobile	20-80	Units/Acre	3,500	2,500-5,000	Auto units = approx. 1 metric ton
Dry Bulk	30-90	Metric Tons/Acre	150,000	80,000-250,000	Varies widely based on density and dwell
Liquid Bulk	20-90	Metric Tons/Acre	150,000	80,000-170,000	Approx. 6-8 BBL/Ton; non-petroleum may have much lower capacity
CFS (Warehouse)	0.3-3	Metric Tons/Acre	20,000	15,000-40,000	0.5-1 ton per ft^2, but varies widely
Lanes	6-15	Moves/Lane	30,000	20,000-60,000	Gate moves may be 1.0-1.5 x throughput

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.12.

Table 116. Cargo Throughput per Berth.

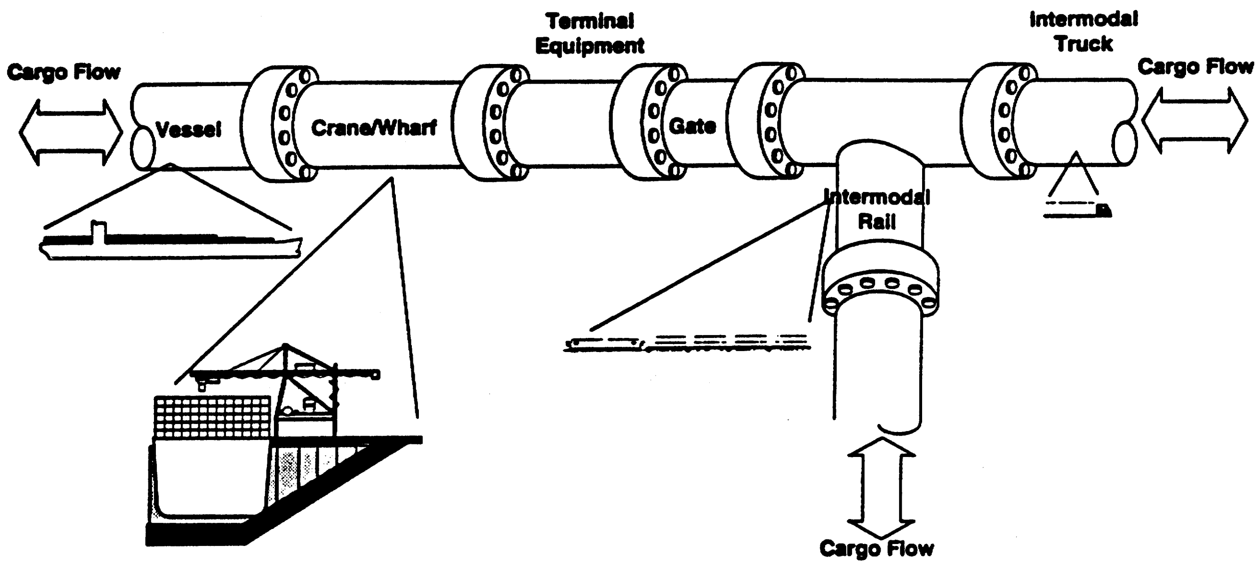
Type	Throughput (short tons/year)
Container, one berth	1,350,000
Container, two berths	1,650,000
Auto	180,000
Neo Bulk, lumber	180,000
Neo Bulk, steel	400,000
Liquid Bulk, petroleum <50,000 DWT	1,500,000
Liquid Bulk, petroleum >50,000 DWT	6,000,000
Liquid Bulk, other	80,000
Dry Bulk, silo storage	1,000,000
Dry Bulk, low density	500,000
Dry Bulk, high density	1,000,000

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 7.13.

Table 117. Modal Split at Selected Seaports.

Port	Trucks (%)	Rail (%)	Other (%)
New York/New Jersey	96	0	4
San Francisco	71	20	9
Barbours Cut Container Terminal, Houston	95	5	0

Source: Guha, Tathagata, and Walton, C. Michael. "Intermodal Container Ports: Application of Automatic Vehicle Classification System for Collecting Trip Generation Data." *Transportation Research Record*, No. 1383, 1993, p. 17.



Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 11.13.

Figure 118. Container Terminal Throughput Capacity Analogy — Balanced Flow.

the containers to an ICTF for transportation by truck or rail or to a CFS for intermediate storage. Adequate truck and rail access has to be provided for the movement of containers out of and into the terminal area. Planners must be familiar with all of these issues in order to provide a balanced flow concept at seaports.

27. Tables 118-120 provide some guidelines for container yard and intermodal facility configuration. Typical facility and operating characteristics for container terminals are shown in Table 118, including a breakdown in terms of terminal area. Operating characteristics for typical intermodal rail terminals are shown in Table 121, including an area breakdown. Typical intermodal yard throughputs in TEUs per year are shown in Table 122.

28. Terminal operations in seaports have changed significantly over the last 20 years. Improved technology in areas of vessel design, container design, on-terminal cargo storage facilities, cargo handling equipment and computerized tracking of cargo have increased the productivity of seaports.

- Container traffic through U.S. ports has grown rapidly in recent years, increasing from 10 million TEUs in 1983 to about 18 million TEUs in 1994. The annual growth rate is expected to be 6% for the next few years. Specialized container terminals with extensive land use requirements are needed to economically handle large volumes of containers. Many existing seaports may be hindered in the growth of container traffic because backland storage areas may not be available. For a given backland area, the container capacity can be increased by switching from chassis to stacked storage. Marine carriers will be reluctant to shift from chassis-mounted storage to ground storage due to increased operating costs. Chassis storage will continue to dominate at seaports.

- The dominant size of containers has become 9 feet 6 inches in height by 40 feet in length. Larger containers are available with lengths up to 48 feet. The increased capacity of containers has reduced the number of cranes necessary to load/unload cargo and the number of trucks and railcars required to haul the containers. A switch to larger containers is not anticipated.

- The design of cranes has improved to the point where the number of containers movements per hour cannot be increased without sacrificing safety to workers and cargo. Significant changes in crane design are not expected.

- Rail transport has become a vitally important factor in seaport access. Railroads have shown a significant growth in recent years in the movement of commodities by container and trailer. In 1994, approximately 8 million containers and trailers were moved by rail compared to only 3 million in the early 1980s. The container and trailer traffic has grown by an average of 7.6 % per year. In the near future, it is expected that more than 40% of the containerized waterborne cargo will be transported inland via railroads. Additional port land will be

Table 118. Typical Characteristics of Container Terminals for Seaports.

Item	Description
Facility Characteristic	
Capacity	3000,000 TEUs/year (chassis and mobile yard crane)
Terminal Area	90-110 acres
Wharf	8 acres (8%)
Storage and Circulation	80 acres (80%)
Maintenance and Miscellaneous	5 acres (5%)
Gate	7acres (7%)
Wharf and Berthing	2,000 to 2,280 feet minimum for two berths
Channel Criteria	Depth = 50 feet, width = 500-700 feet
Crane Requirements	Number = 5-6; gauge = 100 feet
Buildings	
Gate Building	10,000 $ft.^2$
Maintenance/Repair	36,000 $ft.^2$
Warehouse	76,000 $ft.^2$ (optional)
Access Requirements	
Gate	6 inbound lanes, 4 outbound lanes
Rail	Intermodal rail service
Operating Characteristics	
TEU/Unit	1.7
Number of Berths	2
Total Acres	100
Throughput Capacity/Acre	4,000 TEU/Acre/Year
Throughput Capacity Total	400,000 TEU/Year (235,000 Units/Year)
Units per Gate Lane	20,000
Gate Lanes	12

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, pp. 7.26, 11.19.

Table 119. Operating Characteristics for a Typical Intermodal Rail Terminal.

Item	Description
TEU/Unit	1.9
Number of Berths	4-8
Total Acres	80
Track Area	32 acres (40%)
Storage and Circulation	36 acres (45%)
Maintenance and Miscellaneous	5 acres (6%)
Gate	7 acres (9%)
Throughput Capacity/Acre	6,000 TEU/Acre/Year
Throughput Capacity Total	480,000 TEU/Year (252,000 Units/Year)
Units per Gate Lane	20,00
Gate Lanes	12

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, pp. 11.19, 11.20.

Table 120. Typical Intermodal Yard Throughput (TEUs/Year) for Seaports.

Area (acres)	Low	Typical	High
30	105,000	174,000	240,000
100	350,000	580,000	800,000
150	525,000	780,000	1,200,000

Source: Federal Highway Administration. *Landside Access for Intermodal Facilities*, Participant Workbook, National Highway Institute Course No. 15264. U.S. Department of Transportation, Washington, D.C., August 1995, p. 9.5.

required to provide proper rail access. The use of intermodal terminals has improved the efficiency of assembling trainsets.

- Future container ships will be larger, faster, and more fuel efficient than previous models. The ships are expected to have overall lengths up to 1,200 feet and be capable of storing up to 7,600 TEUs. However, the impact of these vessels on terminal capacity will be relatively limited. For a given freight volume, the number of ship movements is reduced but the number of container lifts remains the same. This means that the peak periods of loading/unloading are longer, but they will rarely coincide at all terminals. Additional short-term storage may be necessary at these peak periods.

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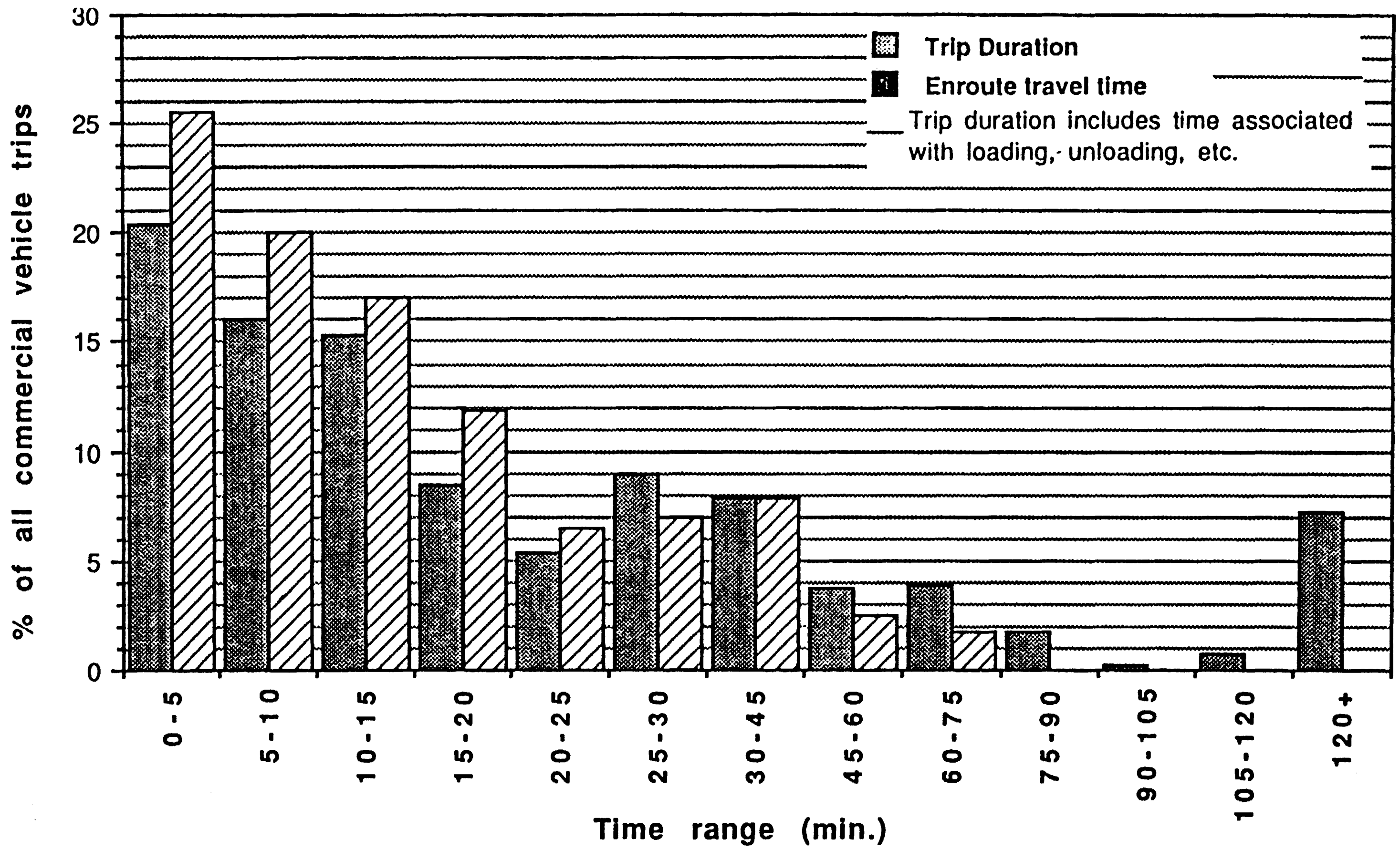
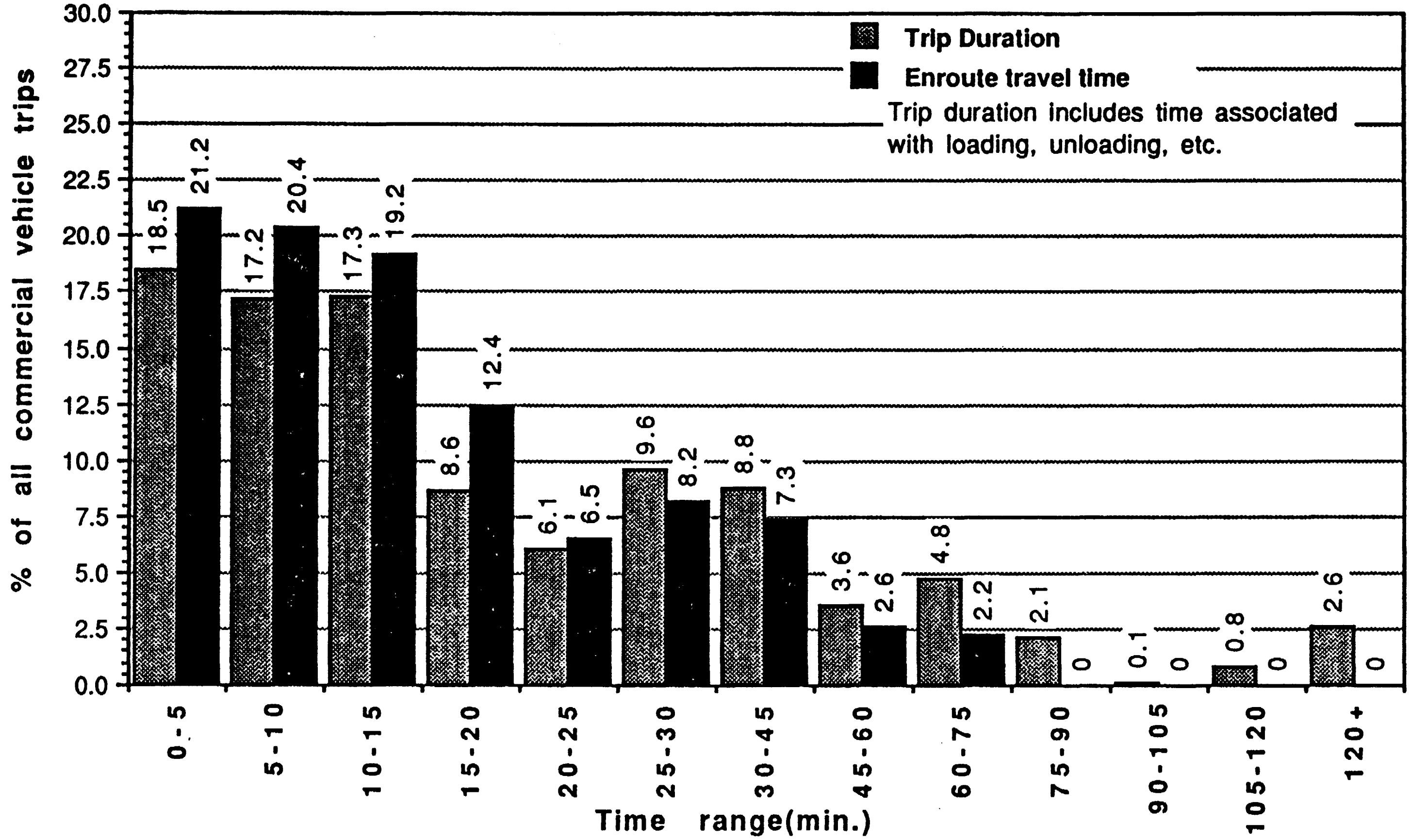
APPENDIX A: COMPARISON OF ENROUTE TRAVEL TIME AND TRIP DURATION

Figures A-1 through A-5 show the distributions of enroute travel time and trip duration for various classes of trucks in Maricopa County (Phoenix), Arizona. Enroute time is the actual time the truck is traveling. Trip duration includes the time required for loading, unloading, and other activities at each stop.



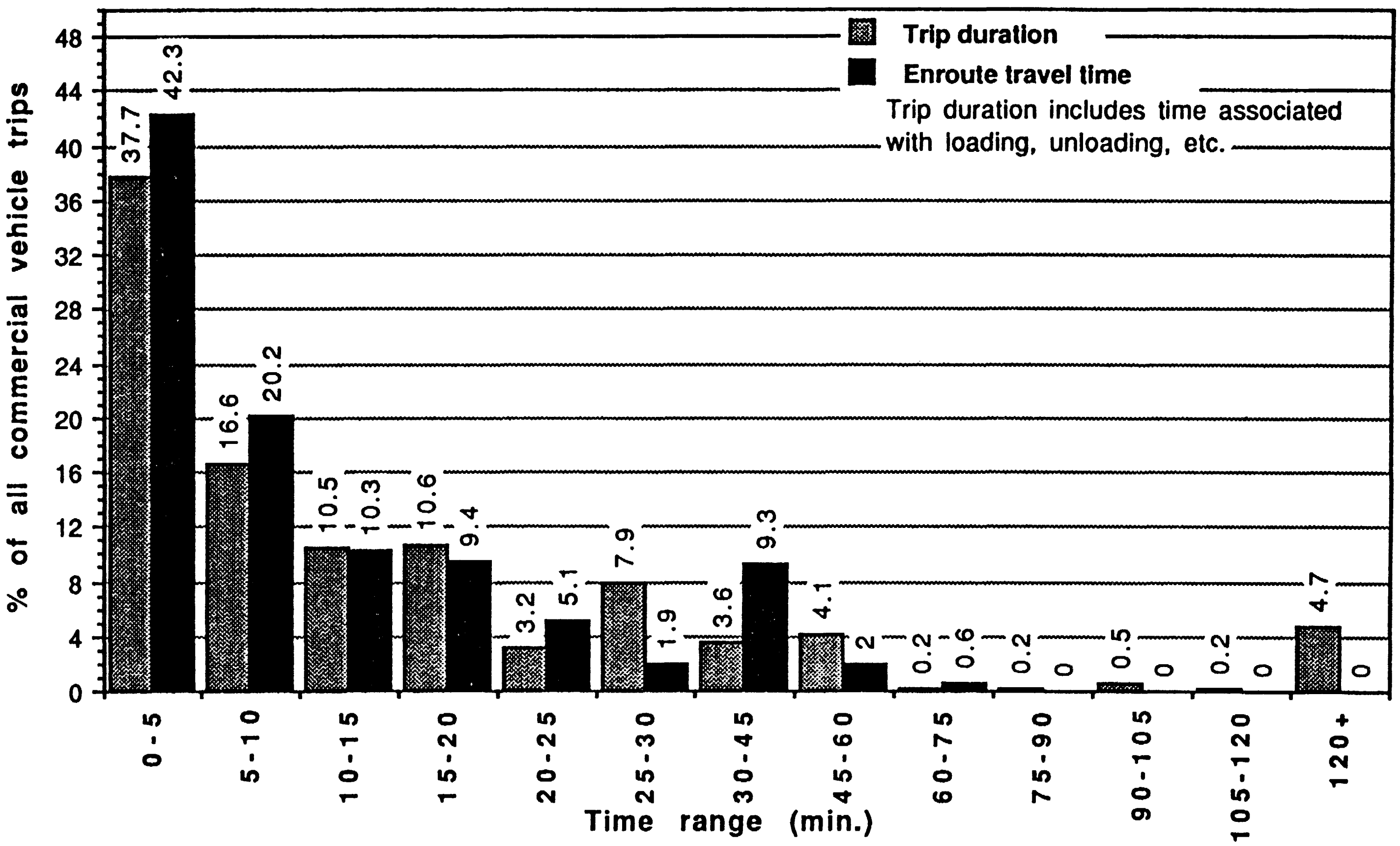
Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.15, p. 3-15; Table 4.6, p. 4-9.

Figure A-1. Distribution of Enroute Travel Time and Trip Duration for Truck Trips in Maricopa County, Arizona, All Trucks.



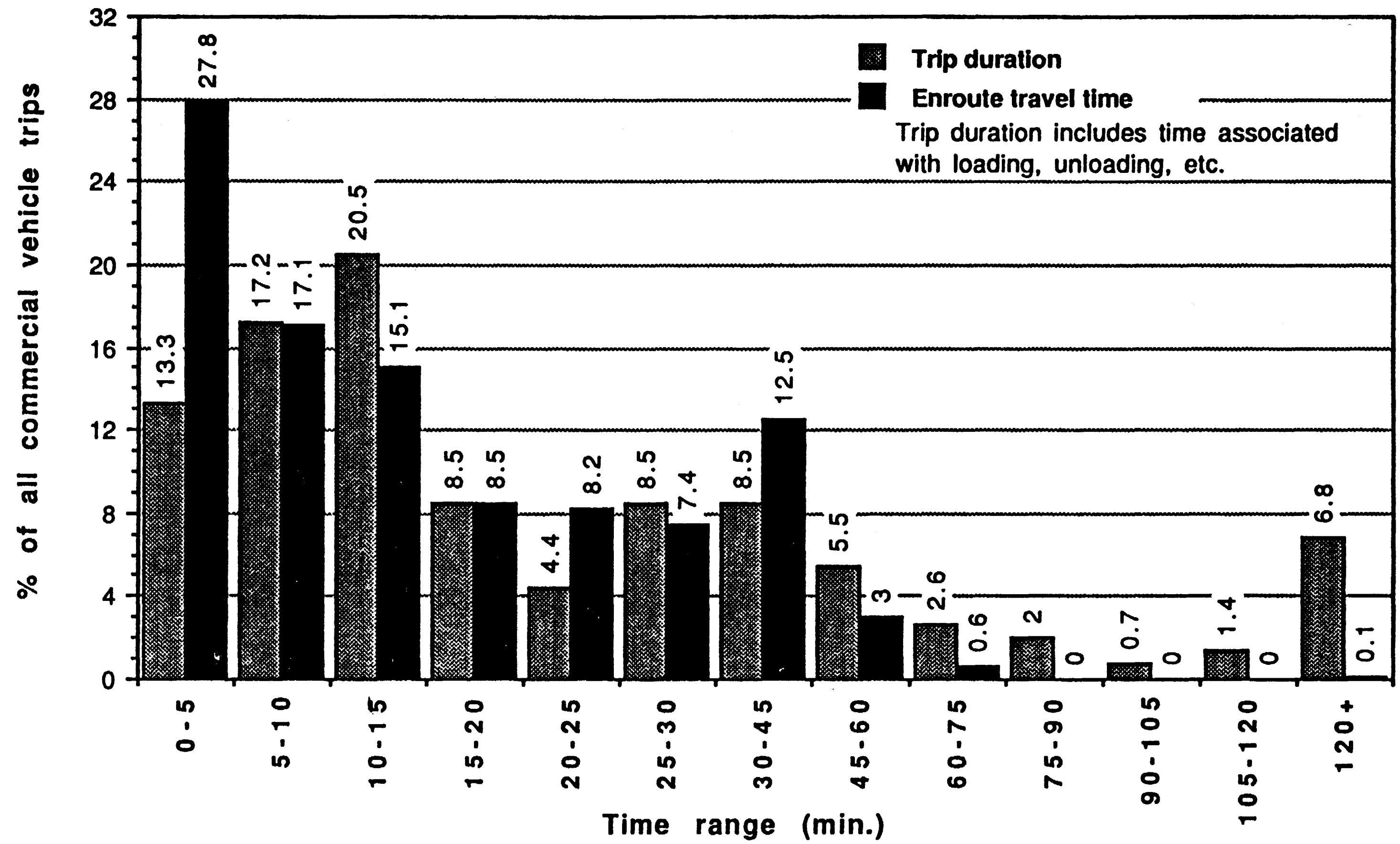
Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.15, p. 3-15; Table 4.6, p. 4-9.

Figure A-2. Distribution of Enroute Travel Time and Trip Duration for Truck Trips in Maricopa County, Arizona, 0-8,000 Pound Trucks.



Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.15, p. 3-15; Table 4.6, p. 4-9.

Figure A-3. Distribution of Enroute Travel Time and Trip Duration for Truck Trips in Maricopa County, Arizona, 8,000-28,000 Pound Trucks.



Source: Ruiter, Earl R. *Development of an Urban Truck Travel Model for the Phoenix Metropolitan Area*, Report No. FHWA-AZ92-314. Arizona Department of Transportation, Phoenix, February 1992, Table 3.15, p. 3-15; Table 4.6, p. 4-9.

Figure A-4. Distribution of Enroute Travel Time and Trip Duration for Truck Trips in Maricopa County, Arizona, 28,000-64,000 Pound Trucks.

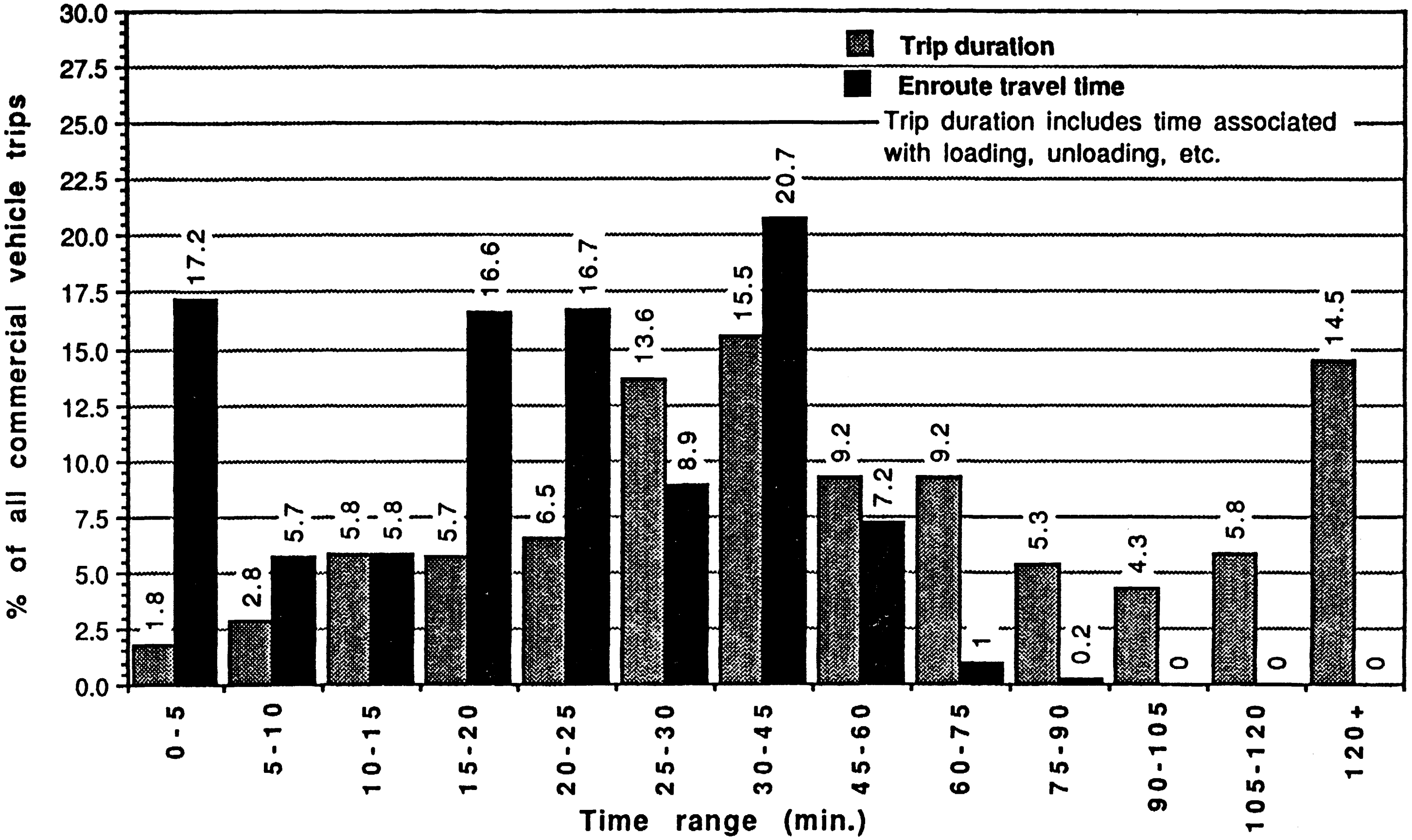


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Figure A-5. Distribution of Enroute Travel Time and Trip Duration for Truck Trips in Maricopa County, Arizona, >64,000 Pound Trucks.

APPENDIX B: TRUCK PERCENTAGES BY FUNCTIONAL CLASSIFICATION, VEHICLE TYPE, AND TIME OF DAY

The tables on the following pages show the distribution of vehicles by vehicle class and time of day. The data are from the Federal Highway Administration's Truck Weight Study, 1993, and were supplied by Science Applications International Corp., Oak Ridge, TN.

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN INTERSTATE
AND Day of week: WEEKDAY

	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
0	0.2	68.1	10.3	0.3	1.5	0.5	0.0	1.6	14.7	2.1	0.2	0.3	0.2	100.0
1	0.9	60.5	9.1	0.3	2.0	0.8	0.0	2.1	20.5	2.7	0.3	0.5	0.2	100.0
2	0.9	56.0	9.7	0.4	2.2	1.0	0.0	2.5	23.1	3.1	0.3	0.4	0.3	100.0
3	0.9	52.3	9.9	0.3	2.8	1.0	0.1	2.9	25.2	3.2	0.3	0.6	0.2	100.0
4	0.9	55.6	11.8	0.3	3.6	1.3	0.1	2.9	20.5	2.2	0.3	0.4	0.2	100.0
5	0.6	66.2	14.1	0.3	2.7	1.0	0.1	1.9	11.4	1.1	0.2	0.2	0.1	100.0
6	0.8	72.6	15.1	0.2	2.4	0.9	0.1	1.3	5.8	0.5	0.2	0.1	0.1	100.0
7	0.1	76.8	12.5	0.2	2.4	0.8	0.7	1.1	4.8	0.3	0.1	0.0	0.1	100.0
8	0.1	74.0	12.4	0.2	3.6	1.3	0.1	1.3	6.4	0.4	0.2	0.1	0.1	100.0
9	0.1	71.1	13.2	0.2	3.7	1.4	0.1	1.5	7.9	0.4	0.2	0.0	0.1	100.0
10	0.1	70.7	13.1	0.2	3.8	1.5	0.1	1.6	8.2	0.4	0.2	0.0	0.1	100.0
11	0.1	71.7	12.7	0.2	3.6	1.4	0.1	1.5	8.1	0.3	0.2	0.0	0.1	100.0
12	0.1	73.0	12.0	0.2	3.3	1.3	0.1	1.4	7.9	0.3	0.2	0.1	0.1	100.0
13	0.1	73.1	12.3	0.2	3.5	1.3	0.1	1.4	7.3	0.3	0.2	0.1	0.1	100.0
14	0.1	73.9	12.6	0.2	3.3	1.3	0.1	1.2	6.7	0.3	0.2	0.0	0.1	100.0
15	0.1	76.1	12.9	0.2	2.8	0.9	0.1	1.1	5.4	0.2	0.1	0.0	0.1	100.0
16	0.1	78.6	12.5	0.2	2.1	0.7	0.0	0.9	4.4	0.2	0.1	0.0	0.1	100.0
17	0.1	80.8	11.3	0.2	1.7	0.5	0.0	0.9	4.0	0.2	0.1	0.0	0.0	100.0
18	0.1	79.7	11.5	0.1	1.7	0.5	0.0	0.8	5.0	0.3	0.1	0.1	0.1	100.0

(CONTINUED)

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN INTERSTATE
AND Day of Week: WEEKDAY

	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
19	0.1	78.9	11.2	0.1	1.4	0.5	0.0	0.9	6.1	0.4	0.1	0.1	0.1	100.0
20	0.8	78.0	10.6	0.2	1.3	0.4	0.0	0.8	6.9	0.6	0.1	0.1	0.1	100.0
21	0.1	78.5	10.4	0.1	1.2	0.4	0.0	0.8	7.3	0.8	0.1	0.2	0.1	100.0
22	0.2	76.9	10.2	0.2	1.1	0.4	0.0	1.0	8.6	1.1	0.1	0.2	0.1	100.0
23	0.2	74.2	9.8	0.2	1.4	0.5	0.0	1.1	10.6	1.6	0.1	0.2	0.1	100.0
TOTAL	0.1	75.2	12.2	0.2	2.5	0.9	0.1	1.2	6.9	0.5	0.2	0.1	0.1	100.0

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****
(ONLY SITES WITH 24 HOURS OF DATA)

Functional Class: URBAN INTERSTATE
AND Day of Week: WEEKEND

HOUR	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0	0.2	83.1	9.2	0.2	1.8	0.2	0.0	0.5	3.9	0.7	0.0	0.1	0.0	100.0
1	0.1	80.3	10.3	0.1	1.1	0.1	0.0	1.2	4.6	1.5	0.0	0.1	0.4	100.0
2	0.2	75.9	10.4	0.1	2.6	0.1	0.0	1.3	6.8	1.4	0.2	0.2	0.8	100.0
3	0.1	71.2	12.2	0.6	2.6	0.2	0.0	1.7	9.2	1.5	0.1	0.2	0.4	100.0
4	0.2	71.0	13.5	0.4	2.2	1.0	0.1	3.0	7.8	0.4	0.2	0.0	0.1	100.0
5	0.4	75.0	15.4	0.3	1.8	0.4	0.0	1.3	4.2	0.8	0.0	0.0	0.2	100.0
6	0.0	77.3	16.1	0.2	0.9	0.4	0.0	0.9	3.3	0.5	0.0	0.1	0.2	100.0
7	0.2	78.4	16.3	0.3	1.6	0.4	0.0	0.6	1.7	0.2	0.0	0.0	0.1	100.0
8	0.1	80.1	14.8	0.3	1.2	0.3	0.0	0.8	2.0	0.1	0.0	0.0	0.3	100.0
9	0.2	81.5	13.9	0.3	1.2	0.2	0.0	0.5	2.0	0.1	0.0	0.0	0.1	100.0
10	0.2	82.2	13.8	0.1	1.1	0.2	0.0	0.7	1.4	0.1	0.0	0.0	0.2	100.0
11	0.2	82.9	13.5	0.1	0.8	0.2	0.0	0.7	1.4	0.1	0.0	0.0	0.1	100.0
12	0.2	82.6	13.6	0.1	1.0	0.2	0.0	0.8	1.4	0.1	0.0	0.0	0.1	100.0
13	0.2	82.8	13.3	0.2	1.0	0.2	0.0	0.8	1.5	0.1	0.0	0.0	0.0	100.0
14	0.2	82.2	13.4	0.1	1.1	0.2	0.0	0.8	1.9	0.1	0.0	0.0	0.1	100.0
15	0.2	82.2	13.4	0.2	1.0	0.1	0.0	0.9	1.7	0.1	0.0	0.0	0.1	100.0
16	0.1	82.8	13.5	0.1	0.9	0.1	0.0	0.8	1.5	0.1	0.0	0.0	0.1	100.0
17	0.2	83.2	13.0	0.2	0.9	0.1	0.0	0.7	1.4	0.1	0.0	0.0	0.1	100.0
18	0.2	83.2	12.8	0.2	0.9	0.1	0.0	0.8	1.7	0.1	0.0	0.1	0.0	100.0

(CONTINUED)

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN INTERSTATE
AND Day of Week: WEEKEND

HOUR	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
19	0.2	83.7	12.2	0.2	0.9	0.1	0.0	0.7	1.8	0.2	0.0	0.0	0.0	100.0
20	0.2	83.6	11.6	0.3	0.9	0.2	0.0	0.5	2.6	0.1	0.0	0.0	0.0	100.0
21	0.1	83.9	11.6	0.2	0.6	0.1	0.0	0.6	2.6	0.3	0.0	0.0	0.0	100.0
22	0.2	84.4	10.8	0.1	0.6	0.1	0.0	0.5	2.9	0.1	0.0	0.1	0.2	100.0
23	0.2	81.2	10.6	0.5	1.4	0.2	0.0	0.7	4.9	0.3	0.0	0.0	0.1	100.0
TOTAL	0.2	82.1	13.2	0.2	1.0	0.2	0.0	0.8	2.0	0.2	0.0	0.0	0.1	100.0

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN FREEWAY
AND Day of Week: WEEKDAY

HOUR	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0	0.1	71.6	9.2	0.3	2.5	0.6	0.0	3.9	10.1	1.3	0.3	0.1	0.0	100.0
1	0.0	65.4	9.3	0.4	3.4	0.9	0.0	4.9	13.5	1.8	0.4	0.1	0.0	100.0
2	0.0	61.4	9.1	0.6	3.9	1.3	0.0	3.5	17.8	1.9	0.4	0.0	0.0	100.0
3	0.1	57.2	10.5	0.4	3.0	2.0	0.0	4.6	20.0	1.7	0.5	0.1	0.0	100.0
4	0.0	57.0	12.3	0.6	4.3	1.7	0.0	3.8	18.5	1.3	0.4	0.0	0.1	100.0
5	0.1	67.2	13.5	0.4	4.6	1.2	0.0	2.0	10.2	0.6	0.2	0.0	0.1	100.0
6	0.0	74.2	14.8	0.5	3.3	0.7	0.0	1.2	4.7	0.3	0.1	0.0	0.0	100.0
7	0.0	79.3	11.3	0.3	2.9	0.7	0.0	1.1	3.9	0.2	0.1	0.0	0.0	100.0
8	0.0	75.5	11.8	0.4	3.7	1.2	0.0	1.6	5.2	0.3	0.1	0.0	0.0	100.0
9	0.0	71.2	13.2	0.4	4.6	1.4	0.1	1.9	6.8	0.3	0.2	0.0	0.0	100.0
10	0.0	71.0	12.8	0.4	4.5	1.6	0.1	1.8	7.4	0.3	0.1	0.0	0.0	100.0
11	0.1	72.0	12.7	0.4	4.1	1.4	0.0	1.7	7.2	0.3	0.1	0.1	0.0	100.0
12	0.1	73.6	12.3	0.3	3.9	1.1	0.0	1.6	6.6	0.3	0.1	0.0	0.0	100.0
13	0.1	73.8	12.5	0.4	4.0	1.1	0.0	1.6	6.1	0.3	0.1	0.0	0.0	100.0
14	0.1	74.3	12.5	0.4	4.2	1.2	0.0	1.6	5.2	0.2	0.1	0.0	0.0	100.0
15	0.1	76.6	12.8	0.7	3.6	0.9	0.0	1.3	3.8	0.2	0.0	0.0	0.0	100.0
16	0.1	79.3	12.3	0.3	2.8	0.6	0.0	1.2	3.1	0.2	0.1	0.0	0.0	100.0
17	0.1	82.6	10.7	0.2	2.1	0.4	0.0	1.0	2.8	0.2	0.0	0.0	0.0	100.0
18	0.1	82.0	10.6	0.2	2.0	0.4	0.0	1.1	3.4	0.2	0.0	0.0	0.0	100.0

(CONTINUED)

DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA

Functiona ass: URBAN FREEWAY
AND Day of week: WEEKDAY

HOUR	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
19	0.1	80.9	10.2	0.3	2.0	0.4	0.0	1.3	4.5	0.3	0.0	0.0	0.0	100.0
20	0.1	80.6	9.8	0.3	1.7	0.4	0.0	1.5	5.2	0.3	0.0	0.0	0.0	100.0
21	0.1	81.0	9.7	0.1	1.5	0.4	0.0	1.5	5.2	0.5	0.1	0.0	0.0	100.0
22	0.1	80.5	9.8	0.2	1.5	0.4	0.0	2.0	5.1	0.4	0.0	0.0	0.0	100.0
23	0.1	77.2	9.3	0.4	2.4	0.6	0.5	2.3	6.3	0.7	0.2	0.0	0.1	100.0
TOTAL	0.1	76.7	11.7	0.3	3.1	0.8	0.0	1.5	5.3	0.3	0.1	0.0	0.0	100.0

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functiona. Class: URBAN FREEWAY
AND Day of Week: WEEKEND

	Motorcyc-les	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
0	0.0	87.1	6.3	0.3	1.7	0.2	0.0	1.9	2.4	0.0	0.0	0.0	0.0	100.0
1	0.0	86.0	6.1	0.4	2.2	0.3	0.0	2.1	3.0	0.0	0.0	0.0	0.0	100.0
2	0.0	84.5	6.0	0.4	3.1	0.6	0.0	1.5	3.8	0.0	0.1	0.0	0.0	100.0
3	0.0	80.5	8.2	0.2	1.7	0.5	0.0	3.2	5.7	0.0	0.0	0.0	0.0	100.0
4	0.0	74.4	9.3	0.6	2.4	0.6	0.0	3.9	8.7	0.0	0.0	0.0	0.0	100.0
5	0.0	75.3	10.0	1.0	3.8	0.3	0.0	3.3	6.2	0.1	0.0	0.0	0.0	100.0
6	0.0	80.1	10.1	0.6	2.4	0.5	0.0	2.1	4.2	0.0	0.0	0.0	0.0	100.0
7	0.0	82.7	9.3	0.3	2.7	0.5	0.0	1.4	3.0	0.0	0.0	0.0	0.0	100.0
8	0.0	85.7	7.9	0.5	2.1	0.3	0.0	1.1	2.3	0.0	0.0	0.0	0.0	100.0
9	0.0	87.4	7.5	0.3	1.9	0.3	0.0	0.8	1.6	0.0	0.0	0.0	0.0	100.0
10	0.0	87.9	7.6	0.2	1.9	0.2	0.0	0.7	1.4	0.0	0.0	0.0	0.0	100.0
11	0.0	89.4	6.7	0.1	1.8	0.1	0.0	0.8	1.1	0.0	0.0	0.0	0.0	100.0
12	0.0	89.7	6.3	0.1	2.1	0.1	0.0	0.7	0.8	0.0	0.0	0.0	0.0	100.0
13	0.0	90.1	6.1	0.1	2.1	0.1	0.0	0.6	0.9	0.0	0.0	0.0	0.0	100.0
14	0.0	90.9	5.7	0.1	2.0	0.1	0.0	0.6	0.6	0.0	0.0	0.0	0.0	100.0
15	0.0	87.3	5.3	0.1	4.9	0.1	0.0	0.6	1.5	0.0	0.0	0.0	0.0	100.0
16	0.0	90.9	5.9	0.2	1.9	0.1	0.0	0.6	0.5	0.0	0.0	0.0	0.0	100.0
17	0.0	88.4	4.8	0.5	2.5	0.4	1.0	0.5	1.5	0.0	0.0	0.0	0.3	100.0
18	0.0	90.9	6.1	0.2	1.7	0.0	0.0	0.5	0.6	0.0	0.0	0.0	0.0	100.0

(CONTINUED)

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN FREEWAY
AND Day of Week: WEEKEND

	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
19	0.0	86.7	5.8	0.4	3.7	0.1	0.0	0.6	2.6	0.0	0.0	0.0	0.0	100.0
20	0.0	89.2	6.9	0.3	1.6	0.0	0.0	0.9	1.0	0.0	0.0	0.0	0.0	100.0
21	0.0	90.4	6.3	0.1	1.3	0.1	0.0	0.5	1.3	0.0	0.0	0.0	0.0	100.0
22	0.0	90.1	6.2	0.2	1.4	0.1	0.0	0.6	1.3	0.0	0.0	0.0	0.0	100.0
23	0.0	88.3	6.6	0.2	1.7	0.2	0.0	0.9	2.0	0.0	0.0	0.0	0.0	100.0
TOTAL	0.0	89.2	6.5	0.2	1.9	0.2	0.0	0.8	1.2	0.0	0.0	0.0	0.0	100.0

...FHWA VEHICLE CLASS DATA *****

Functional ss: URBAN PRINC. ARTERIAL
AND Day of week: WEEKEND

HOUR	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0	0.0	82.9	15.1	0.2	0.5	0.0	0.0	0.4	0.7	0.0	0.0	0.0	0.0	100.0
1	0.0	83.7	14.7	0.1	0.6	0.1	0.0	0.2	0.6	0.0	0.0	0.0	0.0	100.0
2	0.4	82.5	13.4	0.1	1.4	0.2	0.0	0.6	1.3	0.0	0.0	0.0	0.0	100.0
3	0.0	77.1	16.5	0.2	1.6	0.9	0.0	0.2	3.6	0.0	0.0	0.0	0.0	100.0
4	0.1	77.5	16.5	0.3	1.9	0.6	0.0	0.4	2.5	0.0	0.0	0.2	0.0	100.0
5	0.3	77.1	19.2	0.2	1.5	0.1	0.0	0.2	1.2	0.1	0.0	0.0	0.0	100.0
6	0.0	78.2	18.7	0.1	1.7	0.2	0.0	0.1	0.9	0.0	0.0	0.0	0.0	100.0
7	0.5	80.4	16.6	0.1	1.6	0.2	0.0	0.2	0.4	0.0	0.0	0.0	0.0	100.0
8	0.3	78.2	17.6	0.2	2.1	0.4	0.2	0.4	0.7	0.0	0.0	0.0	0.0	100.0
9	0.3	78.2	17.3	0.1	2.2	0.5	0.1	0.4	0.9	0.0	0.0	0.0	0.0	100.0
10	0.3	78.5	16.8	0.2	2.2	0.5	0.0	0.4	1.1	0.0	0.0	0.0	0.0	100.0
11	0.3	78.9	16.6	0.1	2.2	0.5	0.1	0.2	1.0	0.0	0.0	0.0	0.0	100.0
12	0.2	80.4	15.9	0.1	1.7	0.4	0.1	0.4	0.9	0.0	0.0	0.0	0.0	100.0
13	0.3	80.5	15.5	0.1	1.6	0.6	0.0	0.4	0.9	0.0	0.0	0.0	0.0	100.0
14	0.2	80.2	16.0	0.1	1.9	0.4	0.0	0.4	0.7	0.0	0.0	0.0	0.0	100.0
15	0.2	81.0	16.1	0.1	1.6	0.3	0.1	0.2	0.5	0.0	0.0	0.0	0.0	100.0
16	0.2	81.8	15.9	0.1	1.2	0.2	0.0	0.3	0.4	0.0	0.0	0.0	0.0	100.0
17	0.4	83.0	14.9	0.1	1.0	0.1	0.0	0.2	0.3	0.0	0.0	0.0	0.0	100.0
18	0.3	81.6	16.3	0.1	0.9	0.1	0.0	0.3	0.4	0.0	0.0	0.0	0.0	100.0

(CONTINUED)

Functional Class: URBAN PRINC. ARTERIAL
AND Day of Week: WEEKEND

	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
19	0.3	82.9	15.2	0.1	0.8	0.1	0.0	0.3	0.3	0.0	0.0	0.0	0.0	100.0
20	0.2	83.6	14.7	0.1	0.5	0.0	0.0	0.2	0.7	0.0	0.0	0.0	0.0	100.0
21	0.1	83.6	14.4	0.1	0.6	0.2	0.0	0.1	0.9	0.0	0.0	0.0	0.0	100.0
22	0.3	85.1	12.6	0.0	0.9	0.1	0.0	0.1	0.9	0.0	0.0	0.0	0.0	100.0
23	0.3	85.8	11.8	0.0	0.6	0.1	0.0	0.2	1.1	0.1	0.0	0.0	0.0	100.0
TOTAL	0.2	81.0	15.9	0.1	1.4	0.3	0.0	0.3	0.7	0.0	0.0	0.0	0.0	100.0

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN PRINC. ARTERIAL
AND Day of Week: WEEKDAY

HOUR	Motorcyc-les	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0	0.5	77.6	13.2	0.2	1.3	0.5	0.3	0.5	5.3	0.5	0.2	0.0	0.0	100.0
1	0.7	74.4	13.4	0.2	1.5	0.5	0.1	0.7	7.6	0.7	0.1	0.0	0.0	100.0
2	0.5	72.8	12.4	0.2	2.2	0.6	0.0	0.8	9.3	0.9	0.1	0.1	0.0	100.0
3	0.4	67.3	15.3	0.2	2.6	0.9	0.0	0.9	10.9	1.1	0.3	0.1	0.0	100.0
4	0.4	66.2	17.3	0.3	3.3	1.2	0.1	1.2	9.0	0.7	0.2	0.1	0.1	100.0
5	0.4	70.4	19.3	0.3	2.7	0.9	0.0	0.9	4.7	0.3	0.1	0.0	0.1	100.0
6	0.3	73.0	20.6	0.3	2.1	0.6	0.1	0.6	2.2	0.1	0.1	0.0	0.0	100.0
7	0.2	76.6	17.7	0.4	2.0	0.7	0.1	0.5	1.6	0.1	0.1	0.0	0.1	100.0
8	0.3	74.7	17.4	0.3	3.0	0.9	0.1	0.8	2.3	0.0	0.1	0.0	0.0	100.0
9	0.3	72.7	18.6	0.3	3.3	1.0	0.1	0.9	2.6	0.1	0.1	0.0	0.0	100.0
10	0.3	73.1	18.3	0.2	3.1	1.0	0.1	1.0	2.7	0.1	0.1	0.0	0.0	100.0
11	0.3	74.7	17.3	0.3	3.0	0.9	0.1	0.8	2.5	0.0	0.1	0.0	0.0	100.0
12	0.2	76.3	16.6	0.2	2.6	0.8	0.1	0.7	2.2	0.0	0.1	0.0	0.0	100.0
13	0.2	75.9	16.7	0.3	2.7	0.8	0.1	0.7	2.3	0.0	0.1	0.0	0.1	100.0
14	0.2	75.9	16.7	0.3	2.9	0.8	0.1	0.7	2.2	0.0	0.1	0.0	0.1	100.0
15	0.2	76.9	16.7	0.4	2.4	0.8	0.1	0.6	1.7	0.0	0.1	0.0	0.0	100.0
16	0.2	78.6	16.7	0.2	1.8	0.4	0.0	0.5	1.4	0.0	0.0	0.0	0.0	100.0
17	0.2	80.4	15.5	0.2	1.5	0.4	0.0	0.5	1.2	0.0	0.0	0.0	0.0	100.0
18	0.3	80.4	15.7	0.2	1.2	0.4	0.0	0.4	1.4	0.0	0.0	0.0	0.0	100.0

(CONTINUED)

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional C. .s: URBAN PRINC. ARTERIAL
AND Day of Week: WEEKDAY

	Motorcyc-les	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
19	0.3	80.5	15.5	0.1	1.1	0.4	0.0	0.3	1.6	0.1	0.1	0.0	0.0	100.0
20	0.3	81.0	14.7	0.1	1.1	0.3	0.0	0.3	2.0	0.1	0.0	0.0	0.0	100.0
21	0.3	82.1	13.6	0.1	0.9	0.3	0.0	0.3	2.1	0.2	0.1	0.0	0.0	100.0
22	0.4	81.9	13.0	0.2	1.2	0.3	0.0	0.3	2.3	0.2	0.0	0.0	0.0	100.0
23	0.3	80.9	13.3	0.1	1.0	0.3	0.0	0.3	3.1	0.4	0.1	0.0	0.0	100.0
TOTAL	0.2	77.3	16.5	0.2	2.1	0.6	0.1	0.6	2.1	0.1	0.1	0.0	0.0	100.0

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN MINOR ARTERIAL
AND Day of Week: WEEKDAY

HOUR	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0	0.5	85.0	11.5	0.1	1.5	0.5	0.0	0.1	0.7	0.1	0.0	0.0	0.1	100.0
1	0.7	84.4	11.8	0.0	1.1	0.3	0.0	0.4	1.0	0.1	0.0	0.0	0.1	100.0
2	0.7	83.3	12.7	0.0	1.3	0.3	0.0	0.2	1.5	0.1	0.1	0.0	0.0	100.0
3	0.5	78.4	15.1	0.1	1.2	1.8	0.0	0.3	2.2	0.2	0.0	0.0	0.0	100.0
4	0.2	73.4	18.7	0.2	2.4	0.6	0.1	1.0	3.1	0.2	0.1	0.0	0.0	100.0
5	0.2	78.5	17.4	0.1	1.5	0.8	0.0	0.3	1.0	0.0	0.0	0.0	0.0	100.0
6	0.2	80.2	15.9	0.3	1.8	0.7	0.0	0.2	0.7	0.0	0.0	0.0	0.0	100.0
7	0.5	81.8	13.7	0.3	1.7	0.9	0.0	0.3	0.6	0.0	0.1	0.0	0.0	100.0
8	0.4	78.1	15.6	0.4	2.5	1.3	0.0	0.4	1.2	0.0	0.1	0.0	0.0	100.0
9	0.4	77.1	16.1	0.2	2.8	1.3	0.1	0.5	1.4	0.0	0.0	0.0	0.0	100.0
10	0.3	77.7	15.5	0.2	2.8	1.3	0.1	0.6	1.3	0.0	0.0	0.0	0.0	100.0
11	0.4	78.6	14.8	0.2	2.7	1.3	0.0	0.5	1.4	0.0	0.1	0.0	0.0	100.0
12	0.3	80.9	13.6	0.1	2.5	1.0	0.0	0.4	1.0	0.1	0.1	0.0	0.0	100.0
13	0.3	80.1	13.4	0.2	2.8	1.4	0.1	0.4	1.1	0.1	0.1	0.0	0.0	100.0
14	0.4	80.1	14.2	0.3	2.4	0.9	0.0	0.5	1.0	0.0	0.0	0.0	0.0	100.0
15	0.6	80.4	13.8	0.3	2.5	0.8	0.0	0.4	1.1	0.0	0.0	0.0	0.0	100.0
16	0.3	83.1	13.5	0.2	1.6	0.6	0.0	0.2	0.5	0.0	0.0	0.0	0.0	100.0
17	0.3	84.3	12.2	0.1	1.5	0.7	0.0	0.2	0.6	0.0	0.0	0.0	0.0	100.0
18	0.3	85.0	12.1	0.1	1.2	0.6	0.0	0.2	0.5	0.0	0.0	0.0	0.0	100.0

(CONTINUED)

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN MINOR ARTERIAL
AND Day of Week: WEEKDAY

	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
19	0.3	85.1	12.0	0.1	0.9	0.6	0.0	0.3	0.6	0.0	0.0	0.0	0.0	100.0
20	0.4	85.7	11.9	0.1	0.7	0.5	0.0	0.1	0.5	0.0	0.0	0.0	0.0	100.0
21	0.5	86.9	10.7	0.0	0.5	0.8	0.0	0.1	0.4	0.0	0.0	0.0	0.0	100.0
22	0.5	87.1	10.0	0.0	1.2	0.6	0.0	0.1	0.5	0.0	0.0	0.0	0.0	100.0
23	0.5	87.4	10.1	0.0	0.8	0.5	0.0	0.1	0.5	0.0	0.0	0.0	0.0	100.0
TOTAL	0.3	81.9	13.6	0.2	1.9	0.9	0.0	0.3	0.8	0.0	0.0	0.0	0.0	100.0

***** DISTR ,TION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN MINOR ARTERIAL
AND Day of Week: WEEKEND

	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
0	0.0	88.9	5.2	0.0	0.8	0.0	0.0	0.8	4.4	0.0	0.0	0.0	0.0	100.0
1	0.0	91.3	6.8	0.0	0.0	1.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	100.0
2	0.0	84.1	6.3	0.5	3.6	1.0	0.0	1.8	2.6	0.0	0.0	0.0	0.0	100.0
3	0.0	79.7	7.3	0.9	2.6	1.6	0.0	0.0	8.0	0.0	0.0	0.0	0.0	100.0
4	0.0	82.6	3.9	0.0	1.9	2.9	0.0	3.3	5.3	0.0	0.0	0.0	0.0	100.0
5	0.6	87.1	9.5	0.7	1.0	0.4	0.0	0.0	0.4	0.4	0.0	0.0	0.0	100.0
6	0.0	80.6	13.4	0.0	2.6	1.4	0.0	0.8	1.2	0.0	0.0	0.0	0.0	100.0
7	0.0	85.7	9.8	0.0	2.2	1.3	0.0	0.2	0.7	0.0	0.0	0.0	0.0	100.0
8	0.0	81.6	9.5	0.2	3.6	1.7	0.2	1.4	1.8	0.1	0.0	0.0	0.0	100.0
9	0.2	80.3	10.1	0.3	4.0	1.6	0.2	1.0	2.3	0.0	0.1	0.0	0.0	100.0
10	0.2	82.3	8.6	0.4	3.7	1.4	0.0	0.4	3.0	0.0	0.0	0.0	0.0	100.0
11	0.0	81.2	10.3	0.4	3.8	0.8	0.0	1.0	2.4	0.0	0.0	0.0	0.1	100.0
12	0.0	83.8	10.9	0.2	1.5	0.5	0.0	0.5	2.5	0.0	0.0	0.0	0.1	100.0
13	0.0	79.0	12.3	0.2	3.5	1.3	0.0	1.0	2.7	0.0	0.0	0.0	0.0	100.0
14	0.0	82.8	10.3	0.6	3.7	0.6	0.2	0.2	1.5	0.0	0.2	0.0	0.0	100.0
15	0.0	84.1	8.6	0.5	3.7	1.0	0.1	1.1	0.9	0.0	0.0	0.0	0.0	100.0
16	0.1	87.4	8.7	0.3	1.4	0.5	0.0	0.7	0.8	0.1	0.0	0.0	0.1	100.0
17	0.2	88.4	7.6	0.3	1.8	0.7	0.0	0.2	0.7	0.1	0.0	0.0	0.0	100.0
18	0.1	87.9	7.9	0.3	1.9	0.2	0.0	0.6	1.1	0.0	0.0	0.0	0.0	100.0

(CONTINUED)

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functic Class: URBAN MINOR ARTERIAL
AND Day of Week: WEEKEND

	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
19	0.2	89.5	6.2	0.2	1.3	0.3	0.0	0.4	1.8	0.2	0.0	0.0	0.0	100.0
20	0.2	89.4	7.1	0.2	0.7	0.4	0.2	0.4	1.0	0.5	0.1	0.0	0.0	100.0
21	0.2	88.4	7.2	0.6	0.6	0.8	0.0	0.3	1.8	0.3	0.0	0.0	0.0	100.0
22	0.3	87.5	7.4	0.3	0.6	1.2	0.0	0.3	1.9	0.6	0.0	0.0	0.0	100.0
23	0.0	90.4	6.0	0.0	1.3	0.0	0.0	0.8	1.1	0.0	0.0	0.0	0.4	100.0
TOTAL	0.1	85.2	8.9	0.3	2.4	0.9	0.0	0.6	1.5	0.1	0.0	0.0	0.0	100.0

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functic Class: URBAN COLLECTOR
AND Day of Week: WEEKDAY

HOUR	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
0	1.1	77.3	10.0	0.3	0.6	8.2	0.0	0.1	2.1	0.2	0.2	0.0	0.0	100.0
1	0.3	69.5	15.4	0.0	1.4	8.9	0.1	0.2	4.3	0.0	0.0	0.0	0.0	100.0
2	4.7	72.7	11.2	0.3	0.5	4.3	0.1	0.6	3.2	0.2	1.0	0.0	1.2	100.0
3	0.3	63.7	12.7	1.6	1.4	6.9	0.5	1.0	11.0	0.3	0.7	0.0	0.0	100.0
4	1.0	62.2	18.5	0.6	4.2	8.0	0.3	0.0	3.7	0.2	1.0	0.2	0.0	100.0
5	0.2	71.8	19.5	0.4	2.2	3.1	0.0	0.2	2.2	0.0	0.5	0.0	0.0	100.0
6	0.2	68.3	17.4	0.5	1.4	6.1	4.8	0.3	0.9	0.0	0.1	0.0	0.0	100.0
7	0.8	75.4	14.9	0.2	1.2	5.3	0.2	0.3	1.3	0.0	0.4	0.0	0.0	100.0
8	0.3	72.9	16.3	0.3	1.7	5.6	0.1	0.5	2.1	0.0	0.2	0.0	0.0	100.0
9	0.5	71.5	16.5	0.5	1.8	4.9	0.2	0.5	3.1	0.0	0.4	0.0	0.0	100.0
10	0.4	73.7	16.9	0.2	1.6	2.8	0.2	0.6	3.3	0.0	0.1	0.0	0.1	100.0
11	0.4	76.2	16.6	0.2	1.8	1.3	0.1	0.6	2.7	0.0	0.2	0.0	0.0	100.0
12	0.3	79.4	15.7	0.2	1.5	1.0	0.0	0.2	1.6	0.0	0.1	0.0	0.1	100.0
13	0.2	78.7	15.1	0.2	1.6	1.6	0.0	0.5	2.0	0.0	0.0	0.0	0.0	100.0
14	0.5	76.0	16.0	0.2	2.4	2.4	0.1	0.6	1.8	0.0	0.1	0.0	0.0	100.0
15	0.9	75.5	16.0	0.1	1.6	3.6	0.0	0.3	1.7	0.0	0.2	0.0	0.0	100.0
16	0.7	76.0	14.8	0.6	2.0	4.4	0.1	0.3	0.9	0.0	0.1	0.0	0.1	100.0
17	0.3	77.7	13.7	0.8	1.4	4.6	0.1	0.3	0.8	0.0	0.2	0.0	0.2	100.0
18	0.4	80.1	13.2	0.1	0.9	4.3	0.1	0.3	0.6	0.0	0.1	0.0	0.1	100.0

(CONTINUED)

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functio Class: URBAN COLLECTOR
AND Day of Week: WEEKDAY

HOUR	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
19	0.4	78.8	13.3	0.1	0.7	5.1	0.0	0.3	0.7	0.0	0.3	0.0	0.3	100.0
20	0.2	77.7	12.7	0.1	0.8	7.6	0.1	0.1	0.6	0.0	0.0	0.0	0.1	100.0
21	0.4	80.7	11.1	0.1	0.5	6.1	0.0	0.1	0.9	0.0	0.1	0.0	0.0	100.0
22	0.4	78.6	11.9	0.0	0.4	7.4	0.3	0.1	0.4	0.0	0.1	0.0	0.3	100.0
23	0.9	77.4	12.0	0.1	0.6	7.3	0.0	0.1	1.2	0.0	0.3	0.0	0.0	100.0
TOTAL	0.4	77.4	14.9	0.2	1.2	3.5	0.1	0.4	1.7	0.0	0.2	0.0	0.1	100.0

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN COLLECTOR
AND Day of Week: WEEKEND

	Motorcycles	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
0	0.0	84.6	13.5	0.0	0.0	0.0	0.0	0.0	1.9	0.0	0.0	0.0	0.0	100.0
1	0.0	86.2	13.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
2	0.0	90.0	0.0	5.0	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
3	7.7	92.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
4	0.0	85.7	10.7	0.0	0.0	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
5	0.0	82.4	7.7	0.0	1.1	6.6	0.0	1.1	1.1	0.0	0.0	0.0	0.0	100.0
6	0.2	88.0	10.9	0.0	0.7	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
7	0.0	88.7	8.7	0.0	1.7	0.8	0.0	0.1	0.0	0.0	0.0	0.0	0.0	100.0
8	0.0	85.2	11.7	0.0	1.5	0.8	0.0	0.6	0.2	0.0	0.0	0.0	0.0	100.0
9	0.3	78.2	12.1	0.0	4.2	3.0	0.0	0.9	1.2	0.0	0.0	0.0	0.0	100.0
10	0.0	75.2	11.1	0.0	4.6	8.4	0.0	0.4	0.4	0.0	0.0	0.0	0.0	100.0
11	0.0	78.1	12.8	0.0	4.3	4.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	100.0
12	0.0	82.4	8.7	0.0	3.8	3.8	0.0	1.4	0.0	0.0	0.0	0.0	0.0	100.0
13	0.0	82.7	9.9	0.0	3.5	2.6	0.0	0.6	0.6	0.0	0.0	0.0	0.0	100.0
14	0.3	84.4	10.4	0.3	2.7	0.8	0.0	0.8	0.3	0.0	0.0	0.0	0.0	100.0
15	0.0	85.2	11.7	0.0	2.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
16	0.0	86.0	11.6	0.0	1.5	0.4	0.0	0.3	0.1	0.0	0.0	0.0	0.0	100.0
17	0.2	89.8	9.0	0.0	0.5	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	100.0
18	0.0	90.6	8.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0

***** DISTRIBUTION OF HOURLY VOLUMES FROM FHWA VEHICLE CLASS DATA *****

Functional Class: URBAN COLLECTOR
AND Day of Week: WEEKEND

	Motorcyc-les	Passenger Cars	2-axle 4-tire S-Units	Buses	2-axle 6-tire S-Units	3-axle S-Units	4+axle S-Units	3/4-axle S-Trailers	5-axle S-Trailers	6+axle S-Trailers	4/5-axle M-Trailers	6-axle M-Trailers	7+axle M-Trailers	Total
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
HOUR														
19	0.3	85.0	13.8	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
20	0.0	87.5	12.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	100.0
21	0.4	90.6	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
22	0.7	90.8	8.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
23	0.0	91.4	8.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
TOTAL	0.1	85.8	10.4	0.0	1.8	1.3	0.0	0.3	0.2	0.0	0.0	0.0	0.0	100.0

Functional Class: URBAN INTERSTATE

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
0	4722.0	46942.0	16.0	143.0	86.0	1151.0	290.0	10648.0	5114.0	58884.0
1	2822.0	26647.0	3.0	128.0	59.0	1016.0	248.0	9880.0	3132.0	37671.0
2	2042.0	20067.0	4.0	104.0	80.0	1015.0	232.0	9350.0	2358.0	30536.0
3	1435.0	19047.0	9.0	118.0	64.0	1137.0	214.0	9591.0	1722.0	29893.0
4	1926.0	30459.0	7.0	168.0	98.0	1808.0	230.0	10465.0	2261.0	42900.0
5	3962.0	93348.0	16.0	254.0	121.0	3406.0	282.0	12348.0	4381.0	109356.0
6	6456.0	235760.0	7.0	425.0	140.0	6407.0	346.0	13534.0	6949.0	256126.0
7	8603.0	337847.0	17.0	532.0	237.0	8492.0	285.0	14883.0	9142.0	361754.0
8	11473.0	272697.0	33.0	579.0	205.0	10965.0	391.0	18353.0	12102.0	302594.0
9	14642.0	224271.0	38.0	536.0	228.0	11440.0	444.0	20994.0	15352.0	257241.0
10	15924.0	221173.0	23.0	506.0	228.0	11889.0	421.0	22375.0	16596.0	255943.0
11	19600.0	234527.0	22.0	519.0	252.0	11848.0	488.0	22764.0	20362.0	269658.0
12	20111.0	245012.0	15.0	462.0	270.0	11378.0	523.0	22388.0	20919.0	279240.0
13	20095.0	251455.0	37.0	518.0	257.0	12084.0	546.0	21971.0	20935.0	286028.0
14	19037.0	271041.0	21.0	600.0	256.0	12438.0	491.0	21574.0	19805.0	305653.0

(CONTINUED)

Includes only stations and dates with 24 hours of data

Functional Class: URBAN INTERSTATE

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
15	20346.0	318929.0	41.0	624.0	245.0	11777.0	555.0	20152.0	21187.0	351482.0
16	20380.0	372027.0	39.0	730.0	231.0	10185.0	519.0	18405.0	21169.0	401347.0
17	19594.0	387392.0	42.0	603.0	209.0	8067.0	476.0	16980.0	20321.0	413042.0
18	17134.0	291585.0	28.0	413.0	184.0	5921.0	470.0	15741.0	17816.0	313660.0
19	14934.0	213058.0	31.0	335.0	150.0	3876.0	398.0	14268.0	15513.0	231537.0
20	12880.0	169504.0	33.0	271.0	129.0	2870.0	390.0	13188.0	13432.0	185833.0
21	10982.0	151654.0	24.0	224.0	93.0	2239.0	394.0	12558.0	11493.0	166675.0
22	8688.0	118666.0	14.0	201.0	78.0	1759.0	350.0	12070.0	9130.0	132696.0
23	5609.0	83184.0	26.0	187.0	105.0	1509.0	339.0	11281.0	6079.0	96161.0

Includes only stations and dates with 24 hours of data

Functional Class: URBAN FREEWAY

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
0	9335.0	71352.0	37.0	182.0	301.0	4558.0	930.0	8171.0	10603.0	84263.0
1	6013.0	82503.0	47.0	391.0	260.0	4147.0	806.0	7274.0	7126.0	94315.0
2	4219.0	74719.0	43.0	666.0	243.0	4520.0	616.0	11067.0	5121.0	90972.0
3	2986.0	61428.0	16.0	536.0	161.0	2379.0	668.0	12315.0	3831.0	76658.0
4	3185.0	79579.0	32.0	690.0	226.0	6491.0	875.0	17582.0	4318.0	104342.0
5	8598.0	175912.0	54.0	994.0	797.0	16667.0	1373.0	20257.0	10822.0	213830.0
6	22580.0	204534.0	110.0	1740.0	1346.0	10326.0	2014.0	17025.0	26050.0	233625.0
7	34581.0	261875.0	190.0	1127.0	1518.0	10592.0	2232.0	14213.0	38521.0	287807.0
8	34378.0	187216.0	212.0	1271.0	1631.0	10198.0	2441.0	11920.0	38662.0	210605.0
9	37387.0	143396.0	190.0	603.0	1727.0	11196.0	2595.0	13930.0	41899.0	169125.0
10	41734.0	166580.0	174.0	585.0	1760.0	8225.0	2462.0	13280.0	46130.0	188670.0
11	48227.0	150020.0	125.0	534.0	1854.0	7948.0	2589.0	12132.0	52795.0	170634.0
12	51317.0	158329.0	118.0	491.0	1971.0	7792.0	2480.0	11713.0	55886.0	178325.0
13	48886.0	157056.0	155.0	603.0	1908.0	7971.0	2340.0	11436.0	53289.0	177066.0
14	52009.0	168146.0	145.0	713.0	2014.0	8496.0	2313.0	11251.0	56481.0	188606.0

(CONTINUED)

Includes only stations and dates with 24 hours of data

Functional Class: URBAN FREEWAY

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
15	54699.0	201906.0	146.0	736.0	2090.0	9729.0	2197.0	10322.0	59132.0	222693.0
16	63100.0	234803.0	204.0	775.0	1884.0	7694.0	2134.0	8707.0	67322.0	251979.0
17	61283.0	254569.0	170.0	537.0	1438.0	5790.0	1896.0	7712.0	64787.0	268608.0
18	49675.0	184642.0	128.0	364.0	1221.0	3877.0	1454.0	6293.0	52478.0	195176.0
19	38943.0	131150.0	195.0	359.0	1040.0	2924.0	1335.0	5554.0	41513.0	139987.0
20	27353.0	98119.0	100.0	196.0	720.0	1953.0	1109.0	4832.0	29282.0	105100.0
21	23355.0	86784.0	47.0	128.0	533.0	1556.0	912.0	4371.0	24847.0	92839.0
22	18778.0	68049.0	62.0	145.0	404.0	1256.0	899.0	4234.0	20143.0	73684.0
23	15257.0	48930.0	68.0	150.0	406.0	1161.0	901.0	4096.0	16632.0	54337.0

Includes only stations and dates with 24 hours of data

Distribution of Hourly Volumes 11:33 Thursday, August 4, 1994 223

Functional Class: URBAN PRINC. ARTERIAL

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
0	2173.0	17959.0	4.0	40.0	11.0	281.0	55.0	1289.0	2243.0	19569.0
1	1436.0	10192.0	2.0	29.0	9.0	222.0	21.0	1202.0	1468.0	11645.0
2	883.0	6608.0	3.0	14.0	17.0	215.0	36.0	1119.0	939.0	7956.0
3	668.0	5284.0	3.0	21.0	11.0	261.0	43.0	1195.0	725.0	6761.0
4	719.0	8522.0	5.0	39.0	16.0	481.0	51.0	1435.0	791.0	10477.0
5	1883.0	27632.0	6.0	86.0	42.0	1004.0	65.0	1718.0	1996.0	30440.0
6	5408.0	84728.0	8.0	254.0	137.0	2282.0	86.0	2412.0	5639.0	89676.0
7	8250.0	140308.0	7.0	498.0	221.0	3745.0	112.0	3021.0	8590.0	147572.0
8	7866.0	113710.0	13.0	374.0	281.0	4758.0	158.0	3876.0	8318.0	122718.0
9	8168.0	100251.0	12.0	263.0	253.0	4811.0	149.0	4031.0	8582.0	109356.0
10	8841.0	101366.0	17.0	257.0	259.0	4722.0	198.0	4449.0	9315.0	110794.0
11	9232.0	112382.0	14.0	300.0	246.0	5038.0	141.0	4334.0	9633.0	122054.0
12	10282.0	125220.0	14.0	290.0	222.0	4562.0	166.0	4060.0	10684.0	134132.0
13	10446.0	121444.0	12.0	353.0	248.0	4721.0	179.0	4151.0	10885.0	130669.0
14	11404.0	125437.0	17.0	501.0	279.0	5095.0	174.0	4128.0	11874.0	135161.0

(CONTINUED)

Includes only stations and dates with 24 hours of data

Functional Class: URBAN PRINC. ARTERIAL

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
15	12417.0	144897.0	18.0	591.0	262.0	4985.0	145.0	3820.0	12842.0	154293.0
16	13504.0	165707.0	15.0	465.0	209.0	4052.0	132.0	3557.0	13860.0	173781.0
17	13655.0	176632.0	11.0	404.0	167.0	3409.0	119.0	3129.0	13952.0	183574.0
18	11006.0	135726.0	12.0	289.0	118.0	2115.0	110.0	2488.0	11246.0	140618.0
19	8816.0	101448.0	7.0	168.0	77.0	1419.0	87.0	2146.0	8987.0	105181.0
20	7205.0	84801.0	7.0	132.0	38.0	1089.0	84.0	1927.0	7334.0	87949.0
21	5727.0	68880.0	6.0	114.0	42.0	776.0	81.0	1780.0	5856.0	71550.0
22	4369.0	48596.0	1.0	76.0	44.0	596.0	53.0	1505.0	4467.0	50773.0
23	3103.0	31567.0	3.0	46.0	25.0	411.0	48.0	1360.0	3179.0	33384.0

Includes only stations and dates with 24 hours of data

Functional Class: URBAN MINOR ARTERIAL

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
0	325.0	3850.0	0.0	4.0	1.0	54.0	7.0	54.0	333.0	3962.0
1	220.0	2323.0	0.0	1.0	1.0	50.0	1.0	46.0	222.0	2420.0
2	148.0	1541.0	1.0	1.0	3.0	39.0	4.0	43.0	156.0	1624.0
3	92.0	1443.0	1.0	3.0	3.0	61.0	6.0	48.0	102.0	1555.0
4	71.0	1795.0	0.0	5.0	5.0	65.0	8.0	87.0	84.0	1952.0
5	174.0	4675.0	2.0	7.0	4.0	137.0	2.0	71.0	182.0	4890.0
6	486.0	14639.0	0.0	33.0	33.0	358.0	14.0	145.0	533.0	15175.0
7	683.0	27472.0	0.0	59.0	42.0	666.0	13.0	238.0	738.0	28435.0
8	548.0	22367.0	1.0	51.0	42.0	873.0	27.0	327.0	618.0	23618.0
9	641.0	19940.0	2.0	42.0	46.0	863.0	28.0	339.0	717.0	21184.0
10	893.0	20444.0	4.0	42.0	39.0	889.0	27.0	363.0	963.0	21738.0
11	954.0	24285.0	5.0	36.0	37.0	881.0	28.0	332.0	1024.0	25534.0
12	1102.0	26281.0	4.0	43.0	16.0	773.0	29.0	315.0	1151.0	27412.0
13	1049.0	24778.0	4.0	43.0	18.0	953.0	12.0	322.0	1083.0	26096.0
14	1158.0	24722.0	12.0	65.0	28.0	872.0	10.0	339.0	1208.0	25998.0

(CONTINUED)

Includes only stations and dates with 24 hours of data

Functional Class: URBAN MINOR ARTERIAL

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
15	1405.0	30215.0	9.0	65.0	57.0	981.0	27.0	341.0	1498.0	31602.0
16	1291.0	36061.0	4.0	58.0	27.0	871.0	27.0	221.0	1349.0	37211.0
17	1219.0	36492.0	4.0	33.0	32.0	697.0	13.0	231.0	1268.0	37453.0
18	1045.0	27500.0	4.0	23.0	19.0	392.0	15.0	163.0	1083.0	28078.0
19	848.0	20788.0	2.0	14.0	10.0	281.0	13.0	131.0	873.0	21214.0
20	920.0	17859.0	3.0	9.0	7.0	205.0	10.0	112.0	940.0	18185.0
21	712.0	15073.0	5.0	7.0	7.0	146.0	9.0	70.0	733.0	15296.0
22	515.0	10051.0	1.0	5.0	6.0	155.0	9.0	61.0	531.0	10272.0
23	365.0	6722.0	0.0	3.0	3.0	84.0	6.0	53.0	374.0	6862.0

Includes only stations and dates with 24 hours of data

Functional Class: URBAN COLLECTOR

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
0	51.0	857.0	0.0	3.0	0.0	26.0	1.0	22.0	52.0	908.0
1	29.0	446.0	0.0	0.0	0.0	24.0	0.0	25.0	29.0	495.0
2	18.0	362.0	1.0	2.0	1.0	9.0	0.0	23.0	20.0	396.0
3	13.0	234.0	0.0	6.0	0.0	15.0	0.0	33.0	13.0	288.0
4	27.0	249.0	0.0	3.0	1.0	39.0	0.0	23.0	28.0	314.0
5	82.0	901.0	0.0	5.0	7.0	36.0	2.0	37.0	91.0	979.0
6	455.0	3838.0	0.0	16.0	4.0	97.0	0.0	74.0	459.0	4025.0
7	748.0	8141.0	0.0	16.0	19.0	226.0	1.0	168.0	768.0	8551.0
8	464.0	7405.0	0.0	25.0	11.0	299.0	4.0	243.0	479.0	7972.0
9	299.0	6282.0	0.0	31.0	24.0	276.0	7.0	271.0	330.0	6860.0
10	226.0	6739.0	0.0	20.0	34.0	248.0	2.0	336.0	262.0	7343.0
11	320.0	7602.0	0.0	15.0	31.0	226.0	1.0	278.0	352.0	8121.0
12	315.0	9052.0	0.0	17.0	26.0	208.0	5.0	184.0	346.0	9461.0
13	317.0	8441.0	0.0	17.0	21.0	266.0	4.0	216.0	342.0	8940.0
14	347.0	7883.0	1.0	9.0	13.0	289.0	4.0	227.0	365.0	8408.0

(CONTINUED)

Includes only stations and dates with 24 hours of data

Functional Class: URBAN COLLECTOR

	Vehicle Class								Total	
	Passenger Vehicles		Buses		Single Unit Trucks		Combination Trucks			
	Day of Week:		Day of Week:		Day of Week:		Day of Week:		Day of Week:	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
	---	---	---	---	---	---	---	---	---	---
	Count	Count	Count	Count	Count	Count	Count	Count	Count	Count
HOUR										
15	274.0	8554.0	0.0	12.0	9.0	276.0	0.0	219.0	283.0	9061.0
16	671.0	9656.0	0.0	21.0	13.0	333.0	3.0	130.0	687.0	10140.0
17	858.0	11199.0	0.0	11.0	6.0	306.0	2.0	142.0	866.0	11658.0
18	503.0	7843.0	0.0	7.0	5.0	160.0	0.0	84.0	508.0	8094.0
19	351.0	5589.0	0.0	9.0	3.0	107.0	0.0	66.0	354.0	5771.0
20	215.0	4621.0	0.0	5.0	0.0	170.0	1.0	37.0	216.0	4833.0
21	223.0	3771.0	0.0	4.0	0.0	90.0	0.0	34.0	223.0	3899.0
22	142.0	2971.0	0.0	2.0	0.0	56.0	0.0	17.0	142.0	3046.0
23	105.0	1895.0	0.0	3.0	0.0	40.0	0.0	29.0	105.0	1967.0

Includes only stations and dates with 24 hours of data

APPENDIX C: HOURLY ARRIVAL TIMES

The following graphs show the distribution of pickup and delivery vehicle arrival times for various classes of retail outlets, services and industry. Codes found on the graphs include:

Code	Definition
ARRHR	hour of arrival
6	6:00 a.m.-7:00 a.m.
7	7:00 a.m.-8:00 a.m.
8	8:00 a.m.-9:00 a.m.
9	9:00 a.m.-10:00 a.m.
10	10:00 a.m.-11:00 a.m.
11	11:00 a.m.-noon
12	Noon-1:00 p.m.
13	1:00 p.m.-2:00 p.m.
14	2:00 p.m.-3:00 p.m.
15	3:00 p.m.-4:00 p.m.
16	4:00 p.m.-5:00 p.m.

Source: Habib, Philip A. *Curbside Pickup and Delivery Operations and Arterial Traffic Impacts*, Report No. FHWA/RD-80/020. Office of Research and Development, Federal Highway Administration, Washington, D.C., February 1981, pp. 89-97, 100-101, 103-114.

ARRIVAL TIME FREQUENCIES

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

\RRHR

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

VALID CASES     206       MISSING CASES      0
```

BANK

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES   67   MISSING CASES   0

BAR/TAVERN

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES 294 MISSING CASES 0

CLOTHING

```
ARRIVAL TIME FREQUENCIES

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

ARRHR


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

VALID CASES      911      MISSING CASES      0
```

DEPARTMENT STORE

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES      22      MISSING CASES      0
```

DRUG STORE/HEALTH & BEAUTY AIDS

ARRIVAL TIME FREQUENCIES

36/15/79   FILE - NONAME   - CREATED 06/15/79

ARRHR

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

VALID CASES   162   MISSING CASES   0

ELECTRONIC & CAMERA

```
ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES      17      MISSING CASES      0
```

ENTERTAINMENT

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES      22      MISSING CASES     0
```

FABRICS

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

FLOWERS

```
ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES      89      MISSING CASES      0
```

FURNITURE

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES   30   MISSING CASES   0

GARAGE/SERVICE STATION

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES   114   MISSING CASES   0

JEWELRY

```
ARRIVAL TIME FREQUENCIES

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

ARRHR


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

LIGHT INDUSTRIAL

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES   139   MISSING CASES   0

LIQUOR STORE

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES     274      MISSING CASES     0
```

MISCELLANEOUS (RETAIL)

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES   15   MISSING CASES   0

NOVELTIES

```
ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES     445      MISSING CASES     0
```

RESIDENTIAL

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

SERVICE

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES   54   MISSING CASES   0

SHOES

```
ARRIVAL TIME FREQUENCIES

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

ARRHR


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

SIDEWALK USE

ARRIVAL TIME FREQUENCIES

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

ARRHR

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

VALID CASES      140      MISSING CASES       0
```

STATIONERY·

ARRIVAL TIME FREQUENCIES

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

ARRHR


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

VALID CASES      54      MISSING CASES      0
```

VACANT (CONSTRUCTION)

```
ARRIVAL TIME FREQUENCIES

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

ARRHR

    CODE
           I
      6    * (       1)
           I
           I
           I
      7    ***** (      14)
           I
           I
           I
      8    ************************ (      91)
           I
           I
           I
      9    ************************ (      90)
           I
           I
           I
     10    **************************** (     109)
           I
           I
           I
     11    *********************** (      88)
           I
           I
           I
     12    ************** (      53)
           I
           I
           I
     13    ********************* (      78)
           I
           I
           I
     14    ******************* (      73)
           I
           I
           I
     15    ************** (      51)
           I
           I
           I
     16    *** (       8)
           I
           I
           I.........I.........I.........I.........I.........I
           0        40        80       120       160       200
           FREQUENCY
```

APPENDIX D: RAILROAD TERMINOLOGY AND DESIGN CRITERIA

Railroad Definitions/Terminology[1]

- Branch Line — a track diverging from a main track on which a variety of traffic from light to heavy is operated.

- Classification Yard — a yard, either flat or humped, in which cars are sorted and arranged for placement into trains destined for other locations or for distribution to local rail customers.

- Hump Yard — a classification yard which uses an artificial knoll over which rolling stock is first pushed and then released to roll, by gravity, into specific tracks. Because of their expense, hump yards are generally located at line junctions and serve regions of the country instead of just local customers.

- Main Track or Mainline - A principle track, other than an auxiliary track, designated by timetable or special instructions, upon which train movements are generally authorized and controlled by the train dispatcher.

- Siding — a track, auxiliary to a main track, usually used to allow trains to pass each other on a single track.

- Spur Track — a generic term used to describe any light duty track that branches off a main track. Generally, the spur track serves the industrial customers of the railroad.

Clearance Limits for Railroads

Railroads have developed standards for clearance around rail lines as well as tonnage ratings to provide a uniform condition for the U.S. rail network. These standards can generally be described by the conditions below, although specific conditions such as curvature or car length can dictate changes in these numbers. For details, see the AREA standards available through their *Manual for Railway Engineering* and the *Portfolio of Trackwork Plans*.

Minimum vertical distance above top of rails	23' 0"
Minimum horizontal distance from center of track	9' 0"
Minimum vertical distance above top of rails for doorway into an industry	18' 0"

[1]Source: Schulte, Christopher F. *The Dictionary of Railway Track Terms*. Simmons-Boardman Books, Inc., Omaha, NE, 1990.

Minimum horizontal distance from center of track for doorway into an industry...	8' 0"
Minimum gross weight of car and lading limits	215,000#
Light gross weight of car and lading limits	240,000#
Normal gross weight of car and lading limits	263,000#
Recommended gross weight of car and lading limits	315,000#

Public Highway Design Requirement

The American Railway Engineering Association (AREA) has developed and maintains a *Manual for Railway Engineering* which serves as the industry standard for engineering and design issues. A number of these directly relate to vehicle movements within an urban area. Among these are the following standards.

9.1.2. If practical, the highway alignment should be such as to intersect the railroad track at or nearly at right angles.

9.M.10 Location of Highways Parallel with Railways

Many instances have occurred in the past where highways have been built parallel with and close to existing lines of railroad, followed later by the construction of spur or connecting tracks crossing the highways at grade to serve industrial plants subsequently established beyond the highways. In other instances, in residential areas, after streets or highways have been built parallel with and close to existing railroad tracks it has been found necessary to construct streets through an area and across the main running tracks of the railroad at grade in order to serve the area more adequately. Many such cases have not only increased the number of grade crossings, but have greatly increased the accident potential.

To minimize hazards and inconveniences to all who might be affected the following principals are recommended for the guidance of railroads, industries, public authorities, and developers of property, in cooperative planning for the future. Adherence to these principals will insure the locating of highways with due regard to expected traffic conditions and with proper attention to safety, and will have the effect of holding to the minimum the construction of public highways close to and parallel with railroad tracks. Reference to highways in these recommendations include streets, avenues, boulevards, rural roads, through or arterial highways, limited access highways, freeways and parkways.

Industrial or Manufacturing Areas in or Near Cities. It is desirable that public highways paralleling railroad main tracks be located far enough away from railroad right-of-way to make possible the industrial development of suitable areas without having service tracks cross public thoroughfares. The minimum distance between railroad tracks and parallel public roads in industrial areas in or near cities should be 500 feet, with 800 feet preferable in the case of small and medium plants and 2000 feet where large plants are to be accommodated.

The number of public highways crossing railroad main tracks, whether over, under, or at grade of such tracks within a given industrial area should be kept to the minimum. To minimize the interference with track connections serving industrial plants, it is desirable that any such crossings of highways and main tracks be located not closer than 1/2 mile apart, measured along the tracks.

Where highways generally parallel with main tracks intersecting highways that cross the main tracks, there should be sufficient distance between the tracks and the highway intersection to permit appropriate roadway connections that will enable highway traffic in all direction to move expeditiously with safety.

Urban Residential or Retail Commercial Areas. It is desirable that street paralleling railroad main tracks in urban residential or retail commercial areas be located at least 200 feet from the normal right-of-way of the railroad.

It is desirable that highway crossings of main tracks, whether over, under, or at grade of these tracks, be located not closer than 1/2 mile apart, measured along the tracks.

Where a community has been built up alongside a mainline of a railroad, and there are numerous streets crossing main tracks, with other streets generally parallel with and close to the tracks, the parallel streets in some instances can be effectively used to serve as outlets for the immediate intersecting streets, thus enabling the abandonment of some of the intermediate grade crossings.

Where a community is to be developed alongside a mainline of a railroad, the number of highway crossings of main track should be kept to the minimum. This can be accomplished by planning the street layout of the area so that a limited number of streets will cross the tracks, while others will end at the parallel streets nearest the railroad right-of-way.

When property adjacent to a railroad is in a transition stage, such as from retail commercial to either light or heavy industrial, planning for changes of highways in the area should include possible future rail service requirements that would be brought about by the changed conditions and the subsequent industrial development. Care should be taken to avoid locating such public highways immediately adjacent to railroad right-of-way or station grounds.

Physically Restricted Areas. Where highways must be located adjacent to railways because of physical restrictions, they shall be so designed and constructed as not to interfere with railway roadbed section. Provision shall also be made for a subgrade cross section of the track or tracks adequate to include space for such items as the following:

- Signals, signs and appurtenances
- Crossing protective devices
- Pole lines and catenary structures
- Underground facilities
- Drainage
- Utilization of off-track equipment

- Track equipment set-offs.

Where the possibility of intrusion occurs, the highway authorities shall install barriers to prevent highway vehicles from getting on the railway right-of-way and obstructing trains or otherwise endangering railway facilities and operations.

In the design of the highway consideration should be given to the disposal of snow so that it will not be deposited in such a location as to interfere with proper operations of railway facilities.

AREA Recommended Mnimum Distances Between Adjecent or Parallel Roadways and Railways.

Urban Residential or Retail Commercial Areas	200 feet
Urban Industrial Areas	500 feet
Areas For Small or Medium Sized Industry	800 feet
Rural or Park-Type Areas	1,000 feet
Areas For Large Industry	2,000 feet

Specialized Railroad Yards

Chapter 14 of the AREA *Manual for Railway Engineering* provides the basic guidelines for the design and construction for specialized railroad yards. These include waterfront facilities, intermodal terminals, automobile loading and unloading facilities, solid and liquid bulk facilities, and general merchandise terminals.

Chapter 18 of the AREA *Manual for Railway Engineering* covers the clearance requirements necessary for railroad operations. These include both overhead and side clearances as well as any additional requirements needed for special use or oversize railroad cars.

Railroad Classification Yards. There are two basic types of classification yards: flat yards and hump yards. As the name suggests, a flat yard has a relatively flat vertical profile, whereas, a hump yard has a "hump" or raised portion of ground which dominates the vertical profile. Generally, flat yards, in which cars are pushed by locomotives, are applicable to small and medium volume operations. Flat yards are generally labor intensive, whereas hump yards are more automated.

In a hump yard, the hump is used to provide gravity switching, thereby reducing the number of locomotives needed for the switching task. The use of a hump also increases the number of railroad freight cards which a train crew can classify. The location of a hump yard does not necessarily indicate a major source of railroad freight business. Instead, because of their high cost and needed freight volume to be economical, they are generally located where several rail lines come together and where cars with different destinations are present. While the size of a yard, like any rail facility, varies dependent upon the amount of use which is receives, hump yards are typically much larger than traditional flat yards. For example, most hump yards cover a range of 250 to 500 acres. The accompanying drawing demonstrate a typical yard layout.

Bulk Transfer/Transload.[2] Bulk reload facilities are generally designed for a small number of commodities to serve a select number of customers. The facilities are designed to meet the specific requirements of the commodity being handled and the amount of material expected to be handled. Railroads are interested in reducing the amount of switching necessary at each facility, so they are generally designed so that only one switching move a day is necessary. Thus a facility will be at least large enough for a full day of loading/unloading, unless the facility is located at a yard facility where existing yard or industrial switching trains can work the facility without any delay or inconvenience.

There does not appear to be any minimum size limitations for such a yard, as long as the revenue from the operation justifies the expense of its development. Facilities have been identified which handle as few as 45,000 tons (less than 500 rail car or 2,000 truck loads) a year or more than 6 million tons (nearly 60,000 rail car or a quarter of a million truck loads) yearly.

Because the expense of new track construction is very high, railroads tend to locate new facilities in underutilized or formerly abandoned yard areas, on spurs where space exists due to the loss of a previous customer, or anywhere else that trackage already exists. This means that many facilities are located based upon existing track locations and not upon convenient road networks or planned vehicle routings.

Railroads can and do transfer materials to all of the other modes, even though the truck and water modes are the most commonly found. Commodity carrying capacity and the similarity in handling capabilities explains this preference.

Typical Railroad Operating Volumes

Typical average train counts for select cities are noted in Table D-1.

[2]Muller, Gerhardt. *Intermodal Freight Transportation*, Third Edition. Eno Transportation Foundation and Intermodal Association of North America, Lansdowne, Virginia, 1995.

Table D-1. Daily Average Train Counts.

City	Population	Number of Lines	Trains per Day
Altonna, PA	51,881	1	50-60
Binghamton, NY	53,008	2	30-40
Cedar rapids, IA	108,780	1	30-40
Cumberland, MD	23,712	2[1]	30
Fresno, CA	755,580	2	40-50
Gorham, IL	<5,000	2[1]	40
Knoxville, TN	585,000	3[1]	60-70
Lacrosse, WI	51,120	2	70
Laramie, WY	26,687	1	60
Little Rock, AR	513,117	2	60
North Plains, NE	22,605	1	80-100
Pittsburgh, PA	2,394,811	3	80
Scranton, PA	638,466	1	10-15
St. Joseph, MO	71,852	1	25-30
Syracuse, NY	742,177	1	60
Texarkana, TX	54,287	3	70
Topeka, KS	119,883	2	90-110

[1]Junction Location

APPENDIX E: ENPLANED FREIGHT AND MAIL BY HUB SIZE AND MSA POPULATION

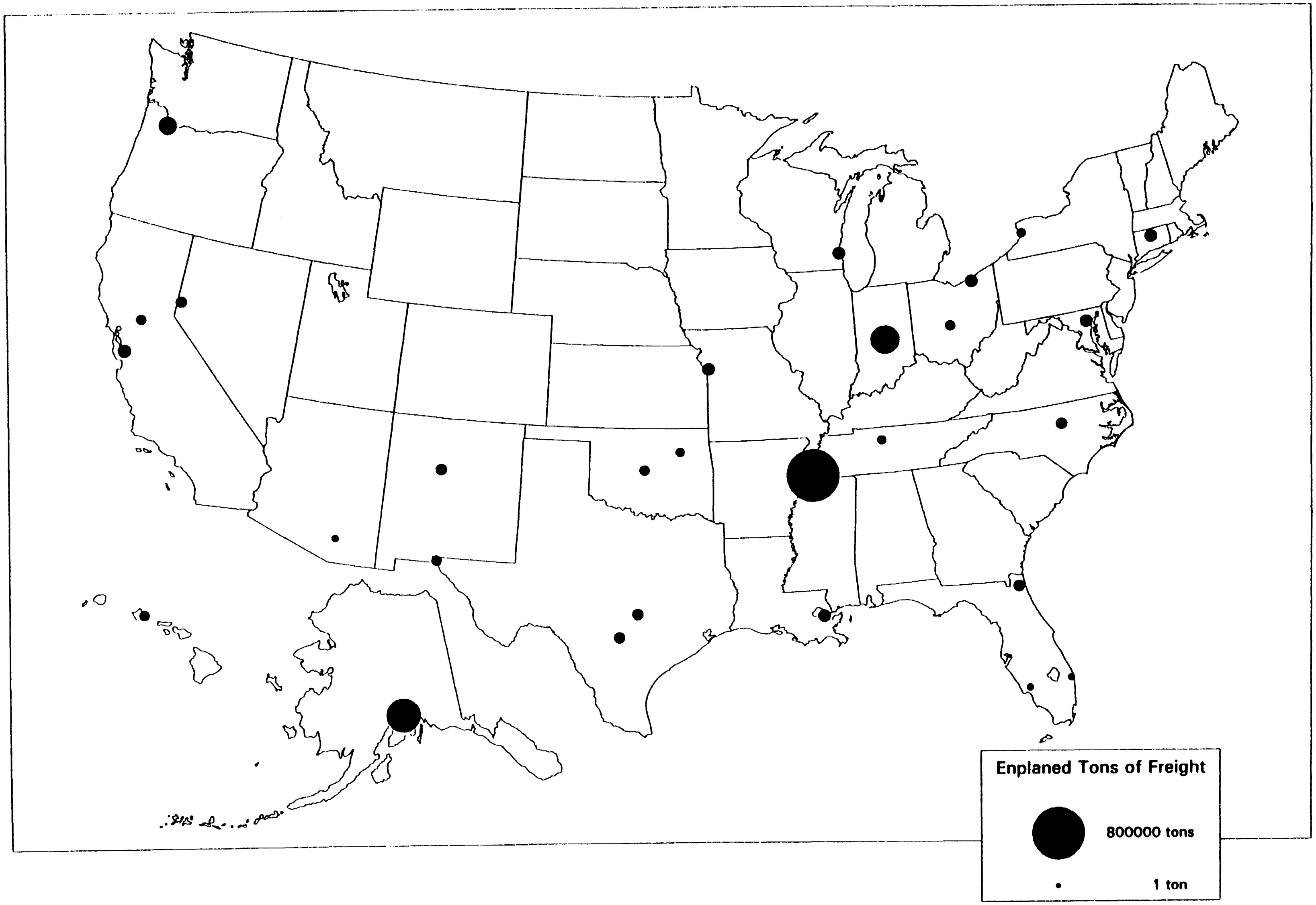
The following figures created by the Federal Aviation Administration compare emplaned freight and mail tonnages by hub size and hub MSA population.

Source: Federal Aviation Administration. *Airport Activity Statistics of Certified Route Carriers, 12 Months Ending December 31, 1993*. U.S. Department of Transportation, Washington, D.C., 1994.

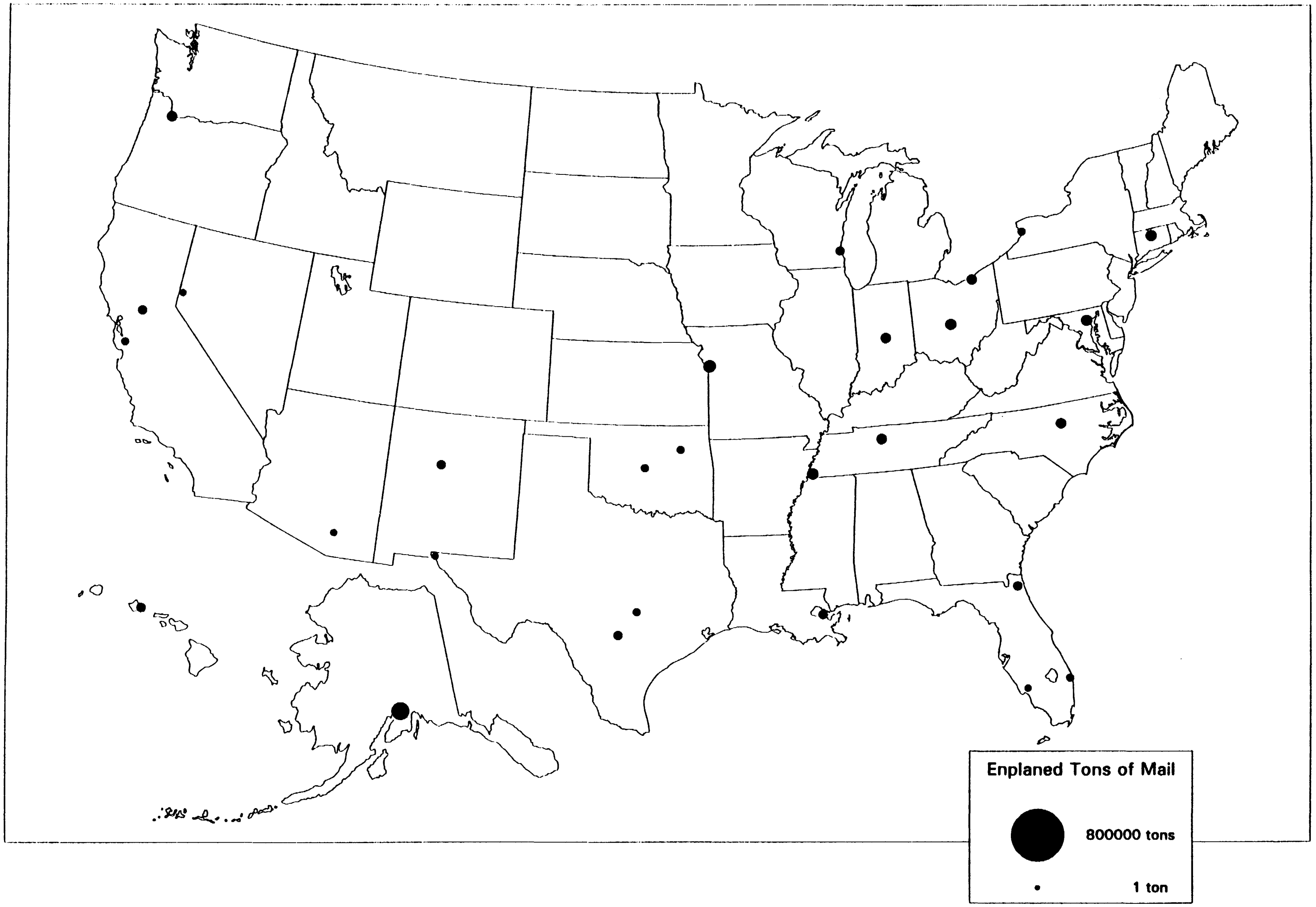
Large Hub-Freight Enplaned by All Carriers

Large Hub-Mail Enplaned by All Carriers

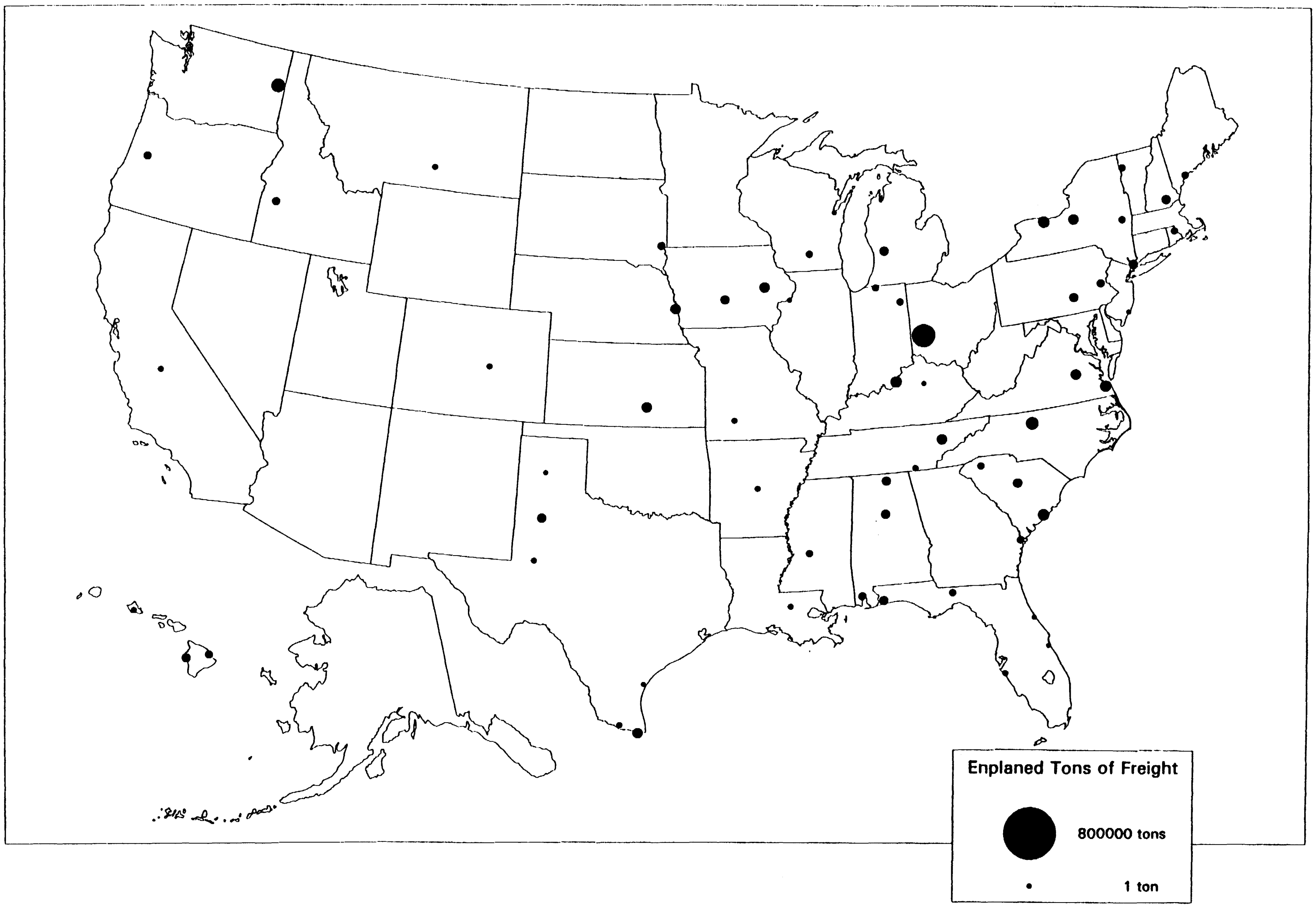
Medium Hubs-Freight Enplaned by All Carriers



Medium Hubs-Mail Enplaned by All Carriers



Small Hubs-Freight Enplaned by All Carriers



Small Hubs-Mail Enplaned by All Carriers

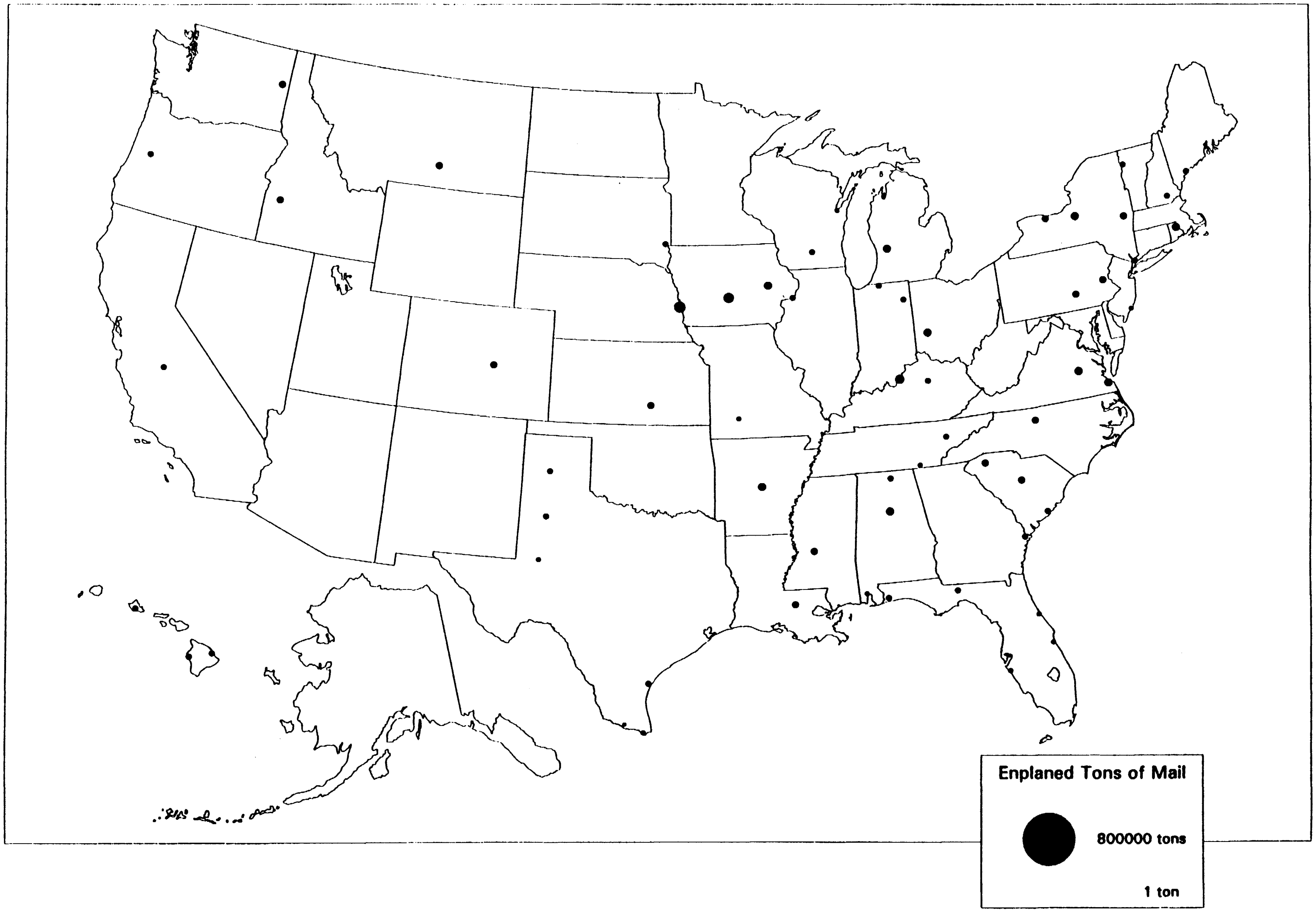


Figure 1
All Hubs-Dedicated Freight Carriers
Enplaned Tons of Freight

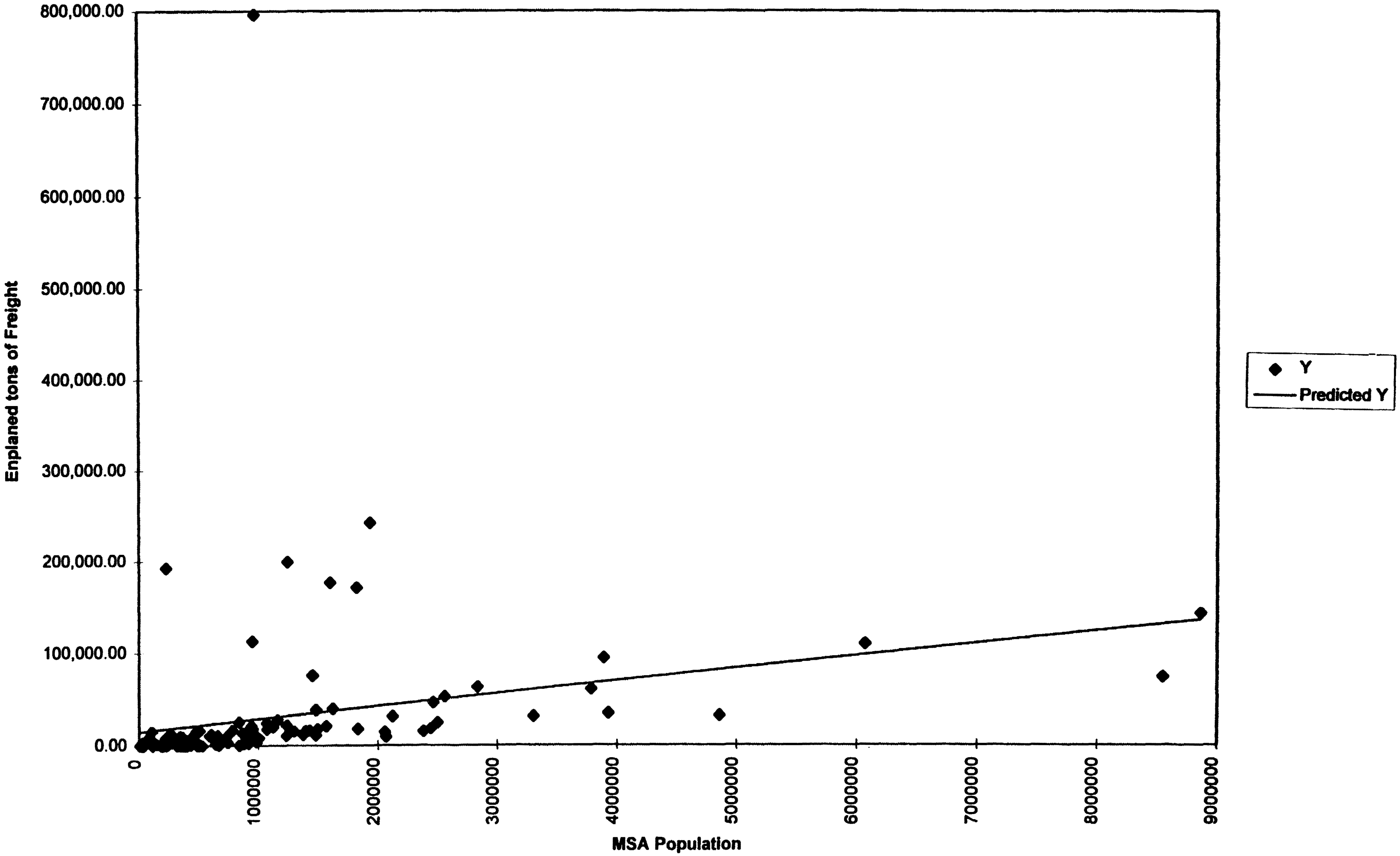


Figure 2
All Hub Airports-Total Freight

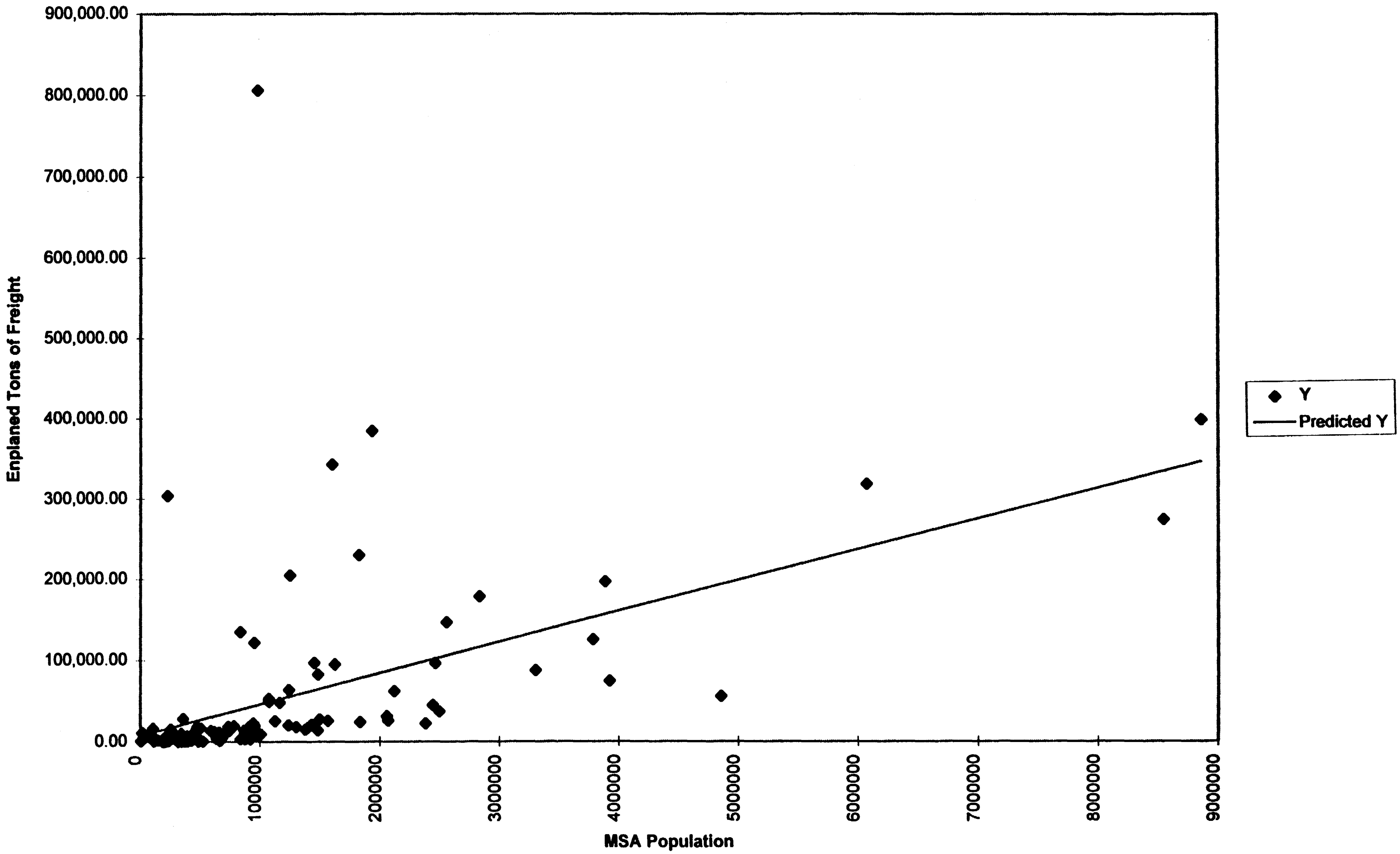
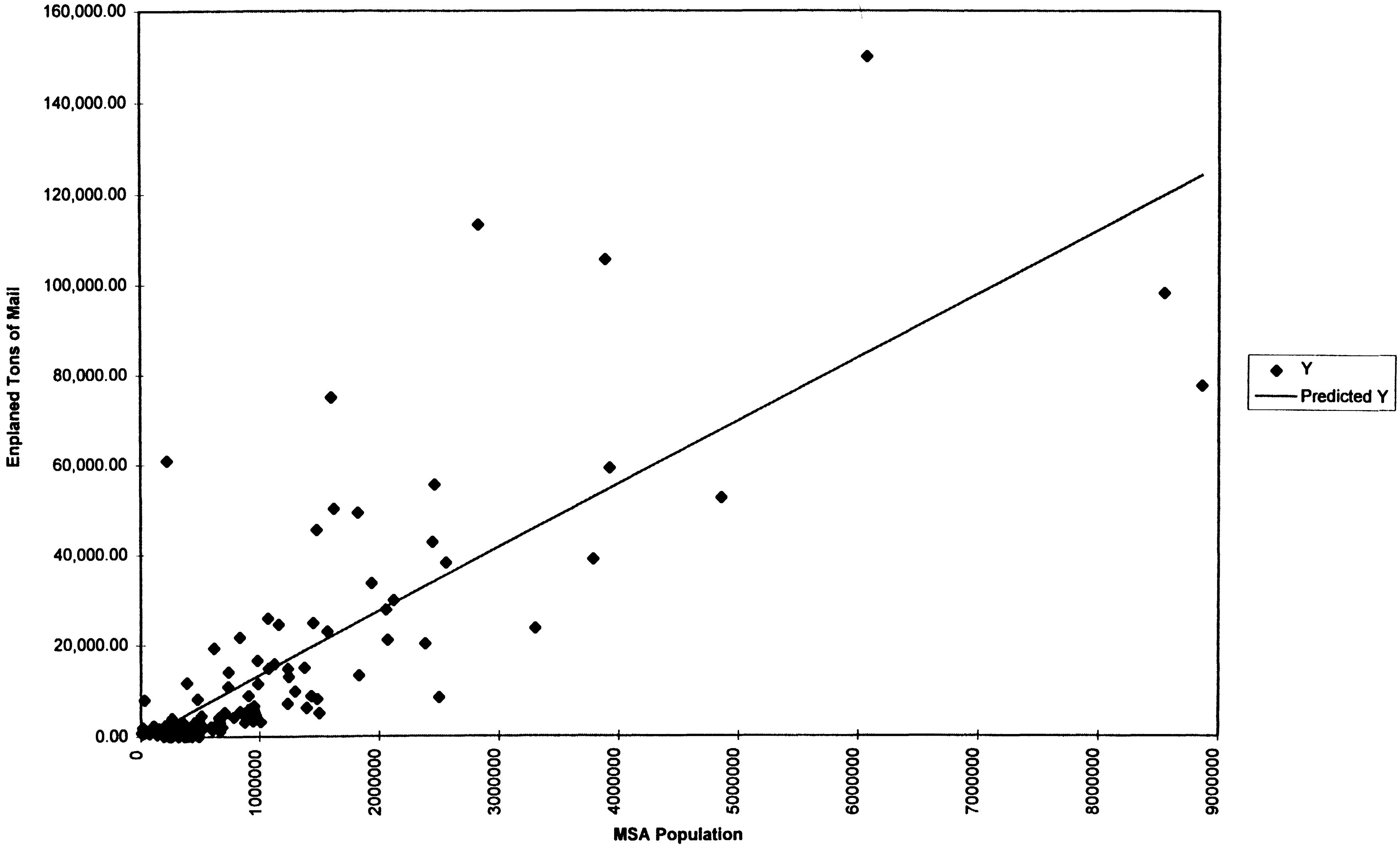


Figure 3
All Hub Airports-Total Mail



396

Figure 4
US Total-Dedicated Freight Carriers
Enplaned tons of freight

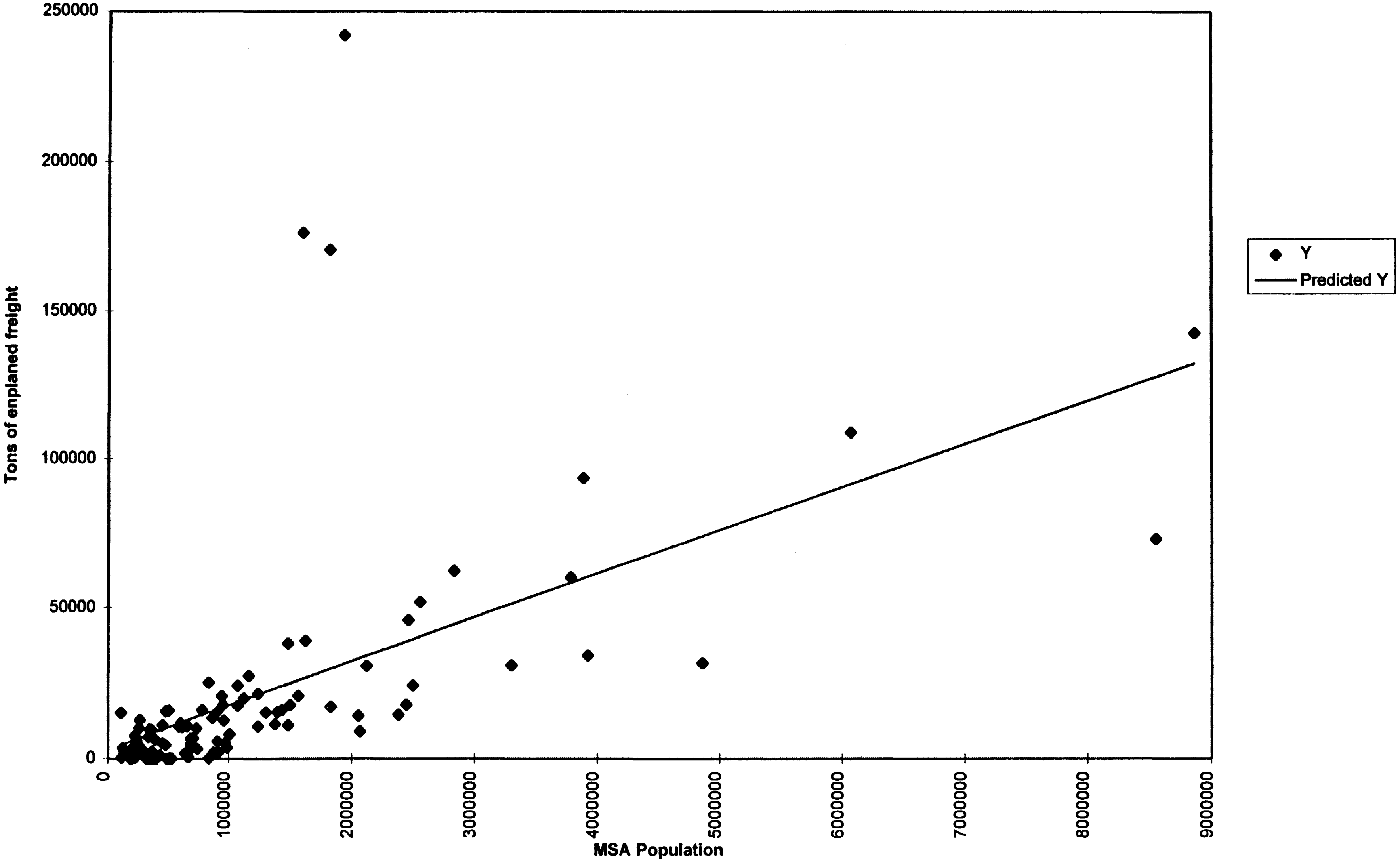


Figure 5
US Airports-Total Freight

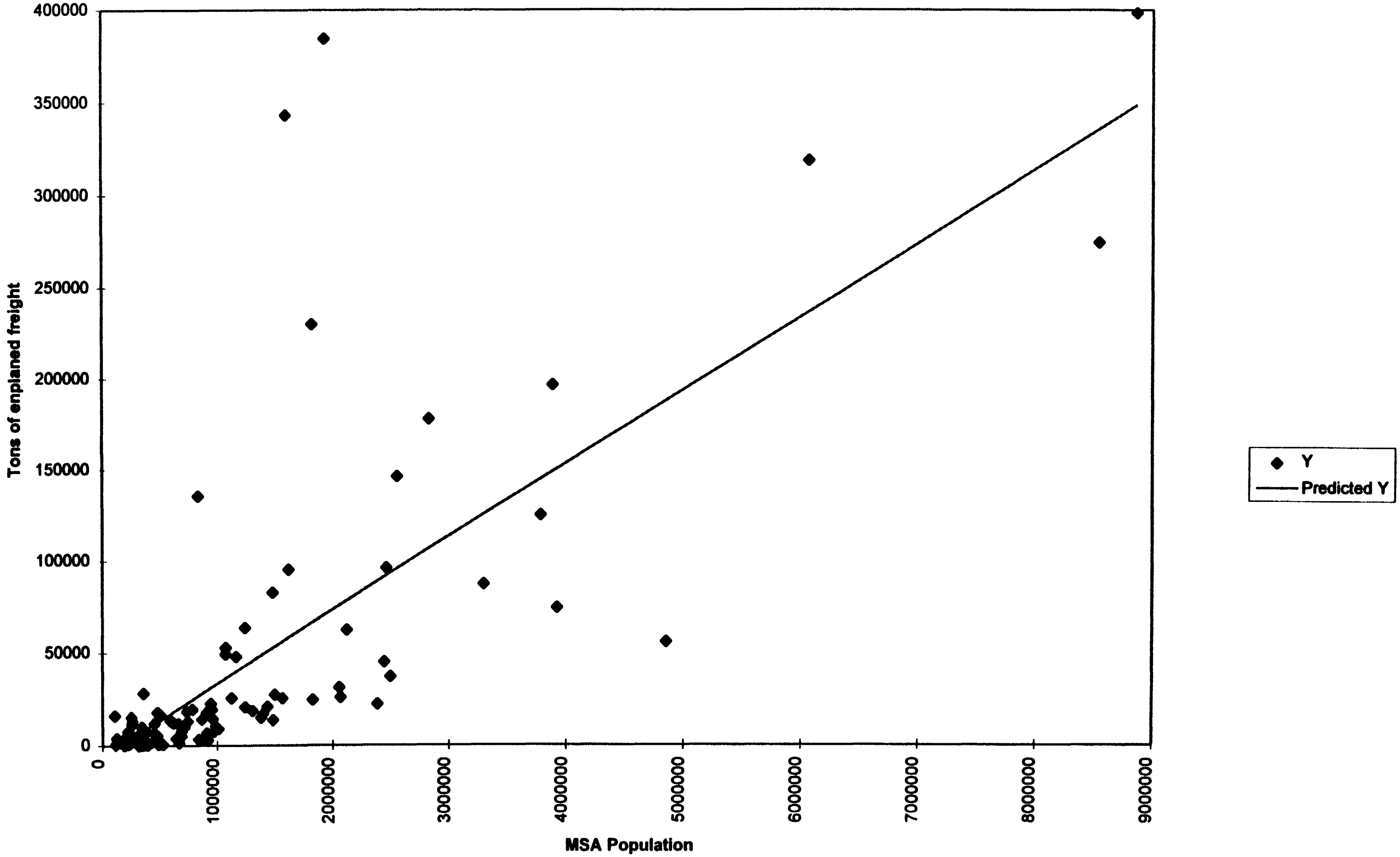


Figure 6
United States-Total Mail

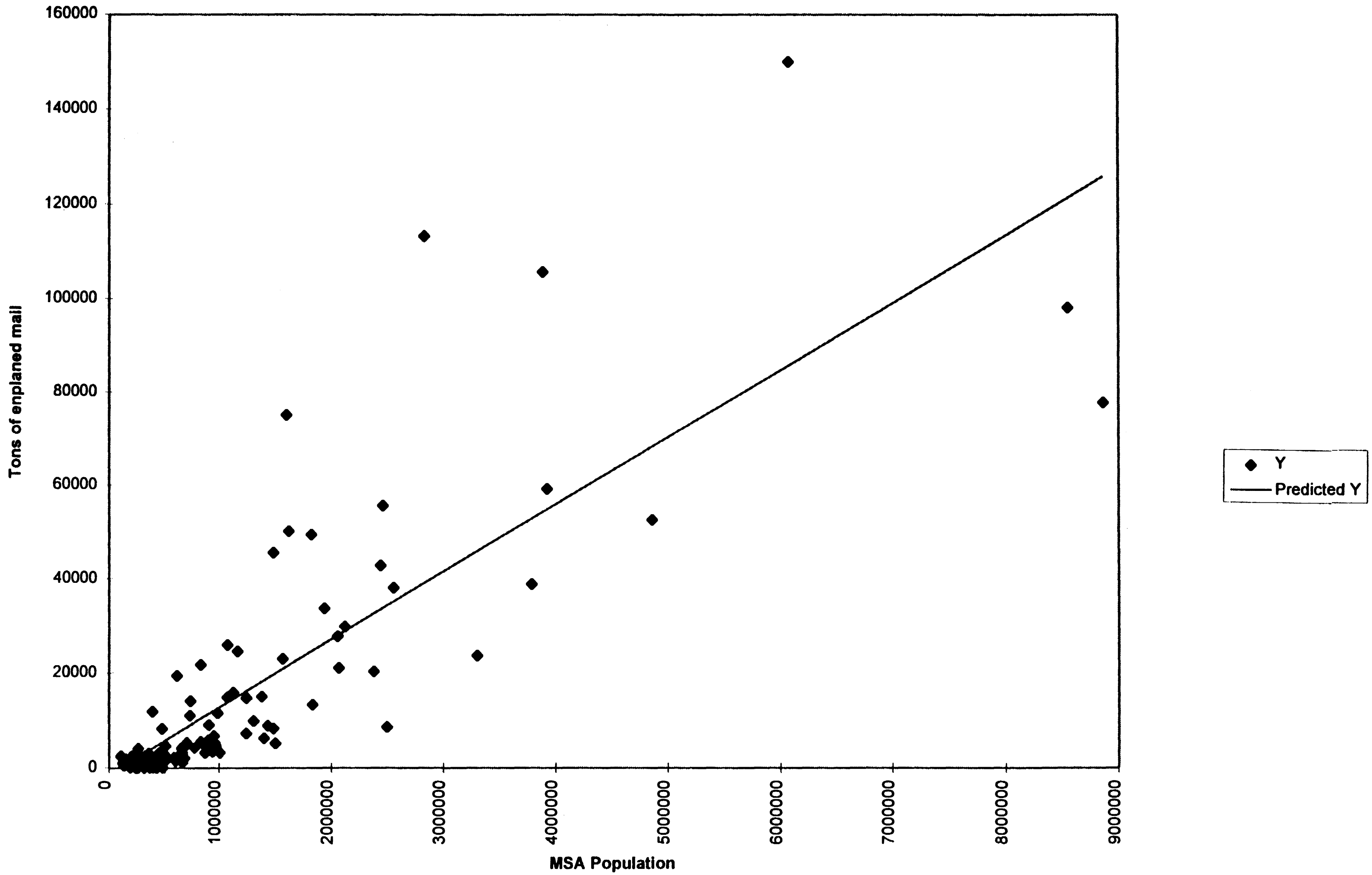


Figure 7
Large Hub-Dedicated Freight Carriers
Enplaned tons of freight

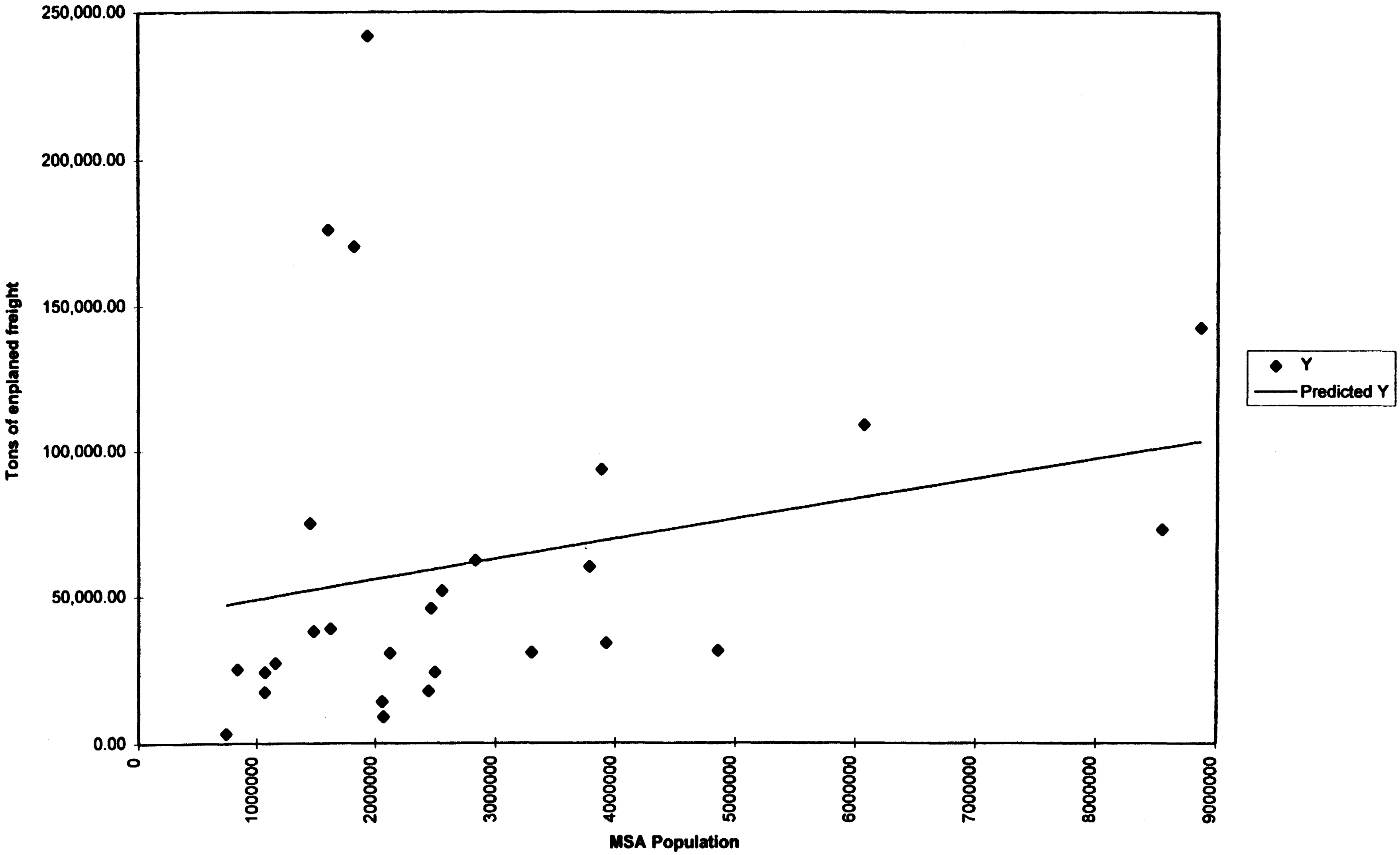


Figure 8
Large Hub-Total Freight

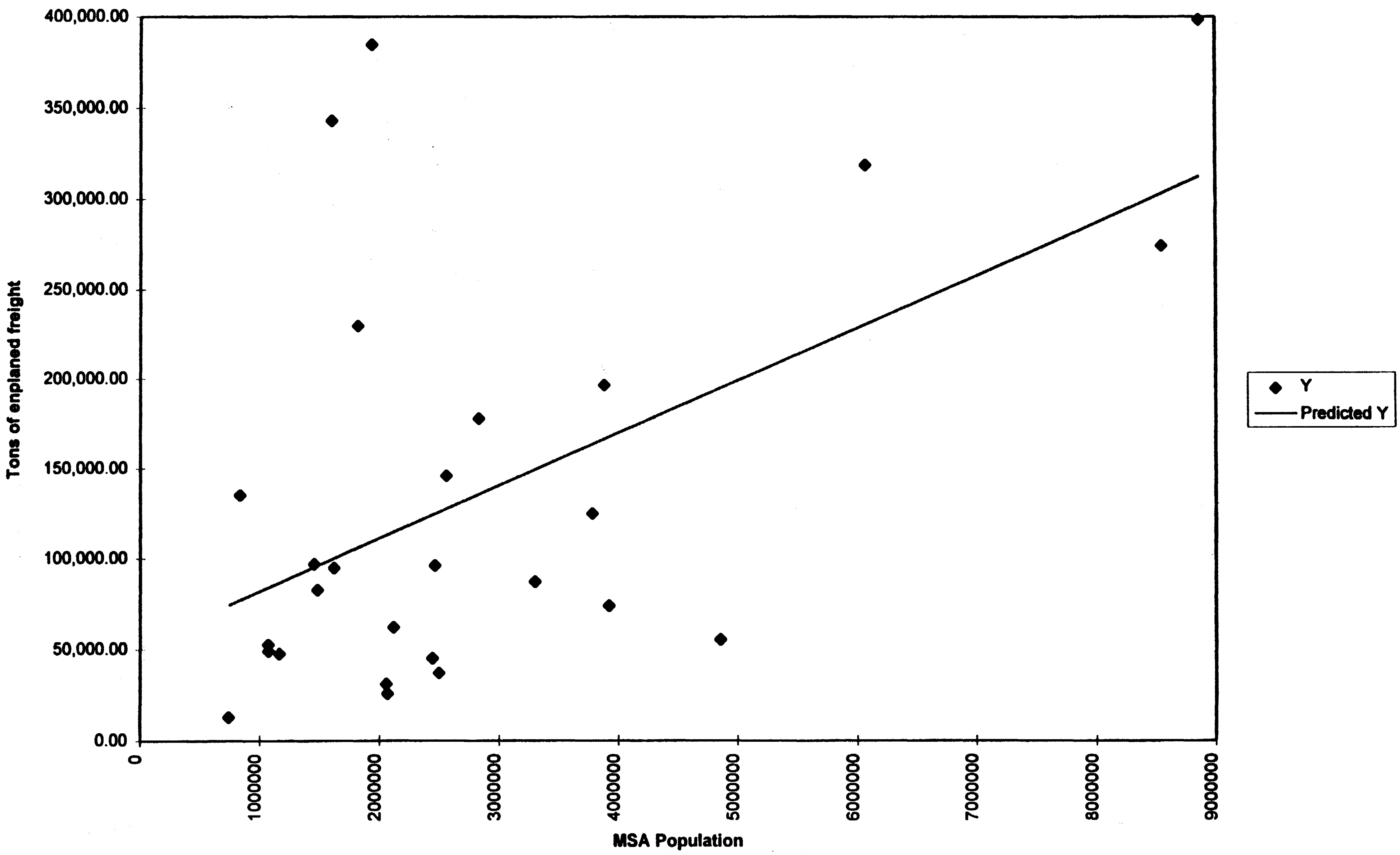


Figure 9
Large Hub-Total Mail

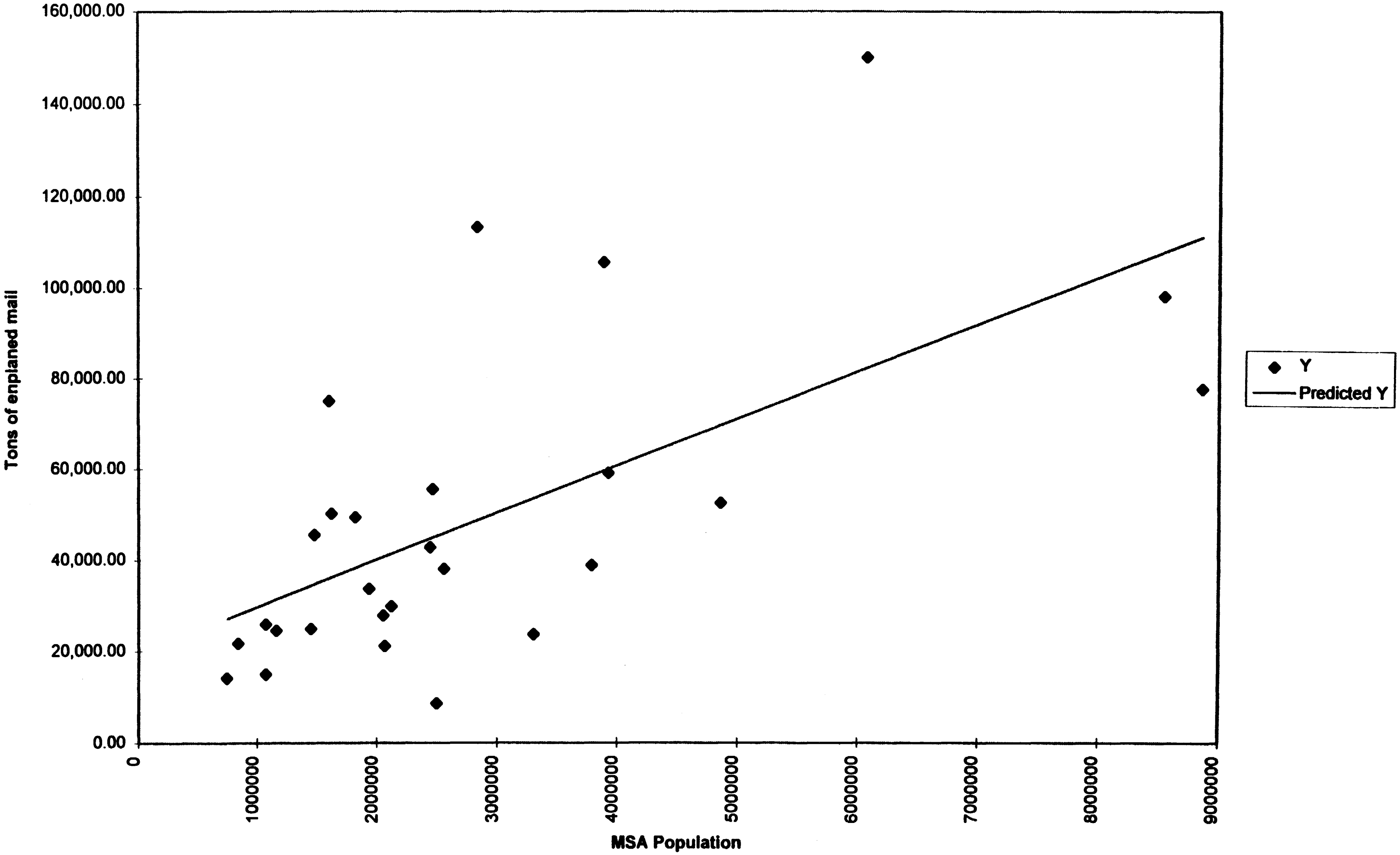


Figure 10
Medium Hub-Dedicated Freight Carriers
Enplaned Tons of Freight

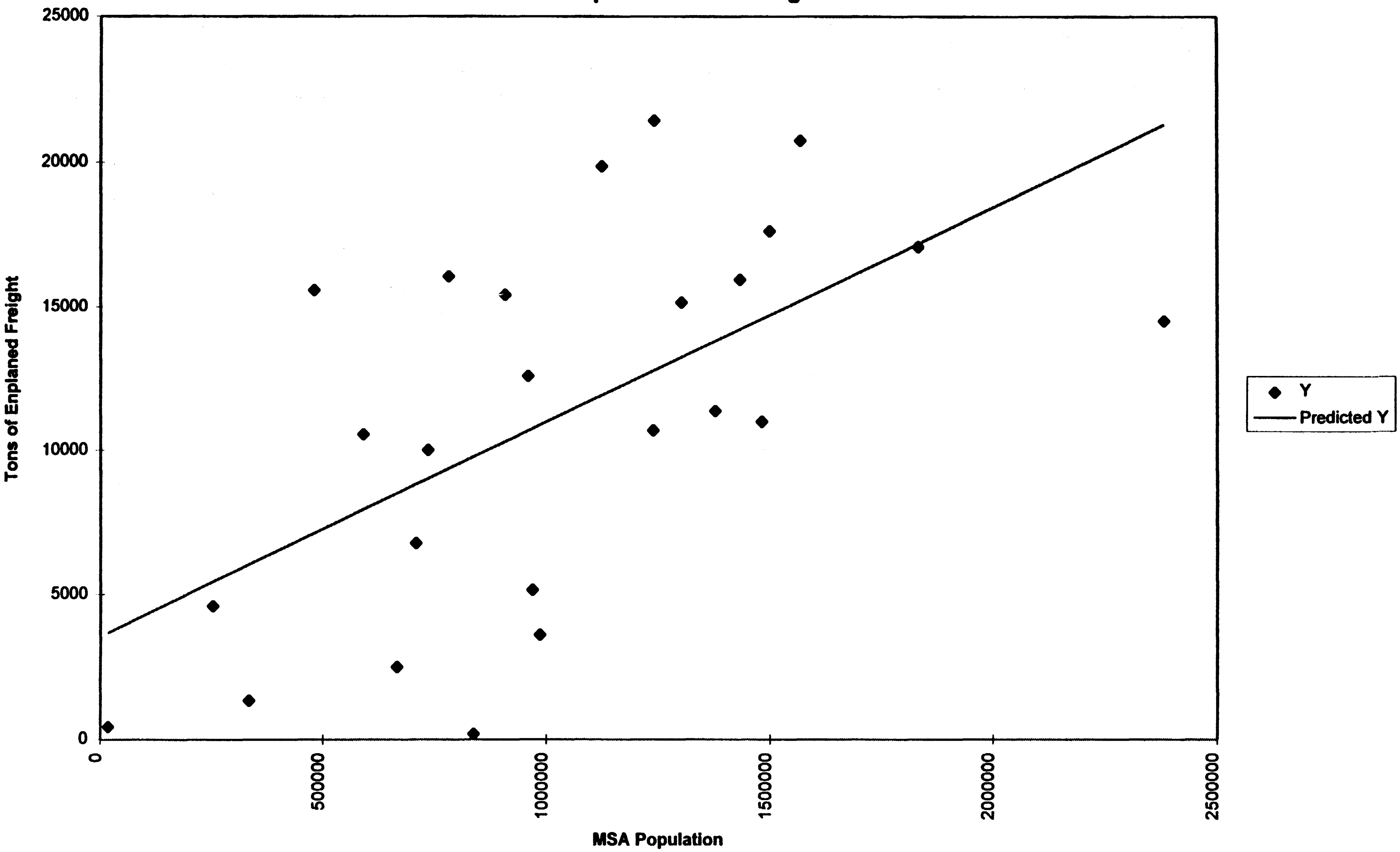


Figure 11
Medium Hub-Total Freight

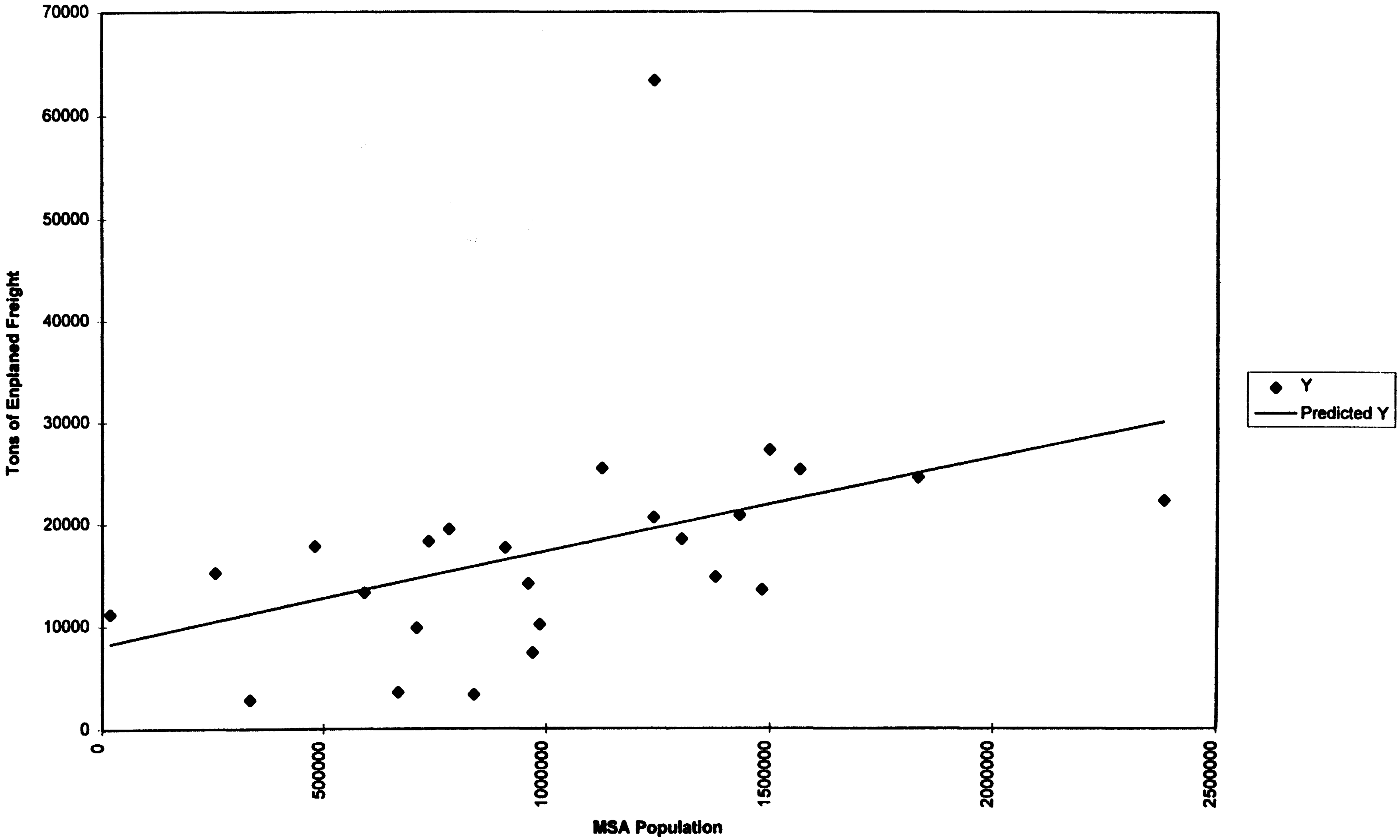
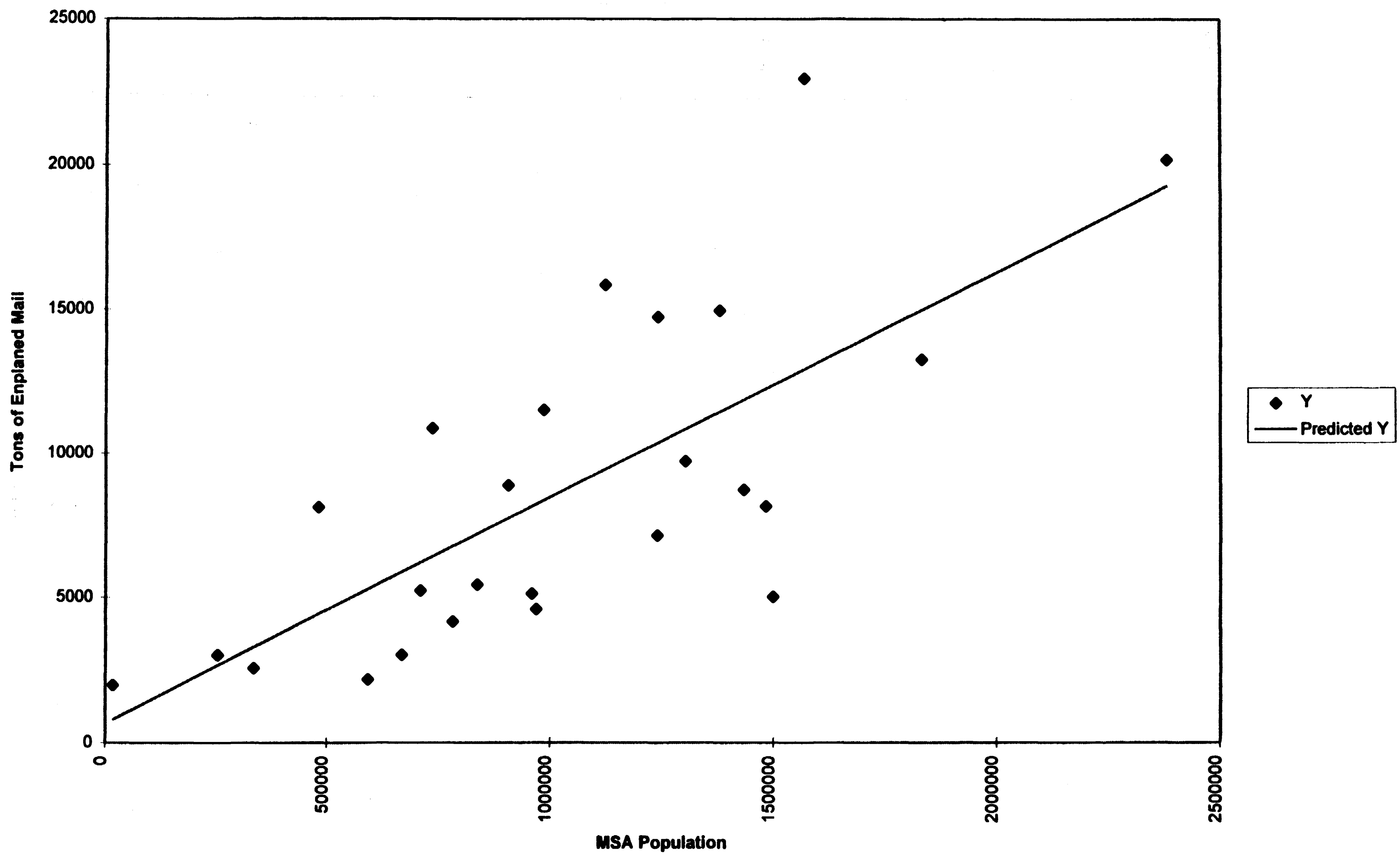


Figure 12
Medium Hub-Total Mail



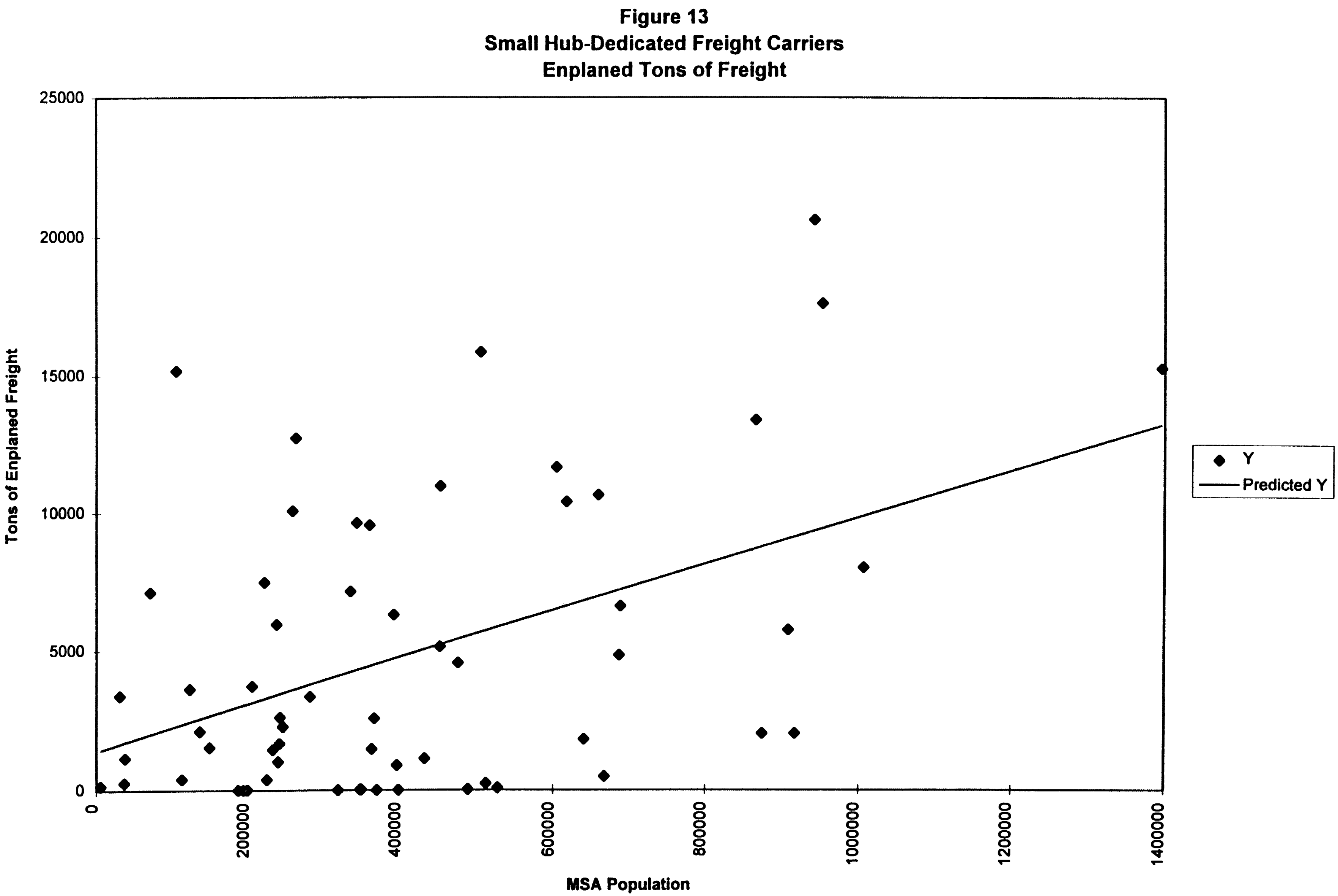


Figure 13
Small Hub-Dedicated Freight Carriers
Enplaned Tons of Freight
Tons of Enplaned Freight
25000
20000
15000
10000
5000
0
200000
400000
600000
800000
1000000
1200000
1400000
MSA Population
Y
Predicted Y

Figure 14
Small Hub-Total Freight

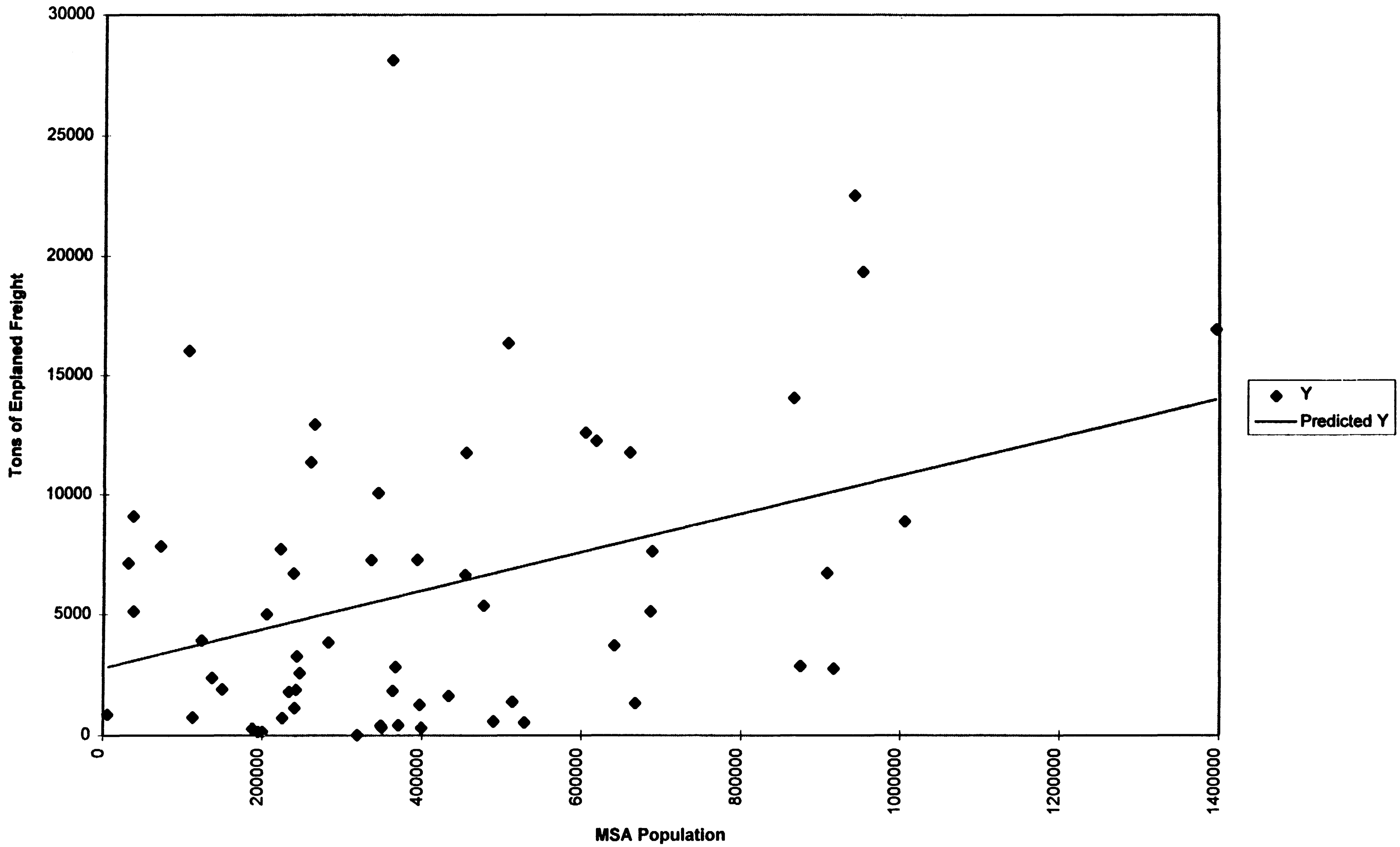
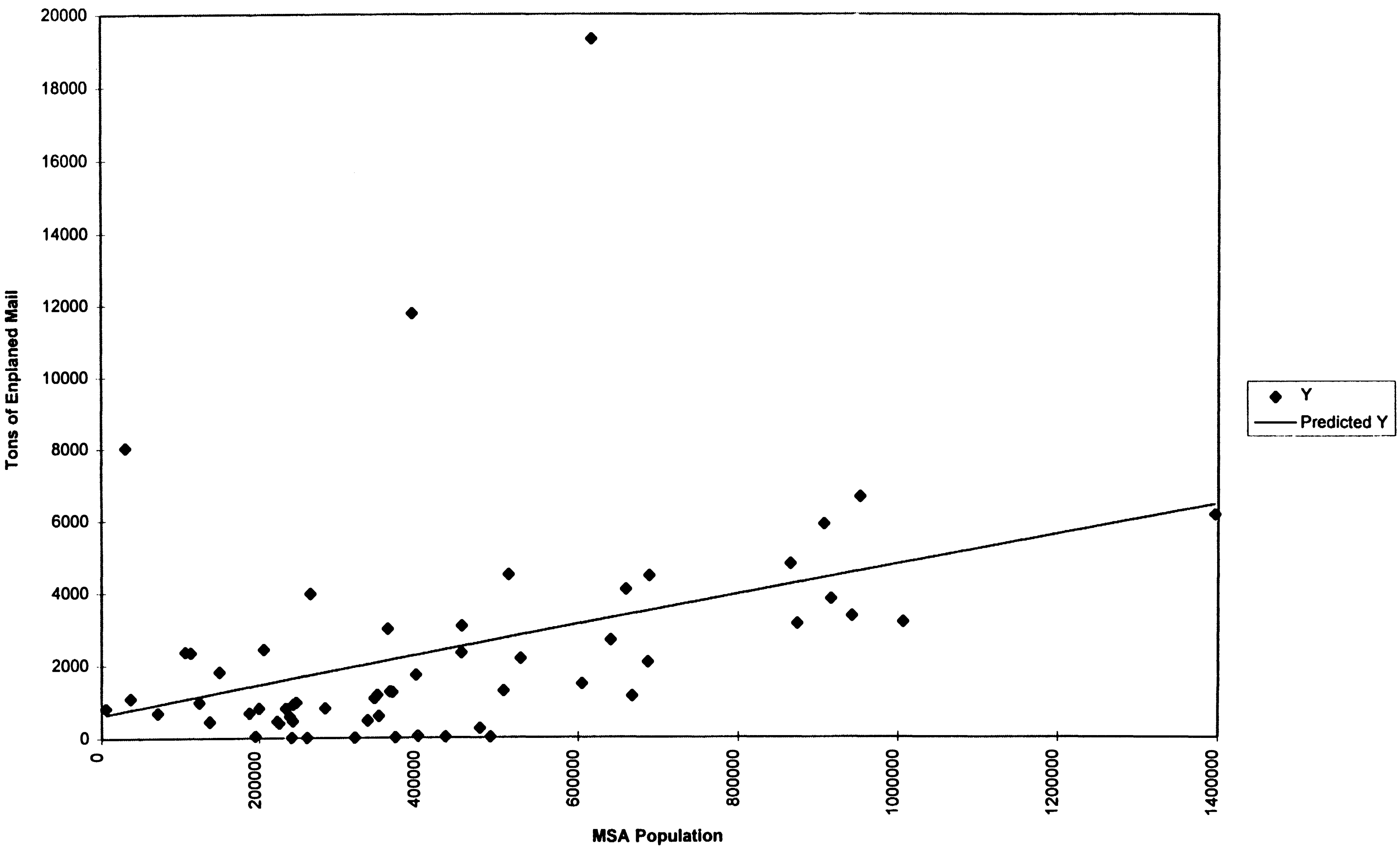


Figure 15
Small Hub-Total Mail



APPENDIX F: DESCRIPTION OF PORTS INCLUDED IN EACH ARMY CORPS OF ENGINEERS PORT SERIES

Port Series #60: The Port of Pittsburgh, Pennsylvania, Ports on the Ohio, Monongahela, and Allegheny Rivers, Pennsylvania

The limits of the Port of Pittsburgh include the Allegheny River from the Point (mile 0) to the head of navigation at mile 72, East Brady, Pennsylvania; the Monongahela River from the Point (mile 0) to its confluence with the Tygart and West Fork Rivers (mile 128.7) at Fairmont, West Virginia; and the Ohio River from mile 0 at the Point to the Pennsylvania-Ohio state line (mile 40).

Port Series #70: The Port of St. Louis, Missouri, and Ports on Upper Mississippi River Miles 0 to 300 AOR (Above Ohio River)

The Port of St. Louis extends 70 miles along both banks of the Mississippi River from the southern boundary of Jefferson County, Missouri, at mile 138.8 AOR to the northern boundary of Madison County, Illinois, at mile 208.8 AOR which, in addition to the City of St. Louis, encompasses the Illinois municipalities of East Carondelet, Cahokia, Sauget, East St. Louis, Venice, Granite City, Wood River, and Alton. Port Series #70 includes the following port authorities: Kaskaskia Regional Port District; City of St. Louis Port Authority; Tri-City Regional Port District; Southwest Regional Port District; St. Charles County Port Authority; Jefferson County Port Authority; St. Louis County Port Authority; and the Southeast Missouri Regional Port Authority.

Port Series #70 also includes other ports located on the Mississippi River between miles 0 and 300 AOR, four on the Kaskaskia River, and eight on the Missouri River in the vicinity of St. Louis.

Port Series #62: The Port of Cincinnati, Ohio, and Ports on Ohio River, Miles 317-560

The Port of Cincinnati encompasses both banks of the Ohio and Licking Rivers within Hamilton County, Ohio, and Kenton and Campbell Counties, Kentucky, extending from about mile 460 to mile 483 on the Ohio River and from mile 0 to about mile 7 on the Licking River.

Three other port complexes are included in Port Series #62. They are the Ports of Ashland and Maysville, Kentucky, and Madison, Indiana, located at miles 321, 407, and 558, respectively.

Other ports located on the Big Sandy River (mile 0 to mile 317) and on the Kentucky River (mile 0 to mile 545.8) are included.

Port Series #61: The Port of Huntington, West Virginia, and Ports on Ohio River Miles 40 to 317 and Kanawha River, West Virginia

The Port of Huntington includes both banks of the Ohio River within Cabell and Wayne Counties, West Virginia, and Lawrence County, Ohio, from mile 304 to mile 313.

The Port of Charleston is located in Port Series #61 and includes both banks of the Kanawha River within Kanawha County, West Virginia, from mile 53 to mile 63.

Five other ports are located on the Ohio River (mile 40 to mile 317). They include the Ports of East Liverpool, Steubenville-Weirton, Wheeling, Marietta, and Parkersburg located at miles 43, 66, 89, 172, and 184, respectively.

Other ports included in Port Series #61 are found on the Kanawha River between mile 0 and mile 97.

Port Series #71: Ports of Memphis, Tennessee; Helena, Arkansas; and Ports on Lower Mississippi River (Miles 620 to 954 AHP)

The Port of Memphis consists of two harbors: McKellar Lake and Wolf River.

The Port of Helena, Arkansas, is located on the right bank of the Mississippi River approximately 75 miles below Memphis.

Other ports located on the Mississippi River between miles 620 and 954 AHP are included in Port Series #71. Notable port/harbors include Hickman, Kentucky, at mile 923 AHP; New Madrid-St. Jude, mile 885 AHP; Caruthersville, Missouri, at mile 847 AHP; Osceola, Arkansas, mile 765 AHP; and West Memphis, Arkansas, at mile 727 AHP. Public facilities at these ports are under the jurisdiction of the following port authorities: Hickman-Fulton County Riverport Authority, St. Jude Industrial Park, Pemiscot County Port Authority, Osceola Riverport Authority, and West Memphis-Crittenden County Port Authority.

Source: Navigation Data Center, Water Resources Support Center, U.S. Army Corps of Engineers. Port Series Nos. 60, 70, 62, 61 and 71. U.S. Government Printing Office, Washington, D.C., 1991-1993.

DOT-T-96-22

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